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KC's Problems and Solutions

for Microelectronic Circuits FOURTH EDITION

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8.15(a) and assume the current source I is implemented with a single BJT that requires a minimum of 0.3 V for proper operation. Chapter 8-11 Thus, the minimum allowable VCM is VCM max = 0.4 + VC1, 2 =+ $(2.5 - 0.99 \times 0.2 \times 5) = +1.91$ V iC1 = 10.78 µA, v BE1 iC2 = 8.82 µA 10.78 × 10-3 = 0.69 + 0.025 ln 1 = 0.5767 V v BE2 $8.82 \times 10-3 = 0.69 + 0.025$ ln 1 = 0.5767 V v BE2 $8.82 \times 10-3 = 0.69 + 0.025$ ln 1 = 0.5767 V v BE2 $8.82 \times 10-3 = 0.69 + 0.025$ ln 1 = 0.5717 V Thus, the input common-mode range is -1.54 V \leq VICM ≤ 1.91 V v B1 = v BE1 - v BE2 = 0.5767 - 0.5717 = 0.005 V = 5 mV 8.26 (a) Refer to Fig. 1(b). This is the same factor by which the re magnitude of the gain is reduced. We can then find the resistor value using = 0.6872 V 1 - 0.6872 = 0.6255 m 2 i = 0.5 0.6255 3. 8.30 Refer to Fig. Next the two parallel resistances 1/gm and rn can be combined as $1 \times \text{rn} \text{ rn} \text{ rn} \text{ gm} = \text{re} = 1.1 + \text{gm} \text{ rn} \text{ } B + 1 + \text{rn} \text{ gm} \text{ When VO} = \text{Vx}$, the Early effect on O1 and O2 will be the same, and IO = IREF /(1 + 2/ β 2) Thus, IO will be 100 = 1 + (2/1002) 99.98 μ A, for an error of -0.02 μ A or -0.02%. This in turn can be achieved by connecting an unbypassed Rs equal to 1/gm , 1 = 300 Rs = 3.33 mA/V Since v²gs does not change, the output voltage also will not change, thus v²o = 1.08 V. Ad = Gm Ro (d) With VBIAS = 1.4 V, the bias voltage at the collectors of Q1 and Q2 is VC1,2 = VBIAS - VBE3,4 where Gm = gm1,2I/2 VT = 1.4 - 0.7 = +0.7 V and The upper limit on VCM is 0.4 V above VC1,2: Ro = Ro4 Ro7 VCM max = 0.7 + 0.4 = +1.1 V Here Ro4 is the output resistance of the cascode amplifier (looking into the collector of Q4), thus Ro4 = gm4 ro4 (ro2 rm 4) Usually rn 4 ro2, Ro4 gm4 rn 4 ro4 = β 4 ro4) 1 β 7 ro7 2 Thus Ro = (β 4 ro4) 1 VT IC VT 0.025 1 × 100 × 800 = 2.67 × 104 V/V 3 8.93 To maximize the positive output voltage swing, we select VBIAS as large as possible while maintaining the pnp current sources in saturation. This figure belongs to Problem 2.73. The current in Q5 will be equal to I, thus terminal Z sinks a constant current I. N = 0.6607 V 1 - 0.6607 = 0.3393 mA 1K 0.3393 = 0.6638 V 3. Thus, Chapter 2-27 v O = v Ofinal - v Oinitial)e-t/ τ i=C d vI = 0.1 × 10-6 × v Ofinal = -1 V × dc gain = $1000(1 - e - t/1000CR) At t = T, which is equal to CR, vI (V) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (V) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR, VI (W) v O (T) = 1000(1 - e - 0.001) = -0.9995 - 1 V 2.82 2 0.5 \times 10 - 3 1 Vo = -sCR = -j\omega CR + 0.001 + 0.00$ $2 = (1 + 0.992) 1 + k2 - 4 = 0 \quad 17 \ \omega H \ 21 \ \omega H \ 4 + 16 \ \omega P \ 116 \ \omega P \ 1 \ 42 \ \omega H \ \omega H + 17 - 16 = 0 \ \omega P \ 1 \ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ \Rightarrow k = 2.78 \ 2 = 1 + 2 = 1 + For \ \omega H = 0.9 \\ \omega P \ 1 \ = 1 + 2 = 1 + For \ \omega H = 0.9$ 1 | AM | |T | = 2 $\omega 21 + \omega 1 + \omega P1 \omega P2 4 \Rightarrow \omega H = 0.84 \omega P1 GB = 1000 \times 100 \times 103 = 108$ Hz Ex: 9.13 T ($j\omega$) = $\omega H \omega P1
\omega H \omega P1 2 1 + \omega H k \omega P1 2 2 = 20 + 5(1 + 1.25 \times 10) = 87.5$ f F fH = = 1 2 π Cin Rsig 1 2 π × 87.5 × 10-15 × 10 × 103 = 181.9 MHz This is greater than the value obtained in Example 9.8, fH = 135.5 MHz, by 34%. v O = 11.3 - 3.78 vI C 100 F R 100 vO Vr 12 = T/4 t \Rightarrow t = (a) = 23.5 µs vI 12 V 11.3 V 1.13 × 1 Vr × (T/4) = 12 12 × 4 Vr vO Now, using the fact that the charge gained by the capacitor during its discharge interval, we can write vI iCav × t = C Vr t \Rightarrow iCav = C Vr 100 × 10-6 × 1.13 = 4.8 A = t 23.5 × 10-6 iDav = iCav + iLav T (b) 1 ms 12 V where iLav is the average current through R during the short interval t. (1), (2), and (3) provides 1 1 1 + + = 0.7 (4) RP RP1 RP2 RP4 But, 1 1 1 1 1 = + + + RP RP0 RP1 RP2 RP4 Chapter 2-14 1 R2 1-x vO = 1+ -1 = 1+ =1+ vI R1 x x Thus, 1 1 1 1 1 = + + + RP RP0 RP1 RP2 RP4 Chapter 2-14 1 R2 1-x vO = 1+ -1 = 1+ =1+ vI R1 x x Thus, 1 1 1 1 1 = + + + RP RP0 RP1 RP2 RP4 Chapter 2-14 1 R2 1-x vO = 1+ -1 = 1+ =1+ vI R1 x x Thus, 1 1 1 1 1 = + + + RP RP0 RP1 RP2 RP4 Chapter 2-14 1 R2 1-x vO = 1+ -1 = 1+ =1+ vI R1 x x Thus, 1 1 1 1 1 = + + + RP RP0 RP1 RP2 RP4 Chapter 2-14 1 R2 1-x vO = 1+ -1 = 1+ =1+ vI R1 x x Thus, 1 1 1 1 1 = + + + RP RP0 RP1 RP2 RP4 Chapter 2-14 1 R2 1-x vO = 1+ -1 = 1+ =1+ vI R1 x x Thus, 1 1 1 1 1 = + + + RP RP0 RP1 RP2 RP4 Chapter 2-14 1 R2 1-x vO = 1+ -1 = 1+ =1+ vI R1 x x Thus, 1 1 1 1 1 = + + + RP RP0 RP1 RP2 RP4 Chapter 2-14 1 R2 1-x vO = 1+ -1 = 1+ =1+ vI R1 x x Thus, 1 1 1 1 1 = + + + RP RP0 RP1 RP2 RP4 Chapter 2-14 1 R2 1-x vO = 1+ -1 = 1+ (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + RP RP0 RP1 RP2 RP4 Chapter 2-14 1 R2 1-x vO = 1+ -1 = 1+ (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + RP RP0 RP1 RP2 RP4 Chapter 2-14 1 R2 1-x vO = 1+ -1 = 1+ (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + + + (1 + 1) R1 x x Thus, 1 1 1 1 1 = + (- = + RP RP0 RP1 RP2 RP4 (5) Equations (4) and (5) can be combined to obtain $\therefore 1 vO = vI x 0 \le x \le 1 \Rightarrow \infty \ge RP RP = 0.7 \Rightarrow RP0 = 1 - RP0 0.3$ (6) $vO \ge 1 vI Add$ a resistor as shown: $vO (1 - x) \times 10 k = 1 + vI x \times 10 k + R$ vO = 11 For vI max Selecting RP0 = 10 k Equation (6) $\Rightarrow RP = 3$ k Equation (1) $\Rightarrow RP1 = 30$ k Equation (2) $\Rightarrow RP2 = 15$ k Equation $(3) \Rightarrow RP4 = 7.5 \text{ k x} = 0, 10 = R4 R3 + R4$ R2 vO R4 1 + R2 /R1 = 1 + vI R1 R3 + R4 1 + R3 /R4 2.46 v + = vI vO 10 k = 11 = 1 + vI R 10 k R R = 1 k 2.49 10 k v O1 = -10v 1 Setting v 1 = 0, we obtain the output component due to v 2 as 10R 10R v O2 = v 2 1 + = 10v 2 R 10R + R The total output voltage is For v 1 = 10 sin(2\pi × 60t) - 0.1 $\sin(2\pi \times 1000 \text{ t})$ vO 10 k vO = vI v O = vO1 + vO2 = 10(v 2 - v 1) 1 \text{ k vI} 1 k 2.47 Refer to Fig. P8.116. From Eq. (1) we see that the maximum value of Rout /ro is obtained with Re = ∞ and its value is 101, which is (β + 1). P8.55, vo = (a) v id Total resistance across which v o appears α Total resistance in the emitter 2 k = $\alpha \times$ re1 + re2 VT, where IE is IE the dc emitter current of each of Q1 and Q2, we use To determine re1 = re2 = re = VE = VB - VBE = 0 - 0.7 = -0.7 V - 0.7 - (-5) = 1 \text{ mA 4.3 IE} = 0.5 \text{ mA 2 IE} = 25 \text{ mV} = 50 0.5 \text{ mA 2 k} = \alpha \times 20 \text{ V/V 0.1 k re1} = re2 = vo v id Chapter 8-20 (b) The common-mode half-circuit is shown in the figure, $\alpha \times 2 \text{ k vo} = -v \text{ icm} (0.05 + 8.6) \text{ k} - 0.23 \text{ V/V vo}$ $v = 0.23 V/V icm (c) CMRR = 20 |v o /v id| = 86.5 |v o /v icm| 0.23 or 38.7 dB (d) v o = -0.023 sin 2\pi \times 60t + 0.2 sin 2\pi \times 1000 t volts 8.56 RC 2RSS RC RC 10 \times 0.02 = 0.001 V/V 200 To obtain Ricm, we use Eq. (8.96): |Acm| = Figure (a) shows the differential half-circuit. This in turn is achieved by biasing the transistor at the lowest VCE$ consistent with the transistor remaining in the active mode at the negative peak of v o . Thus $\alpha \beta \beta Q.E.D. \beta \alpha$ For 4.5 Old technology: $\alpha 1 - \alpha \beta = -10\% \alpha 100 4.10$ Transistor is operating in active region: $\beta = 50 \rightarrow 300$ IB = 10 μ A IC = β IB = 0.5 mA $\rightarrow 3$ mA IE = ($\beta + 1$)IB = 0.51 mA $\rightarrow 3.01$ mA Maximum power dissipated in transistor is 4.6 IB = 10 μ A IB × 0.7 V + IC × VC IC = 800 μ A = 0.01 × 0.7 + 3 × 10 30 mW Chapter 4-2 4.11 For iB = 10 μ A, 4.14 First we determine IS, β , and α : iC = iE - iB = 1000 - 10 = 990 μ A 1 × 10-3 = IS e700/25 β = \Rightarrow IS = 6.91 × 10-16 A iC 990 = 99 = iB 10 β 99 α = $= 0.99 \beta$ + 1 100 β = IC 1 mA = 100 = IB 10 μ A For iB = $20 \ \mu A$, $\alpha = \beta \ 100 = = 0.99 \ \beta + 1 \ 101 \ iC = iE - iB = 1000 - 20 = 980 \ \mu A$ Then we can determine ISE and ISB : $\beta = iC \ 980 = 49 = iB \ 20 \ ISE = IS = 6.98 \ \times \ 10 - 18 \ A \ \beta \ For \ iB = 50 \ \mu A$, The figure below and on next page shows the four large-signal models, corresponding to Fig. From Eq. (2.36), we know that the output dc voltage due to VOS is RF RF \Rightarrow 2 V = 2 mV 1 + VO = VOS 1 + R 10 k RF = 1000 \Rightarrow RF 10 M 10 k The corner frequency of the resulting STC 1 network is $\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ Thus $\omega 0 = f0 = 1 = 1 rad/s 0.1 \mu F \times 10 M 1 \omega 0 = = 0.16 Hz 2\pi 2\pi Ex: 2.26 20 log A0 = 106 dB \Rightarrow A0 = 106 dB \Rightarrow A0 = 100 the resulting STC 1 network is <math>\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ Thus $\omega 0 = f0 = 1 = 1 rad/s 0.1 \mu F \times 10 M 1 \omega 0 = = 0.16 Hz 2\pi 2\pi Ex: 2.26 20 log A0 = 106 dB \Rightarrow A0 = 100 the resulting STC 1 network is <math>\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ Thus $\omega 0 = f0 = 1 = 1 rad/s 0.1 \mu F \times 10 M 1 \omega 0 = = 0.16 Hz 2\pi 2\pi Ex: 2.26 20 log A0 = 106 dB \Rightarrow A0 = 100 the resulting STC 1 network is <math>\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ Thus $\omega 0 = f0 = 1 = 1 rad/s 0.1 \mu F \times 10 M 1 \omega 0 = = 0.16 Hz 2\pi 2\pi Ex: 2.26 20 log A0 = 106 dB \Rightarrow A0 = 100 the resulting STC 1 network is <math>\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ Thus $\omega 0 = f0 = 1 = 1 rad/s 0.1 \mu F \times 10 M 1 \omega 0 = = 0.16 Hz 2\pi 2\pi Ex: 2.26 20 log A0 = 106 dB \Rightarrow A0 = 100 the resulting STC 1 network is <math>\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ the resulting STC 1 network is $\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ the resulting STC 1 network is $\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ the resulting STC 1 network is $\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ the resulting STC 1 network is $\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ the resulting STC 1 network is $\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ the resulting STC 1 network is $\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ the resulting STC 1 network is $\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ the resulting STC 1 network is $\omega 0 = CRF 1 + We know RC = 1 ms and R = 10 k \Rightarrow C = 0.1 \mu F$ the resulting STC 1 network is $\omega 0 = 0.16 Hz = 0.16 Hz = 0.16 Hz$ 200,000 V/V ft = 3 MHz fb = ft /A0 = 3 MHz = 15 Hz 200,000 Exercise 2-8 At fb, the open-loop gain drops by 3 dB below its value at dc; thus it becomes 103 dB. Observe that 1 2 it intersects the horizontal line iD /k n = VOV 3 at 2 1 v DS = VOV 3 . 1 through 3 (see preceding page). 7.38, Ron = (gm2 ro2) (ro1 rm 2) = (8 mA/V) (25 k) (25 k 12.5 k) Ron = 1.67 M For the pnp transistors, gm3 = gm4 = rn 3 = rn 4 |IC | 0.2 mA = 8 mA/V = VT 25 mV β 50 = 6.25 k = = gm 8 mA/V ro3 = ro4 = |VA | 4V = 20 k = |IC | 0.2 mA Rop = (gm3 ro3) (ro4 rn 3) = (8 mA/V) (20 k) (20 k 6.25 k) Rop = 762 k Av = -gm1 Ron Rop = - (8 mA/V) (1.67 M 762 k) Av = -4186 V/V gm = 2 ID 2 × 0.1 = 0.88 mA/V = VOV 0.227 ro = VA VL 5 × 0.36 = 18 k = A = ID ID 0.1 Ro = (gm3 ro3) ro2 = (0.88 × 18) × 18 = 285 k Ex: 7.26 For the Wilson mirror from Eq. (7.94), we have IO 1 = 0.9998 2 IREF 1 + 2 β Thus |IO - IREF | × 100 = 0.02% IREF whereas for the simple mirror from Eq. (7.18) we have 1 IO = 0.98 = 2 IREF 1 + β |IO - IREF | × 100 = 2% IREF Av max occurs when ro1 and ro4 are rn. Thus, $I5 = 0.545Vx - 0.5Vx = 0.022Vx 0.5 + 1 + 0.545Vx + 0.022Vx \times 0.5 2 = 0.57Vx \times 1.022 = 0.511Vx V1 = Between node 2 and ground, V2 = V1 + I5 R5 = 0.533Vx RTh = 9.1 k 11 k = 4.98 k VTh = 10 \times Vx - V1 = 0.489Vx 1 k Vx - V2 I2 = 0.467Vx 1 k Ix = I1 + I2 = 0.956Vx I1 = 11 = 5.47 V 11 + 9.1 The$ resulting simplified circuit is $0.545 \text{ k} 1 \text{ I5} 2 4.98 \text{ k} \Rightarrow \text{Req} \equiv \text{R5} 2 \text{ k} 5.47 \text{ V} 5.47 \text{ V} 5.47 \text{ -} 5.45 4.98 \text{ +} 2 + 0.545 \text{ =} 2.66 \mu \text{A} \text{ V5} = 2.66 \mu \text{A} \text{ V5}$ D2 conducts, thus steering I into the battery. At $\omega = 104$ rad/s, Vo 10 = $\sqrt{100} = \sqrt{9.95}$ V/V V 100 + 1 1 + 0.01 i $\varphi = 180^{\circ} + 94^{\circ} - \tan -10.1 = 180^{\circ} + 84.3^{\circ}$ Both these results differ slightly from
the ideal values. vI vO R IL Exercise 3-9 v I ≥ 0 ~ diode is cut off, loop is open, and the opamp is saturated: vO = 0 V v I ≤ 0 ~ diode conducts and by the battery. At w = 104 rad/s, vo ro = v 100 = v 1 but resistance, choose R2 R2 = 1 M 1 M = 5 k 200 Rin = R1 = 5 k R1 = R1 vI vO 2.15 The circled numbers indicate the order of the analysis steps. RC iC1 RC iC2 vo2 vo1 vicm Q1 2 Q2 ie1 vicm ie2 ve vicm vicm REE REE With a common-mode input signal v icm applied, as shown in the figure, the current (v icm /REE) will sp between Q1 and Q2 in the same ratio as that of their base-emitter junction areas, thus ie1 = 2 v icm 3 REE and ie2 = 1 v icm 3 REE and v o2 = -1 RC v icm 3 REE Thus, v o1 = -ic1 RC = -2 RC v icm 3 REE and v o2 = -1 RC v icm 3 REE and v o3 REE and v o3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = -1 RC v icm 3 REE and v o4 = $-1 \text$ the output is taken single-endedly, then | Acm | = RC 2REE | Ad | = 1 gm RC 2 Chapter 8-23 CMRRs = | Acm | = gm REE | Ad | VOS = VOV 2 RD RD If the output is taken differentially, then RC RC | Acm | = 2REE RC Thus, | Ad | = gm RC (b) For each value of VOS we use Eq. (2) to determine I and then Eq. (1) to determine Ad . Thus, IE = IC2 = α IE2 = 0.99 × 0.542 = 0.537 mA I2 = IC2 - IB3 = 0.537 - IE3 101 Since the voltage drop across the 6.2-k resistor is equal to (0.7 + IE3 × 2.4), I2 × 6.2 = 0.7 + 2.4IE3 2 - 0.7 = 1.1 mA 10 1 + 51 VE = +1.1 VVB = 1.8 V (c) For vI = -2.5, Q1 will be off and Q2 vN vp 10 k 3.33 k vp 10 k 10 RP RP = 1 = 0.1 RP1 RP1 (1) Similarly, equating the coefficients of v I 2 gives 10 RP RP = 2 = 0.2 RP2 RP2 (2) and equating the coefficients of v I 1 provides Rf RP = 1 + RN RP1 10 v RP RP = 4 = 0.4 RP4 RP4 (3) Now, summing Eqs. If |T| = 100 V/V at $\omega RC f = 10 kHz$ = 1 V/V, f has to be 10 kHz × 100 = 1 MHz. 1 1 = 0.159 μ s = ω int $2\pi \times 1$ MHz 2.76 CR = 1 s and Rin = 100 k. (1) (2) Thus, 1 1 1 1 1, = + + in Substituting for RP RP RP0 RP1 RP2 Eqs. The current through each diode is I : 2 2VT VT 0.05 = = I I I 2 From the equivalent circuit rd = R R vo = = vi R + (2rd 2rd) R + rd I vo vi rd 0 μ A ∞ 0 1 μ A 50 k 0.167 10 μ A 5 k 0.667 100 μ A 5 k 0.667 100 μ A 50 0.995 10 mA 5 0.995 10 mA 5 0.9995 I = 1 μ A, I I I I rd rd rd rd vo vI R Equivalent Circuit 10 k Chapter 3-15 b. Refer to the analysis shown in the figure, which leads to β = 3.952 IC = = 82.3 IB 0.048 Chapter 4-7 VE = +0.68 V (c) and 2.5 - 0.68 = 3.64 k 0.5 The maximum allowable value for RC while the transistor remains in the active mode corresponds to VC = +0.4 V. Chapter 3-8 Taking the ratio of the above two equations, we have The power dissipation is given by $PD = (10 \text{ A})(0.6 \text{ V}) = 6 \text{ W ID1} = \text{IS e}(\text{VD1} - \text{VD2})/\text{VT} \Rightarrow \text{VD1} - \text{VD2} \text{ ID1} = \text{VT ln ID2}$ The thermal resistance is given by 50° C T = 8.33° C/W = PD 6W 3.29 For ID = 1 mA, we have $1 \times 10-3 \text{ A} = -230 \text{ mV V} = \text{VT ln } 10 \text{ A } 10 \text{ V I R1} \Rightarrow \text{VD} = 570 \text{ mV D1}$ V1 D2 V2 For ID = 3 mA, we have $3 \times 10-3 \text{ A} = -202 \text{ mV V} = \text{VT ln } 10 \text{ A} \Rightarrow \text{VD} = 598 \text{ mV Assuming VD changes by } -2 \text{ mV per } 1^{\circ} \text{ C}$ increase in temperature, we have, for $\pm 20^{\circ} \text{ C}$ changes: For ID = 1 mA, 530 mV $\leq \text{VD} \leq 610 \text{ mV At } 20^{\circ} \text{ C}$: For ID = 3 mA, 558 mV $\leq \text{VD} \leq 10^{\circ} \text{ C}$ increase in temperature, we have, for $\pm 20^{\circ} \text{ C}$ changes: For ID = 1 mA, 530 mV $\leq \text{VD} \leq 610 \text{ mV At } 20^{\circ} \text{ C}$: For ID = 3 mA, 558 mV $\leq \text{VD} \leq 500 \text{ mV At } 20^{\circ} \text{ C}$: For ID = 3 mA, 558 mV $\leq \text{VD} \leq 10^{\circ} \text{ C}$ changes by $-2 \text{ mV P} = 10^{\circ} \text{ C}$ changes in temperature, we have, for $\pm 20^{\circ} \text{ C}$ changes: For ID = 1 mA, 530 mV $\leq \text{VD} \leq 610 \text{ mV At } 20^{\circ} \text{ C}$: For ID = 3 mA, 558 mV $\leq \text{VD} \leq 10^{\circ} \text{ C}$ changes by $-2 \text{ mV P} = 10^{\circ} \text{ C}$ changes by $-2 \text{ mV P} = 10^{\circ} \text{ C}$ changes by $-2 \text{ mV} = 10^{\circ} \text{ C}$ changes by -2 mV $638 \text{ mV VR1} = V2 = 520 \text{ mV R1} = 520 \text{ k} 520 \text{ mV} = 1 \text{ } \mu \text{A} I = 520 \text{ k} \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } \text{ } k \text{ } 520 \text{ } \text{mV} = 4 \text{ } \mu \text{A} I = 520 \text{ } \text{ } k \text{ } 520 \text{ } \text{mV} = 4 \text{ } \mu \text{A} I = 520 \text{ } \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ }
\text{mV} = 1 \text{ } 4 \text{ } \mu \text{A} I = 520 \text{ } k \text{ } 520 \text{ } \text{mV} = 1 \text{ } 4 \text{ } 4 \text{ } 1 \text{ } 520 \text{ } 1 \text$ 3.30 Given two different voltage/current measurements for a diode, we have ID1 = IS eVD1 /VT \Rightarrow VD1 - VD2 ID2 ID1 = VT ln ID2 20°C For the first diode, with ID = 0.1 mA and 1 μ A 480 Thus the overall range of VD is between 530 mV and 638 mV. 10-5 cm = 9.63 pC Reverse current I = IS = Aqn2i Ex: 1.34 Equation (1.65) IS = Since Aqn2i = $10-14 \times 1.6 \times 10-4 \times 1016$ 10 × $10-4 \times 100$ 10 × 1 + R1 - 0.2 = VOS 1 + R2 R1 = VOS Open input: v O = v + R2 IB1 = VOS + R2 IB1 $(1), (2) \Rightarrow 100VOS = -0.3 \Rightarrow VOS = -3 \text{ mV} \Rightarrow IB1 = 530 \text{ nA } IB = 530 \text{ nA } 2.90 \text{ Input offset voltage} = 3 \text{ mV} \text{ and both flow into the op-amp input terminals}.$ P8.19. $IE3 = 0.7 + 2.4IE3 6.2 \ 0.537 - 101 \Rightarrow IE3 = 1.07 \text{ mA } VS = -3 \text{ mV} \Rightarrow IB1 = 530 \text{ nA } IB = 530 \text{ nA } 2.90 \text{ Input offset voltage} = 3 \text{ mV} \text{ and both flow into the op-amp input terminals}.$ P8.19. $IE3 = 0.7 + 2.4IE3 6.2 \ 0.537 - 101 \Rightarrow IE3 = 1.07 \text{ mA } VS = -3 \text{ mV} \Rightarrow IB1 = 530 \text{ nA } IB = 530$ Since VB > -2.5, VC will be lower than VB and Q2 will be operating in the active region. The corresponding input signal amplitude (320 V/V), resulting in 5.3 mV. 1 v BE /VT IE = IS 1 + e β (3) When the base is left open-circuited, iB = 0 and Eq. (1) yields IS v BE /VT e ICBO = β 4.31 Refer to the circuit in Fig. Since ID2 = ID1 and k n = k p, then VOV 2 = VOV 1. Halving VOV results in decreasing ID by a factor of 4. 2 = $6.91 \times 10 - 16 \times e0.75/0.025$ Voltage drop across each diode = Correspondingly, the voltage across each diode = Correspondingly, the voltage drop across each diode = Correspondingly, the vol + IL = 7.39 mA + 1 mA and the output voltage changes by $VO = 2 \times VD = -49$ mV With I = 15 mA, the diodes current changes from 13 to 8 mA. It follows that our assumption is wrong and D1 must be off. 3.81 v I > 0: D1 conducts and D2 cutoff (b) See figure (b) on next page. 1 VGS2 = 1.84 V Since Q1 is identical to Q2 and is conducting the same ID , then VGS1 = $1.84 \text{ V} \Rightarrow \text{V1} = 2.5 - 1.84 = 0.66 \text{ V}$ which confirms that Q1 is operating in saturation, as assumed. For IE to remain unchanged, 4.545 V IB 3 - 0.7 3 - 0.7 = 20 100 2.2 + 2.2 + 41 β + 1 = RB RC 1 k VC 20 100 = 41 β + 1 β + 1 = RB RC 1 k VC 20 100 = 41 β + 1 β + 1 = RB RC 1 k VC 20 100 = 41 β + 1 β + 1 = RB RC 1 k VC 20 100 = 41 β + 1 β + 1 = RB RC 1 k VC 20 100 = 41 β + 1 β + 1 = RB RC 1 k VC 20 100 = 41 β + 1 β + 1 = RB RC 1 k VC 20 100 = 41 β + 1 β + 1 = RB RC 1 k VC 20 100 = 41 β + 1 β + 1 = RB RC 1 k VC 20 100 = 41 β + 1 β + 1 = RC 1 k VC 20 100 = 41 β + 1 β + 1 = RB RC 1 k VC 20 100 = 41 β + 1 β + 1 = RC 1 k VC 20 100 = 41 β + 1 + IE RE RE = VE 0.7 V IE = VBC 1 V VC 1 V IC RC 5 - 0.7 RB RE + β + 1 4.3 RB 1 + 101 (a) For RB = 100 k, IE = 3 V 4.3 = 2.16 mA 100 1 + 101 VE = IE RE = 2.16 × 1 = 2.16 V Refer to the figure. First consider Q1 and Q2 . 7.39. C aiE B iE DE IS ISE a vBE () E Figure 1 If iE undergoes an incremental change ie from its equilibrium or bias value IE, the voltage v BE will correspondingly change by an incremental amount v be (from its equilibrium or bias value VBE), which is related to ie by the incremental resistance of diode DE. $2(Vp - VD) VO 1 + \pi = RL Vr$ $2(13.7 - 0.7) 12 1 + \pi = 0.2 2 = 739 \text{ mA } 13.7 - 0.7 2 \times 60 \times 200 \times C \Rightarrow C \Rightarrow C \Rightarrow Vp - VD 2fCR vO = 739 \text{ mA } 3.77 120 \text{ Vrms } 60$ Hz D4 D1 C R vS vO D2 D3 Chapter 3-31 12 V 11.3 11.3 Vr 10.2 V (a) VO = Vp - 2VD - 1 \Rightarrow Vp = VO + 2VD + 1 = 12+2×0.7+1 = 14.4 V 14.4 Vrms = $\sqrt{=10.2 \text{ V} 2 \text{ V} p} - 2 \text{ VD}$ (b) Vr = 2fCR } T 0 14.4 - 1.4 = 271 \mu\text{F} 2 \times 2 \times 60 \times 200 (c) The maximum reverse voltage across D1 occurs when Vs = -Vp = -14.4 V. Thus \Rightarrow VO, avg 2Vs - 2VD $\pi \sqrt{2} \times 2 \times 60 \times 200$ (c) The maximum reverse voltage across D1 occurs when Vs = -Vp = -14.4 V. Thus \Rightarrow VO, avg 2Vs - 2VD $\pi \sqrt{2} \times 2 \times 60 \times 200$ (c) The maximum reverse voltage across D1 occurs when Vs = -Vp = -14.4 V. Thus \Rightarrow VO, avg 2Vs - 2VD $\pi \sqrt{2} \times 2 \times 60 \times 200$ (c) The maximum reverse voltage across D1 occurs when Vs = -Vp = -14.4 V. 122 - 1.4 = 9.4 V = π Peak voltage (b) Peak diode current = R $\sqrt{Vs} - 2VD$ 122 - 1.4 = R 100 = 156 mA $\sqrt{PIV} = Vs - VD = 122 - 0.7 = 16.3$ V Ex: 3.22 Full-wave peak rectifier: D1 vO vS vS 97.4 % Average output voltage VO is $\sqrt{Vs} 2 \times 122$ VO = 2 - VD = -0.7 = 10.1 V π π Peak diode current iD is $\sqrt{iD} = Vs - VD = 122 - 0.7$ R 100 - 120 R 100 - 120 $2 [-Vs \cos \varphi - 2VD \varphi]\pi - \theta \varphi = \theta 2\pi 1 = [Vs \cos \varphi - Vs \cos(\pi - \theta) - 2VD (\pi - 2\theta)]\pi$ But $\cos \theta \approx 1$, for θ small. P6.49. 7.13(b). = $\tau T \cdot VT 1$ Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn 2 DP (d) Cd = (c) For Q Qp, I Ip, Q 1 Wn $2 \cdot Ip$ for Wn xn $2 \cdot Ip$ for Wn $2 \cdot Ip$ for Wn required by a single op amp is 5: two input terminals, one output terminal for positive power supply, and one terminal for negative power supply, and one terminal for negative power supply. This restriction is imposed by the current I = 1 mA 157 µA to 157 × 10 vOR iD = IS ev D/VT = 0.324 V iD = e[v D - v D (at 1 mA)]/VT iD (1 mA) = VT ln 1 mA v D = v D (at 1 mA) = VT ln 1 mA v D = v D (at 1 mA) = VT ln 1 mA v D = v D (at 1 mA) = VT ln 1 mA v D = v D (at 1 mA) = VT ln 1 mA v D = v D (at 1 mA) = VT ln 2 mA v D = v D (at 1
mA) = VT ln 2 mA v D = v D (at 1 mA) = VT ln 2 mA v D = v D (at 1 mA) = VT ln 2 mA v D = v D (at 1 mA) = VT ln 2 mA v D = v D (at 1 mA) = VT ln 2 mA v D = v D (atthe dc collector voltage. Similarly, for v I < -10.7 V, v O will be saturated at -10 V. When we short circuit the voltage source, we see that the Thévenin resistance will be zero. P8.82: RSS = gm7 ro7 ro9 Transistor Q7 has the same k (W/L) as Q1 and Q2, but Q7 carries a current I twice that of Q1 and Q2. At IC = 0.5 mA, 8 = Cde + 2 \Rightarrow Cde = 6 pF $2VA 2VA L 9.16 A0 = = VOV VOV A0 = 2 \times 5 \times L = 50L, V/V (L in \mu m) 0.2 fT 3 \mu VOV 3 \times 400 \times 108 \times 0.2 = 2 4 \pi L 4 \pi L2 fT = 1.91$, GHz (L in μm) L2 1 At IC = 0.25 mA, Cde = $\times 6 = 3 pF$, and 2 C $\pi = 3 + 2 = 5 pF$. Since VC VB, VC must be set to 0.7 by selecting RC according to VC = 0.7 = VCC - IE RC Thus, VC 0.5 V IC RC 2.5 V From the figure we see that VC = -0.5 V is lower than the base voltage (VB = 0 V); thus the transistor will be operating in the active mode. R2 vO = $-10 V/V = -vI R1 31 mA 10 k \Rightarrow R2 = 10R1 1 k Total resistance used is 110 k 1 V <math>\therefore$ R1 + R2 = 110 k 1 mA 2 6 6 mA 0V 1 10 V 4 5 mA 5 2 k R1 + 10R1 = 110 k R1 = 10 k and R2 = 10R1 = 100 k 2.13 2.16 The circuit will be as follows: R + 10 V R 15 V 15 k Average = +5 V Highest = +10 V Lowest = 0 V Variation of the -15-V supply by ±1% results in v O = 50 V, which is impossible; thus the op amp saturates and v O = +10 V. Transistor Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 ID I 2 I 2 current through R equal to 0.21, we shunt R by a resistance R1 having a value such Rin = 1.1R 1.1R 4 1.1R 5 that is, 10% higher than in case (a). 100 = 21 V/V Ad = 1 1 + 5 Acm = 0 CMRR = ∞ If all resistors have ±1% tolerance, the differential gain will be slightly affected; Eq. (1) indicates that in the worst case Ad can deviate by approximately $\pm 4\%$ of the nominal value. Rs 10 k vs 5 mV #1 #2 #n vi1 vi2 vin vo RL 200 Ri1 10 k Ron 1 k 1 k #m vim vi(m 1) vin Ri(m 1) vin Ri(m 1) to k = 0.5 V/V = vs 10 k + 10 k (m 1) 10 vin Thus Ri = 40 k. 1 = 50 gm2 1 A/V = 20 mA/V 50 If Q1 is biased at the same point as Q2, then \Rightarrow gm2 = gm1 = gm2 = 20 mA/V id 1 = gm1 × 5 (mV) = vs 10 k + 10 k vi(m 1) 10 vin Thus Ri = 40 k. 1 = 50 gm2 1 A/V = 20 mA/V 50 If Q1 is biased at the same point as Q2, then \Rightarrow gm2 = gm1 = gm2 = 20 mA/V id 1 = gm1 × 5 (mV) = vs 10 k + 10 k vi(m 1) vin Ri(m 1) $20 \times 0.005 = 0.1 \text{ mA v d} 1 = \text{id } 1 \times 50 = 5 \text{ mV v} = 10 - 16 \text{ A} \beta 50 0.5 \times 10 - 3 \text{ IC} = 10 - 5 \text{ A} \beta 50 \text{ IB VB} = \text{VBE}$ = VT ln ISB -5 10 = 0.025 ln 10-16 IB = (d) B iC iB C vBE DB IS ISB b biB = 0.633 V We can determine RB from iE RB = E b 100 ISB 6.91 1018 A 15 - 0.633 = 1.44 M 10-5 To obtain VCE = 1 V, we select RC according to = 4.15 5 V RC = 2 k VC C aiE DE E = VCC - VCE IC 15 - 1 = 28 k 0.5 4.17 IS = 10-15 A B iE VCC - VB IB VE 2 mA Thus, a forward-biased EBJ conducting a current of 1 mA will have a forward voltage drop VBE : I VBE = VT ln IS -3 10 = 0.025 ln = 0.691 V 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln IS -3 10 = 0.025 ln = 0.691 V 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln IS -3 10 = 0.025 ln = 0.691 V 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln IS -3 10 = 0.025 ln = 0.691 V 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln IS -3 10 = 0.025 ln = 0.691 V 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln -3 1 × 10 1 × 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln -3 1 × 10 1 × 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln -3 1 × 10 1 × 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln -3 1 × 10 1 × 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln -3 1 × 10 1 × 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln -3 1 × 10 1 × 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln -3 1 × 10 1 × 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln -3 1 × 10 1 × 10-13 4.19 The equations utilized are CBJ conducting a 1-mA current will have a forward voltage drop VBE : I VBE = VT ln -3 1 × 10 -3 1 × 10 -3 1 × 10 -3 1 × 10 -3 1 × 10 -3 1 × 10 -3 1 × 10 -3 1 × 10 -3 1 × 10 v BC = v BE - v CE = 0.7 - v CE iBC = ISC ev BC /VT = 10-13 ev BC /0.025 = 0.576 V iBE = ISB ev BE /VT = 10-17 e0.7/0.025 When forward-biased with 0.5 V, the emitter-base junction conducts iB = iBC + iBE I = IS e0.5/0.025 Performing these calculations for v CE = 0.4 V, 0.3 V, and 0.2 V, we obtain the results shown in the table below. R For VS = -1 V (10% low), VO = -0.15 V and VO = 7.35 V. IC = $\alpha (VBB - VBE) RB RE + \beta + 1 6.116 Refer to the circuit of Fig. v O = -(3v 1 + 3v 2) 100 k 100 k v2 100 k v2 100 k 100 k v2 100 k v2 100 k 100 k v2 100 k 100 k v2 100 k v2 100 k 100 k v2 100 k v2$ equivalency v o = 10 mV × Rs is (t) = v s (t) 10 9.1 mV 10 + 1 If RL = 1 k: Rs a v o = 10 mV × 1 = 5 mV 1+1 If RL = 100 : vs (t) v o = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 1 k, a is (t) RL = 4 k Ex: 1.4 Using current divider: Rs io b is 10 A RL Rs Figure 1.1b Ex: 1.2 io = is × Rs voc vs isc = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 1 k, a is (t) RL = 4 k Ex: 1.4 Using current divider: Rs io b is 10 A RL Rs Figure 1.1b Ex: 1.2 io = is × Rs voc vs isc = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 1 k, a is (t) RL = 4 k Ex: 1.4 Using current divider: Rs io b is 10 A RL Rs Figure 1.1b Ex: 1.2 io = is × Rs voc vs isc = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 1 k, a is (t) RL = 4 k Ex: 1.4 Using current divider: Rs io b is 10 A RL Rs Figure 1.1b Ex: 1.2 io = is × Rs voc vs isc = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 1 k, a is (t) Rs voc vs isc = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 1 k, a is (t) Rs voc vs isc = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 1 k, a is (t) Rs voc vs isc = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 1 k, a is (t) Rs voc vs isc = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 1 k, a is (t) Rs voc vs isc = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 1 k, a is (t) Rs voc vs isc = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 1 k, a is (t) Rs voc vs isc = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0.8v s, b RL = 0.8 RL + Rs Figure 1.1a Since Rs = 10 mV × 100 0.91 mV 100 + 1 K For v o = 0. $10 \ \mu\text{A} \text{ v oc } 10 \ \text{mV} = = 1 \ \text{k isc } 10 \ \mu\text{A} \ \text{Ex: } 1.3 \ \text{Using voltage divider: v o } (t) = v \ \text{s} \ (t) \times \text{Given is} = 10 \ \mu\text{A}, \ \text{Rs} = 100 \ \text{k}.$ The value of $VV = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{VOV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{VOV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{VOV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{VOV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{VOV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{VOV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{VOV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{VOV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{CV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{VOV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{CV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{CV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{CV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{CV} = \sqrt{2} \ \text{CV} = 0.25 \ \text{V} \ 0.25 \Rightarrow \text{CV} = \sqrt{2} \ \text{CV} = 0.25 \$ 3.6 k Finally, the required value of W/L can be determined from I W 2 1 ID = = μ Cox VOV 2 2 L 1 W 0.25 = \times 0.4 \times \times 0.182 2 L W \Rightarrow = 38.6 L \Rightarrow VOV = 0.25 Thus, the maximum value we can use for I is \Rightarrow I = 0.5 mA I = Ad = 1V = 10 0.1 V gm RD = 10 0.1 10 = 5 k 2 I 1 W 2 = $\mu n \operatorname{Cox VOV} 2 2 \text{ L} \Rightarrow \text{RD} = 1 \text{ mW} = 0.5 \text{ mA} 2 \text{ Using this value, we obtain I RD 2 } 0.2 = 1 - 0.25 \times \text{RD VD} = 3.2 \text{ kAd} = \text{gm RD 10} = \text{gm} \times 3.2 \text{ Chapter 8-6 gm} = 10 = 3.125 \text{ mA/V} 3.2 \text{ 8.15 Since both circuits use the same supply voltages and dissipate equal powers, then their currents must be equal, that is, <math>2 \times (\text{I} + 1) = 3.2 \text{ kAd} = \text{gm RD} 10 = 3.2 \text{ kAd} = 3.2 \text{$ /2) I = VOV VOV ID = I But gm = 3.125 = 0.5 VOV = 0.16 V To obtain W/L, we use 1 W 2 VOV ID = μ n Cox 2 L W 1 × 0.162 0.25 = × 0.4 × 2 L W = 48.8 50 L where ID is
the bias current of the CS amplifier and I is the bias current of the differential pair. v I = 2.5 V: if we assume that the NMOS is turned on, then v O would be less than 2.5V, and this implies that PMOS is off (VSGP < 0). 6.55(a) and (c) and to the values found in the solution to Exercise 6.37 above. 2 pn = n2i (1.5 × 1010) = 2.25×103 /cm3 ND 1017 Using R = $\rho \cdot L$ with L = 0.001 cm and A Hole concentration = pn = 2.25×103 /cm3 A = $3 \times 10-8$ cm2, we have T = $125 \circ C = 273 + 125 = 398$ K R = 7.6×109 . 6.83 Thus, Gv becomes $Gv = -100 \times 9.1 \text{ k} 10 \text{ k} i = -91 \text{ V/V} 0$ 6.82 Adapting Eq. (6.114) gives RC RL ro $Gv = -\beta \text{ Rsig } + (\beta + 1)\text{re RC RL ro} = -\text{Rsig } \beta + 1 + \text{re } \beta \beta \text{ Rsig } G$ vsig ro vg i 1 gm RL vo Chapter 6-29 v g = v sig RS = Noting that ro appears in effect in parallel with RL, v o is obtained as the ratio of the voltage divider formed by (1/gm) and (RL ro), Gv = vovo = = v sigvg(RL ro)(RL ro) + 1 gm Also, With RL removed, ro = 0.98 Gv = 1 ro + gm (1) With RL = 500, (500 ro) + gm (2) ro 1 = gm 49 VDD = 3V 3 3 \Rightarrow RD = = 3 k 1 VG = VS + VGS ID RD = Q.E.D. From Eq. (1), we have 3 = 3 k 1 = 3+2=5V Thus the voltage drop across RG2 (5 V) is larger than that across RG1 (4 V). (b) Replacing the BJT with its T model (without ro) and replacing the capacitors with short circuits results in the equivalent-circuit model shown in Fig. P5.46. 1 on next page. $v = 0.7 + 0.025 \ln(10) = 0.76 V 0.43 1$ \therefore The iteration yields ID = 0.43 mA, VD = 0.68 V Ex: 3.8 T = 125 - 25 = 100 ° C b. Practically speaking, one normally uses the low value to minimize power dissipation. Thus, we can write for Q4, I4 = I3 = 40 μ A and using 1 W μ n Cox V2 2 L 4 OV 1 W 40 = × 400 × × 0.22 2 L 4 OV 1 W 40 = × 400 × × 0.22 2 L 4 W \Rightarrow = 5 L 4 ID4 = W4 = 2.5 μ m To find the value of R, we use |VSG1| = |Vtp| + |VOV 1| = 0.5 + 0.2 = 0.7 V R = 1 - |VSG1| $0.3 \text{ V} = \text{IREF} \ 0.02 \text{ mA} = 15 \text{ k} \ 7.8 \text{ (a)}$ If IS = 10-17 A and we ignore base currents, then IREF = IS eVBE /VT so that IREF VBE = VT ln 10-17 For IREF = 10 mA, -2 10 = 0.863 \text{ V VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} = 0.025 \text{ ln} \ 10-17 \text{ For IREF} = 10 \text{ mA}, -5 10 \text{ VBE} 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mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 For IREF = 1 mA, I mA = 0.98 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = The output resistance of the current source Q2 is ro2 = 1 1 + 2/ β 0.1 mA = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = 0.098 mA 2 1 + 100 5 × 0.5 = 25 k = 0.1 mA IO = 0.098 m current sink Q5 is For IREF = 10 mA, ro5 VA5 V × L = = An I5 I5 = 5 × 0.5 = 31.25 k 80 IO = 10 mA = 9.62 mA 2 1 + 50 Chapter 7-4 7.11 7.9 VDD VDD Q1 Q2 IO IREF IO = mIC1 A node equation at the collector of Q1 yields IREF For identical transistors, the transfer ratio is 1 IO = = IREF 1 + 2/\beta IO + IC1 = IC1 + \beta 1 1 + 2 50 = 0.96 Substituting IC1 = IO /m results in m m+1 1+ β IO = IREF Q.E.D. For β = 80 and the error in the current transfer ratio to be limited to 10%, that is, m \geq 0.9m m+1 1+ β I - 1 - 1 0.9 I - 1 - 1 = 7.88 m \leq 80 0.9 Thus, the largest current transfer ratio possible is 7.88. Thus, the diode-connected MOSFETs of Fig. Since the two NMOS transistors are identical and have the same ID, their VGS values will be equal. Active Saturation Active S 2 - Gm1 v 1 v 0 = v 3 = μ v d = μ R (Gm2 v 2 - Gm1 v 1) 2.3 vO = vd = v2 - v1 vO v 0/v d 1 0.00 0.00 0.00 - 2 1.00 1.00 10.1 101 5 2.01 2.00 -0.01 -0.99 99 6 1.99 2.00 0.01 1.00 100 7 5.10 (d) -5.10 # v1 (a) v2 (c) we have v O = Ad v Id + Acm v Icm Experiments 4, 5, and 6 show that the gain is approximately 100 V/V. E2.5 to the input of this amplifier, we have: v i is a virtual ground that is v i = 0, thus the current flowing through the 10-k resistor connected between v i and ground is zero. This frequency is found as follows: The transfer function of each STC circuit is T (s) = $1 + 1 = 1.4 \times 10 - 8$ F $2\pi \times 110 \times 103 \times 102$ Thus we select C1 = 0, thus the current flowing through the 10-k resistor connected between v i and ground is zero. $1 \times 10-7$ F = 0.1 μ F. Obviously, in this case there is no need for output trimming. VO = Vx - RL IL = $-1 - RL \times 10.1$ I3 4I RL = 100, VO = -2.01 V; RL = 1 k, VO = -2.01 V; RL = 1 k, VO = -1.1 V Figure 2.3 2.31 1.5 V iI 10 k I1 R1 Vx IL I2 I i RL R R2 which is independent of the value of RL. The equivalent circuit is then R 1 To limit v s \leq 1 V, the net resistance has to be \leq 2 k. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior permission of Oxford University Press. 6.95 RB1 × 3 = 0.710 RB1 + RB2 RB2 = 3.225 RB1 Given that RB1 and RB2 are 1% resistors, the maximum and minimum values of the ratio RB2 /RB1 will be $3.225 \times 1.02 = 3.2895$ and $3.225 \times 0.98 = 3.1605$. iE1 = 11 µA, iE2 = 9 µA = I /2 ≤ 2 µA β +1 iE1 - 0.5 I Chapter 8-12 This table belongs to Problem 8.29. 1 + 10/A vO = vI If A = 103, then G = 9.901 and G - 10 × 100 = -0.99% -1% 10 For vI = 1.2895 $V, v O = G \times v I = 9.901 V$ and 10 mA iL = ∞ iI 0 v O × iL 10 × 10 PL = ∞ = PI v I × iI 1×0 Ex: 2.14 (a) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (b) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (b) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (b) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (c) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (c) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (c) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (c) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (c) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (c) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (c) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (c) Load
voltage = 1 k × 1 V 1 mV 1 k + 1 M (c) Load voltage = 1 k × 1 V 1 mV 1 k + 1 M (c) the circuit to find ix and hence Rin , as vx Rin = ix 0.2 = 0.1998 mA 2 + 250 0.4 = = 0.3997 mA 2 + 250 IO2 = IO4 re3 Note that all three transistors are operating at equal emitter currents, approximately equal to IREF . 2.31(a), then the input offset voltage VOS will see a unity-gain amplifier [Fig. The 5.75 k collector current becomes $\beta \times 0.4356$ mA 2 + 250 IO2 = IO4 re3 Note that all three transistors are operating at equal to IREF . 2.31(a), then the input offset voltage VOS will see a unity-gain amplifier [Fig. The 5.75 k collector current becomes $\beta \times 0.4356$ mA 2 + 250 IO2 = IO4 re3 Note that all three transistors are operating at equal to IREF . 2.31(a), then the input offset voltage VOS will see a unity-gain amplifier [Fig. The 5.75 k collector current becomes $\beta \times 0.4356$ mA 2 + 250 IO2 = IO4 re3 Note that all three transistors are operating at equal to IREF . 2.31(a), then the input offset voltage VOS will see a unity-gain amplifier [Fig. The 5.75 k collector current becomes $\beta \times 0.4356$ mA 2 + 250 IO2 = IO4 mA 2 + $IC = \beta + 1$ where β is the increased value of 150, 150 IC = $\times 0.435$ mA 151 = 0.432 mA Required: IC = 0.5 mA and VC = VE + 2. This indicates that the CG amplifier functions as an effective current buffer. From the solution to Problem 8.100, we know that I = 0.25 mA. Transistor a b c d e VBE (mV) 700 690 580 780 820 IC (mA) 1.000 1.000 0.230 10.10 73.95 IB (μ A) 10 20 5 120 1050 IE (mA) 1.010 1.020 0.235 10.22 75 α 0.99 0.98 0.979 0.988 0.978 0 emitter VE is ISE = iB B VE = $-VDE \ vBE = -VDE \ vBE = -VT \ln(IE / ISE) \ 2 \times 10 - 3 = -0.025 \ln 5.05 \times 10 - 15 DE ISE \ IS /a iE = -0.668 V E a \ 0.99 ISE \ 6.98 \ 1016 A The voltage at the collector VC is found from VC = 5 - IC \times 2 = 5 - 0.99 \times 2 \times 2 = 1.04 V 4.16 Refer to the circuit in Fig. Indeed inserting the amplifier increases the gain by a$ factor 8.3/0.001 = 8300. The gain of the CS amplifier is |A| = gm RD where gm = Thus, $2\mu Cox |A| = W L 2\mu Cox ID CS W L ID RD$ (1) CS The gain of the differential amplifier is 8.14 (a) Ad = gm RD AdAcross each RD the dc voltage is $0.085 \text{ I RD} = \times 47 = 2 \text{ V } 2 2$ (d) The peak sine-wave signal across each drain will be v Dmin = VDD - RD ID - Vpeak = VDD - 2 - 0.1 gm = Thus, $2\mu \text{ Cox}$ Ad = $2\mu \text{ Cox}$ I 2 diff I RD 2 diff (2) If all transistors have the same channel length, each of the differential pair transistors must be twice as wide as the transistor in the CS amplifier. C $0.1 \,\mu\text{F}$ 0 vO iR To increase the value of R has to be increased by 1.5 times: $20 \,\text{k} \times 1.5 = 30 \,\text{k}$ Chapter 2-28 ω 0 (unity-gain frequency) = 103 rad/s 2.84 Vo At $\omega = 0.1 \ \omega 0$, $= 0.1 \ V/V$, $\varphi = 270 \circ V \ vI$ i Vo At $\omega = 10 \ \omega 0$, $= 10 \ V/V$, $\varphi = 270 \circ V \ 1V$ i 0 0.2 ms When a series input resistor R1 is added as shown, then the high-frequency gain is limited to R2 /R1. P6.50. Writing expressions for the currents, we have ID = IS eVD /VT ID = IS eVD /VT ID = IS eVD /VT = IS eVD $v^{0} = max downward amplitude$, we get Point A occurs at VGS = Vt = 1 V, iD = 0 v^{0} v DS B = v GS B - Vt = VGS + -Vt | Av | Point A = (1 V, 5 V) (VGS , VDS) = VDS - v^{0} Point B occurs at sat/triode boundary (VGD = Vt) VOV + VGD = 1 V \Rightarrow V GS - [5 - iD RD] = 1 1 (1)(24) [VGS - 1]2 - 1 = 0 VGS - 5 + 22 - 23VGS + 6 = 0 12VGS VGS VGS VGS + 6 = 0 12VGS VGS + 6 = 0 12 = 1.605 V iD = 0.183 mA VDS = 0.608 V Point B = (+1.61 V, 0.61 V) v^{o} = VDS - v^{o} | Av | VDS - VOV v^{o} = 1 + | A1v | (1) For VDD = 5 V, VOV = 0.5 V, and W k n = 1 mA/V2, we use L -2(VDD - VDS) Av = VOV and Eq. (1) to obtain (b) For VOV = VGS - Vt = 0.5 V, we have VGS = 1.5 V 1 ID = k n (VGS - Vt) 2 2 1 = × 1(1.5 - 1) 2 2 ID = 0.125 V 10 = 0. $mA VDS = +2.00 V v^{\circ} o v^{i} V DS Av 1V - 16 471 mV 29.4 mV 1.5 V - 14 933 mV 66.7 mV - 12 1385 mV 115 mV 2.5 V - 10 1818 mV 182 mV 2V Point Q = (1.50 V, 2.00 V) Av = -k n VOV RD (c) From part (a) above, the maximum instantaneous input signal while the transistor ID RD = 4 V, ID = -k n VOV RD (c) From part (a) above, the maximum instantaneous input signal while the transistor ID RD = 4 V, ID = -k n VOV RD (c) From part (a) above, the maximum instantaneous input signal while the transistor ID RD = 4 V, ID = -k n VOV RD (c) From part (a) above, the maximum instantaneous input signal while the transistor ID RD = 4 V, ID = -k n VOV RD (c) From part (a) above, the maximum instantaneous input signal while the transistor ID RD = 4 V, ID = -k n VOV RD (c) From part (a) above, the maximum instantaneous input signal while the transistor ID RD = 4 V, ID = -k n VOV RD (c) From part (a) above, the maximum instantaneous input signal while the transistor ID RD = 4 V, ID = -k n VOV RD (c) From part (a) above, the maximum instantaneous input signal while the transistor ID RD = 4 V, ID = -k n VOV RD (c) From part (a) above, the maximum instantaneous input signal while the transistor ID RD = 4 V, ID = -k n VOV RD (c) From part (a) above, the maximum instantaneous input signal while the transistor ID RD = 4 V, ID = -k n VOV RD (c) From part (a) above, the maximum instantaneous input signal while the transistor ID RD = 4 V, ID = -10 V V V POV RD (c) From part (b) above, the maximum instantaneous input signal while the transistor ID RD (c) From part (b) above, the maximum instantaneous input signal while the transistor ID RD (c) From part (b) above, the maximum instantaneous input signal while the transistor ID RD (c) From part (b) above (c) From part (c) Above (c) Ab$ 0.125 mA \therefore RD = 32 k Chapter 6-3 solving the resulting quadratic equation results in 6.8 k n RD = 213.7 vDS which can be substituted into Eq. (2) to obtain VDS B = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be
found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 V (b) The gain achieved can be found as Q VDSQ Av = -k n RD VOV = 0.212 + 0.5 = 0.712 + 0.5 = 0.712 + 0.5 = 0.712 + 0.5 = 0.712 + 0.5 $-213.7 \times 0.2 = -42.7 \text{ V/V} 0.5 0.5 \text{ v}^2\text{gs} = = 11.7 \text{ mV} | \text{Av} | 42.7 0.5 \text{ V} \text{ B} \text{ VDSB VOV}$ (c) ID = 100 $\mu\text{A v}^2$ gs Vt vGS VDSB To obtain maximum gain while allowing for a -0.5 V signal swing at the output, we bias the MOSFET at point Q where VDS Q = VDS B + 0.5 V (1) as indicated in the figure above. V R For I = 0.5 mA, the output will saturate at $I 1 \mu A RG1 = 5 - 3.4 = 1.6 M 1 \mu A RS = 10 k VS = 5 k 0.32 VD = 3.4 V$, then RD = IDN = $5 - 3.4 = 5 k 0.32 RL 1 \times 1(2.5 - VO - 1)2 2$ IDN = $0.5(1.5 - 10IDN)2 Ex: 5.14 2 \Rightarrow 100IDN - 32IDN + 2.25 = 0 \Rightarrow IDN 1.8 V = 0.104 mA RD IDP = 0$, $V O = 10 \times 0.104 = 1.04V ID VO IDP QP 10 k - 2.5 V Vtp$ $= -0.4 \text{ V} - 2.5 \text{ V} \text{ k} \text{ p} = 0.1 \text{ mA/V2 W } 10 \text{ µm} = \Rightarrow \text{ k} \text{ p} = 5.56 \text{ mA/V2 L} 0.18 \text{ µm VSG} = |\text{Vtp}| + |\text{VOV}| = 0.4 + 0.6 = 1 \text{ V} \text{ VS} = +1 \text{ V} \text{ Since VDG} = 0$, which implies that the transistors are turned off and IDN = IDP = 0. To find the peak-to-peak amplitude of the square wave, we note that $4V/\pi = 441 \text{ mV}$. Thus the largest symmetrical Chapter 3-14 output signal allowed is 2.38 mV in amplitude. RE = (a) IE = VBB - VBE RB RE + $\beta + 1 \text{ RB} = 5.73 \times \text{RE} = 19.08 \text{ k VBB} = \text{VCC VBB} - \text{VBE IE nominal} = \text{RB RE} + 101$ IE high 2.46 = 5 VBB - VBE = RB RB + RE + 101 51 RB / RE 101 0.95 = RB / RE 1 + 51 RB \Rightarrow = 5.73 RE R2 R1 + R2 = 5 × 19.08 high 1 + R2 = 5 × 19.08 hi $/3 5/3 = 3.33 \text{ k} = \text{IE } 0.5 \Rightarrow \text{R1} = 38.8 \text{ k}$ 11 - 37.5 k R2 = 1 RB R1 (d) VCE = VCC - RC IG $1 = 5 - \text{RC} \times 0.99 \times 0.5 \Rightarrow \text{RC} = 8.1 \text{ k}$ Check design: VBB = VCC $37.5 \text{ R2} = 5 \times \text{R1} + \text{R2} 37.5 + 38.8 = 19.07 \text{ k}$ Chapter 6-36 IE nominal = 2.46 - 0.7 = 0.5 mA 19.07 3.33 + 101 IE low = 2.46 - 0.7 = 0.475 mA 19.07 3.33 + 151, and which is 5% lower than IE Thus, IC = 0.432 - 0.39 = 0.042 mA for a percentage increase of IC $0.042 \times 100 = \times 100 = 10.8\%$ IC 0.39 nominal IE 2.46 - 0.7 = 0.509 mA = high 19.07 3.33 + 151. If in any design W/L is held constant while L is increased by a factor of 10, gm remains unchanged but ro increases by a factor of 10, resulting in A0 increasing by a factor of 10. Between the two collectors there will be a sine wave with 0.9 V peak amplitude. (c) I = P/V = 10 W/0.1 mA = 10 V/1 = 10 V/0.1 mA = 10 V/0.R2 R1 + R2 Chapter 1-2 This figure belongs to 1.4. 10 10 10 40 46.7 20 20 20 10 40 20 30 40 10 10 40 50 20 6.7 20 40 60 10 10 40 20.3 10 10 20 40 1.7 Use voltage divider to find VO VO = 5 2 = 2V 2+3 28 5 V 3 k Equivalent output resistance RO is VO RO = (2 k 3) k) = 1.2 k The extreme values of VO for $\pm 5\%$ tolerance resistor are VOmin = 5 2(1 - 0.05) 2(1 - 0.05) + 3(1 + 0.05) 2(1 + 0.05) + 3(1 - 0.0 Dn 10 - 4 (Note 1 um = 10 Find current component In \cdot pn (xn) = pn0 eV (V T and pn0 = cm) tn = 100 ns In = AIn = AGDn OP = tn In (Eq. 1.76) n2i ND dn dx dn pn (xn) - pn0 pn0 eV (V T - nn0 = dx Wn - xn Wn - xn V/V e T - 1 = pn0 Wn - xn) = 100 x 10 - 9 x 0.1 x 10 - 3 = 10 x 10 - 12 C tn I Cd = VT $100 \times 10-9 = \times 0.1 \times 10-3 25.9 \times 10-3 \therefore$ Ip = AqDp = 386 pF = Aqn2i 1.98 Equation (1.81): $\tau T \land 1 \times 10-3 5 pF = 25.9 \times 10-3 dp dx$ Dp × eV /V T - 1 (Wn - xn) ND Similarly, Dn × eV /V T - 1 (Wn - xn) ND Similarly, Dn × eV /V T - 1 Aqn2i = 129.5 ps For I = 0.1 mA: $\tau T \times I Cd = VT$ 129.5 × 10-12 = × 0.1 × 10-3 = 0.5 pF 25.9 × 10-3 The excess change, Qp, can be obtained by multiplying the area of the pn (x) distibution graph by Aq. 1.99 (a) pn, np n region pn(xn) pn(x) np (xp) np (x) pn0 np0 Wp xp 0 xn Depletion region Widths of p and n regions Wn Chapter $1-33 \text{ Qp} = \text{Aq} \times 1 [\text{pn}(\text{xn}) - \text{pn0}] (\text{Wn} - \text{xn}) 2 \text{ Thus}, \tau T = 1 \text{ Wn2}, \text{and } 2 \text{ Dp} = 1 \text{ Aq} \text{ pn0} \text{ eV}/\text{V} T - 1 (\text{Wn} - \text{xn}) 2 \text{ Q} \text{ dI} = \tau T \text{ dV} \text{ dV} \text{ V}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 (\text{Wn} - \text{xn}) 2 \text{ dQ} \text{ dI} = \tau T \text{ dV} \text{ dV} \text{ V}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS}
\text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ T} - 1 2 \text{ ND} \text{ IS} \text{ eV}/\text{V} \text{ eV} + 1 2 \text{ IS} \text{ eV}/\text{V} \text{ eV} + 1 2 \text{ IS} \text{ eV}/\text{V} \text{ eV} + 1 2 \text{ IS} \text{ eV}/\text{V} \text{ eV} + 1 2 \text{ IS} \text{ eV}/\text{V} \text{ eV} + 1 2 \text{ IS} \text{ eV}/\text{V} \text{ eV} + 1 2 \text{ IS} \text{ eV}/\text{V} \text{ eV} + 1 2 \text{ eV}/\text{V} \text{ eV} + 1 2 \text{ IS} \text{ eV}/\text{V} +$ AND COMPUTER ENGINEERING A del S. Correspondingly, the voltage across each diode changes by VD where 8 = e VD/VT 13 8 = VD = 25 ln = -12.1 mV 13 = 7.38 mA = 8.39 mA. R = 5 - 1.5 = 417 8.39 mA Use a small-signal model to find voltage VO when the value of the load resistor, RL, changes: rd = VT 0.025 = 3.4 = ID 7.39 When load is disconnected, all the current I flows through the diode. $v D1 = -2.5 + 0.5 \times 4 = -0.5 V$ Observe that since v G1 = v D1, Q1 is still operating in saturation, as implicitly assumed. The load current iL comes from the power supply of the op amp. $vO 10 V 5 V \rightarrow C = 868 \mu F$ To specify the diodes, we determine iDav and iDmax, iDav = IL (1 + $\pi (Vp - 10 V 5 V) \rightarrow C = 868 \mu F$ To specify the diodes. (0.7)/2 Vr) = $0.1(1 + \pi 12.5/2) = 785$ mA 0 vI 5 V 1 ms t Chapter 3-33 Thus, v O is a square wave with 0-V and +10-V levels, i.e. 5-V average and, of course, the same frequency (1 kHz) as the input. The transistor continues to operate in the saturation region until v G reaches 0.5 V, at which point v DG will be 0.5 V, which is equal to |Vtp|, and the transistor enters the triode region. Therefore, v o = v i - R × 0.5 mA = $0 - 10 \text{ k} \times 0.5 \text{ mA} = -5 \text{ V}$. Thus, to obtain a dc level shift of 0.9 V, we write = (58.5 250) + 4000 + 0.4 × 4000 × (58.5 250) + 4000 + 0.4 × 4000 × (58.5 250) + 4000 + 0.4 × 4000 × (58.5 250) + 4000 + 0.4 × 4000 × (58.5 250) + 4000 + 0.4 × 4000 × (58.5 250) + resistance between the collectors of Q1 and Q2 Total resistance in emitters of Q1 and Q2 40 k 10 k = $20 \text{ V/V} 2 \times 0.1 + 2 \times 0.1$ Thus the gain of the first stage decreases but only slightly. Thus, vO = = It - $10 \text{ C} 10-5 \text{ t} - 10 = \text{t} - 10 \text{ c} 10-5 \text{ c} - 10 = \text{t} - 10 \text{ c} 10-5 \text{ c} - 10 = \text{t$ However, each of the two diodes conducts for only half the time, i.e., for 48.4% of the cycle. 2.5 V t (f) Vp + = 5 V, Vp - = -2.5 V, V0 5V t Vp + = 5 V, V - = -2.5 V, To obtain the W/L values, 1 W |VOV |2 I = ID = up Cox 2 L 3,4 1 W 100 = $\times 100 \times \times 0.22 2 L 3,4$ W = 50 L 3,4 (b) I = 0.5 mA 2 $\times 42$ = 160 0.2 Ro = 320 k W 1 |VOV |2 I = up Cox 2 L 3,4 W = 50 L 3,4 0.5 Ro = 7.60 Refer to Fig. Ro = ∞ (because iL is independent of the value of RL). The result is as follows: 60 50 40 Ro1 20 dB/decade 20 dB/decade 20 dB/decade 20 vol C 10 Ri2 0 1 Now Ri2 = 100 k. If we choose 5.1 k, the gain will be vo = $-0.385 \times 73.4 \times (5.1 2) = -40.6$ V/V v sig (2) = 5 - 0.92 × 0.22 RC = 8.7RC 0.025 and VB = $-0.22 \times 90 = -0.2$ V 101 Thus, 5 - 0.22RC = 8.7RC $\times 0.005 = -0.2$ -0.395 Chapter 6-46 B 100 = 5 k = gm 20 vo 5 Gv = - × 20 × (5 10) v sig 5 + 2.5 = RC = 21.2 k rm = Selecting 5% resistors, we find RB = 91 k RC = 22 k and specifying I to one significant digit gives I = 0.2 mA aIC 0.2 gm = = 8 mA/V VT 0.025 Av o = -gm RC = -8 × 22 = -176 V/V B 100 = = 12.5 k rm = gm 8 Rin = RB rm = 91 12.5 = 11 k 11 × 100 k rm = 100 k rm = 12.5 k rm = 100 k rm = $8(22\ 20)$ Gv = -20 + 11 = -29.7 V/V = -44.4 V/V 6.119 Refer to the circuit of Fig. (d) Rin = rn 1 = 5 k Ro = ro1\ ro2 = 120\ k 120\ k = 60\ k 7.49 Refer to Fig. The common-mode gain, however, will be lower: ro4 Acm = $-\beta3$ REE But = $-800 = 6.45 \times 10 - 3$ V/V 100×1240 and the CMRR will be 2000 | Ad | = 3.1×105 = CMRR = | Acm | $6.45 \times 10 - 3$ or 110 dB 8.102 Gm = gm1.2 I = 1 2 k (W/L)VOV 2 n 1 2 2 × 2 × VOV = VOV 2 Thus = 2 = 20 - 2 × 0.7 - 2VOV 144 VOV + 2VOV - 18.6 = 0 = VOV = 0.35 V and I/2 0.2 = 8 mA/V = VT 0.025 I = 0.352 = 0.12 mA (a) Rid = 2rII = 28/gm Ro = ro2 ro4 where |VA| 40 ro2 = ro4 = = 200 k I/2 0.2 gm = gm1.2 I/2 0.06 = 2.4 mA VT 0.025 Chapter 8-37 2 × 100 = 83.3 k 2.4 (b) Ad = gm1,2 Ro Rid = ro2 = ro4 = 60 k I/2 1 Ro = 60 k 60 k = 30 k where Ad = 40 × 30 = 1200 V/V Ro = ro2 ro4 (c) Acm can be found using Eq. (8.165), ro4 Acm = - β 3 REE But ro2 = ro4 = $|VA| 60 = = 30 k I 2 60 = -0.02 V/V = -100 \times 30$ REE $= ro5 = Ad = 2.4 \times 500 = 1200 V/V$ (c) Acm can be found from Eq. (8.165): ro4 Acm = - β 3 REE Acm where REE is
the output resistance of the Wilson mirror, or 95.6 dB REE = qm7 ro7 ro5 1200 | Ad | = = 60,000 | Acm | 0.02 CMRR = 8.105 Refer to Fig. However, the unequal β 's will mean unequal α 's. (c) Since the input offset voltage is proportional to |VOV 1,2|, it will decrease by a factor of 2. Thus VD = 770 mV. Also, the output signal of the amplifier loses approximately 90% of its strength when the load is connected (because RL = Ro /10). Thus in (T /2) seconds, the capacitor voltage changes by 20 V. 8.33 gm = IC $\alpha \times 0.2 = 8 \text{ mA/V VT } 0.025 \text{ Rid} = 2\pi\pi = 2\beta 160 = 40 \text{ k} = 2 \times \text{gm}$ model results in the circuit in the figure. IE I2 = I1 + IB = I1 + β + 1 iC = 10-15 ev BE /VT A Intercept (mA) VBE = 0.68 V IE = I - I1 = 1.1 - 0.1 = 1 mA To find the intercept of the straight-line characteristics on the ic axis, we substitute v CE = 0 and evaluate v BE (V) 0.65 VE I 1.1 mA with IS = 10-15 A and VA = 100 V, to get v CE iC = 10-15 ev BE / 0.025 1 + 100 vCE IE 0.70 0.72 0.73 0.74 1.45 3.22 4.80 7.16 Slope (mA/V) 0.002 0.015 0.032 0.048 0.072 II R1 = VBE I2 R2 II R2 = VBE R2 R1 VE = -(I1 R1 + I2 R2) R2 (1) = -VBE 1 + R1 6.8 = -11 VBE = -7.48 V = -VBE 1 + 0.68 which gives this circuit the name "VBE multiplier." A more accurate value of VE can be obtained by taking IB into account: VE = -(I1 R1 + I2 R2) R2 = -VBE + VBE + IB R2 R1 R2 VBE - IB R2 = -1 + R1 (2) = $-7.48 - 0.01 \times 68 = -8.16 V$ As temperature increases, an approximate estimate for the temperature increases, and the $nn \approx ND = 5 \times 1016 \text{ cm} - 3$; $pn = n2i = 4.5 \times 103 \text{ cm} - 3$ $nn 10 \mu \text{m}$ Using $\mu n = 1200 \text{ cm} 2$ /V · s and 3 V $\mu p = 400 \text{ cm} 2$ /V · s, we have $\rho = 0.10 \text{ -cm}$; R = 3.33 k. iB E C vBE v be ib = - gm v be α gm v be α gm v be α gm v be $\beta = = r\pi$ Rin \equiv ib gm B Rin ro bib DB (ISB IS) b biB E Figure 1 For v BE undergoing an incremental change v be from its equilibrium value of VBE, the current iB Chapter 6-15 C changes from IB by an incremental resistance of DB at the bias current iB, which is related to v be by the incremental resistance of DB at the bias current IB. The peak diode current occurs at the peak diode voltage. 2.28 and observe that R v + - v - = VOS + v 2 - v 1 = VOS + v Id Vi C Vo and since v O = v 3 = A(v + -v -), then v O = A(v Id + VOS) C = 0.01 μ F is the input capacitance of this differentiator. 4.21. Thus, for equivalence, we write Av o Gm = Ro Thus, Rin vo = Gm (Ro RL) v sig Rin + Rsig These figures belong to Problem 6.56. Thus the cascode transistor must have A0 = 100. Thus VD - 1 = v Dmin = VG - Vt = 0.01 μ F is the input capacitance of this differentiator. 4.21. Thus, for equivalence, we write Av o Gm = Ro Thus, Rin vo = Gm (Ro RL) v sig Rin + Rsig These figures belong to Problem 6.56. Thus the cascode transistor must have A0 = 100. Thus VD - 1 = v Dmin = VG - Vt = 0.01 μ F is the input capacitance of this differentiator. $0 - 1 \Rightarrow VD = 0$ V VS = ID RS = 3ID VGS = 5 - VS = 5 - 3ID 1 ID = k n (VGS - Vt) 2 2 1 = x 2(5 - 3ID - 1)2 2 = 16 - 24ID + 9ID2 9ID2 - 25I + 16 = 0 where we have assumed that the signal voltage at the gate is small. We just saw that 0.5 v 2 appears at the input of the v 2 transconductance amplifier. ii vi RG1 2 M Rin vgs 0.5 + 2.375 - 0.95 1 1 + |Av| Substituting |Av| = 86.5, we obtain $|v^{\circ}| = 1.9$ V An approximate value of $|v^{\circ}|$ could have been obtained from vOmin = VOV = 0.45 V VDS - $|v^{\circ}| = 1.9$ V An approximate value of $|v^{\circ}| = 1.9$ V An approximate value source generates 0-0.5 mA, a voltage of 0-2 V may appear across the source (b) Same procedure is used for (b) to obtain 0.5 k 2 0.75 V 3 is 00.5 mA RL vs (c) Between terminals 1 and 3, the open-circuit voltage is 1.5 V. 6.59. Assuming saturation-mode operation, the terminal voltages are interrelated as shown in the figure, which corresponds to Fig. Assuming that D1 and D2 are both conducting gives the results shown in Fig. Rsig 200 k vsig vgs1 gm1vgs1 Gv = gm2vgs2 RD2 R L vo v gs2 vo × v gs1 v gs2 (b) $\beta = 50$, $|Gv| = -gm1 RD1 × -gm2 (RD2 RL) 10 (10/50) + 0.025 = 44.4 V/V = 3 × 10 × 3 × (10 10) \beta = 150$, |Gv| = -450 V/V 10 (10/150) + 0.025 = 109.1 V/V IC 0.5 mA = 20 $mA/V = 6.63 \text{ gm} = VT \ 0.025 \text{ V} \ \beta \ 100 \ r\pi = = 5 \text{ k} = \text{gm} \ 20 \text{ mA/V} \ \text{Rin} = r\pi = 5 \text{ k} = \text{gm} \ 20 \text{ mA/V} \ \text{Rin} = r\pi = 5 \text{ k} = 0 \text{ k} \ \text{Av} \ \text{o} = -200 \text{ V/V} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ V/V} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ V/V} \ \text{Rin} = r\pi = 5 \text{ k} = 0 \text{ m} \ \text{Av} \ \text{o} = -200 \text{ v} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ v} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ v} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ v} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ v} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ v} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ v} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ v} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ v} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ v} \ \text{Rin} + \text{Rsig} \ \text{Rin} + \text{Rsig} \ \text{Av} = -200 \text{ v} \ \text{Rin} + \text{Rsig} \ \text{Rin} + \text{Rsi} \ \text{Rin} +$ $v^{sig} = 15 \text{ mV Correspondingly}, v^{o} \text{ will be } v^{o} = Gvv^{sig} = 15 \times 33.3 = 500 \text{ mV} = 0.5 \text{ V } 6.64 | Gv| = RL (Rsig / \beta) + (1/gm) RL = 10 \text{ k}, Rsig = 10 \text{ k}, gm = IC \text{ VT } 1 = 40 \text{ mA/V} 0.025 \text{ Nominal} | Gv| = (10/100) + 0.025 = 80 \text{ V/V Thus}, | Gv| ranges from 44.4 \text{ V/V to } 109.1 \text{ V/V}.$ For Gnominal = -100 and x = 1, the closed-loop gain will be in the range -98 V/V to -102 V/V. 5 V 0.5 mA 0.5 mA 1 mA R3 R2 R5 V4 0 V7 1 V Q2 V3 = 0 Q1 0 0.5 mA V2 Q3 R1 V5 = -2 V R4 0.5 mA V6 R6 1 mA -5 V Figure 1 This figure belongs to Problem 4.59. The charge equilibrium equation can be expressed as i(T/2) = C × 20 V = (5 + 5.005 \sin \omega t) V v + (op amp A3) = v O2 × 10 V R4 10 = v O2 $R3 + R4 10 + 10 1 1 v O2 = (5 + 5.005 \sin \omega t) 2 2 = (2.5 + 2.5025 \sin \omega t) V 10 T 10T 1 = 20C \Rightarrow CR = = × 2 × 10 - 3 R 2 40 4 = 0.5 ms = Ex: 2.19 v - (op amp A3) = v + (op amp$ resistance of this inverting integrator is R; therefore, R = 10 k. Thus v O = v I. Thus at the limit VDG = -0.5 V, we can determine VOV : $1.2 \times 2 \times \text{VOV} = 0.45 \text{ V} = 0.5 + 0.45 = 0.95 \text{ V}$ The current in the feedback network can now be found as VGS 0.95 = -0.5 V. $0.475 \mu A \ IR = 2 \ M \ 2 \ which indeed is much smaller than the 200 \ \mu A \ delivered by the current source.$ Sedra and Kenneth C. 9.10 can be used to determine the three short-circuit time constants, again with RE = ∞ . At f = 60 kHz, |A| = 3 MHz = 50 V/V 60 kHz or 34 dB = 1 + R2 R1 2 MHz = 20 kHz 100 Ex: 2.29 For the input voltage step of magnitude V the output waveform will still be given by the exponential waveform of Eq. (2.58) if $\omega t V \leq SR SR SR = V \leq resulting$ in that is, $V \leq \omega t 2\pi f V \leq 0.16 V Ex$: 2.27 From Appendix F we know that the 10% to 90% rise time of the output waveform of 2.2. (b) The upper limit of VICM is determined by the need to keep Q1 and Q2 in saturation, thus 1 W µn Cox V2 2 L 1,2 OV W 1 100 = $\times 400 \times \times 0.04$ 2 L 1,2 W W = = 12.5 = L 1 L 2 1 W |VOV|2 ID3 = ID4 = 100 = µp Cox 2 L 3,4 1 W 100 = $\times 100 \times \times 0.04$ 2 L 3,4 W W = = 50 = L 3 L 4 8.106 (a) ID1 = ID2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = VDD - |VSG4| + Vt = 0.9 - |Vt| - |VOV 4| + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = VDD - |VSG4| + Vt = 0.9 - |Vt| - |VOV 4| + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = VDD - |VSG4| + Vt = 0.9 - |Vt| - |VOV 4| + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = VDD - |VSG4| + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = VDD - |VSG4| + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = VDD - |VSG4| + Vt = 0.9 - |Vt| - |VOV 4| + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = 0.9 - 0.2 = 100 = ID5 = ID7 = ID8 = 200 µA VICM max = VD1 + Vt = 0.9 + 0.2 = 100 = ID5 = ID7 = ID8 = 100 = ID7 = ID8 = +0.7 V The lower limit of VICM is determined by the need to keep Q5 in saturation, VICM min = -0.9 + |VOV 5| + |VGS1| = -0.9 + 0.2 + 0.2 + 0.4 = -0.1 V Thus -0.1 V Chapter 8-39 v Omin = -VSS + |VOV 7| = IREF = -0.9 + 0.2 = -0.7 V (48/0.8) (40/0.8) = $90 \times 1.2 = 108$ μ Thus $-0.7 V \le v O \le +0.7 V$ Thus ID7 will exceed ID6 by 18 μ A, which will result in a systematic offset voltage, (d) A1 = -gm1.2 (ro2 ro4) $VO = 18 \mu$ A(ro6 ro7) where where $2 \times 0.1 \text{ gm} 1.2 = 1 \text{ mA/V} 0.2 \text{ 6}$ (VA | ro2 = ro4 = = 60 k 0.1 mA 0.1 ro6 = 111 k and ro7 now becomes $10 = 92.6 \text{ k} 0.108 \text{ A1} = -1 \times (60 \ 60) = -30 \text{ V/V}$ ro7 = A2 = -100 V/V = 100 m 1.2 m 1.-gm6 (ro6 ro7) Thus where VO = 18 × 10-3 × (111 92.6) 2 × 0.2 = 2 mA/V 0.2 6 |VA| = 30 k ro6 = ro7 = 0.2 0.2 = 909 mV gm6 = The corresponding
input offset voltage will be VOS = A2 = -2 × (30 30) = -30 V/V A0 = A1 A2 = 30 × 30 = 900 V/V = 8.107 (a) Increasing (W/L)1 and (W/L)2 by a factor of 4 reduces |VOV 1,2| by a factor of 2. v d = $(Gm v 2 - Gm v 1)R = Gm R(v 2 - v 1) Exercise 2-2 R 10 k R1 10 k 0.5 mA Rf v1 vo R2 vi Ex: 2.7 v2 vO Connecting the signal source shown in Fig. The voltage v b can be related to ib by writing for the input loop: v b = ib rn + (\beta + 1)ib RE Thus, v b = [rn + (\beta + 1)RE]ib (2)$ Dividing Eq. (1) by Eq. (2) yields $\beta RL vc = -vb r\pi + (\beta + 1)RE$ Av = vo $10(2/4) = vi 1 \times 10 - 6 \times (200 5) \times 103$ Q.E.D The voltage v e is related to ib by v e = $(\beta + 1)ib$ RE $1025 \times vi$ RL 2k = 2562.5 A/A or 62.8 dB That is, v e = $[(\beta + 1)RE]ib$ Dividing Eq. (3) by Eq. (2) yields ve $(\beta + 1)RE$ vb $(\beta + 1)RE + r\pi$ (3) Chapter 1-21 amplifier circuit. The resulting dc offset voltage at the output will be therefore from Eq. (2.40): VO = IOS × R2 = 0.2 × 100 = 20 mV Since IOS can be of either polarity, IOS = -60 nA VO = ±20 mV The same result could have been found by replacing R3 in Eq. (1) by (R3 + R4) where R4 = 5 k, P6.117. 6.2(a) and 6.2(b). An equal positive swing is possible. Thus RG2 is the larger of the two resistances, and we select RG2 = 22 M and find RG1 from RG1 1.2 \Rightarrow RG1 = 20.3 M = RG2 1.3 Specifying all resistors to two significant digits, we have RD = 2.5 k, RG1 = 22 M, and RG1 = 20 M. At v O = 3.7 V, the diode is conducting is possible. 1 mA and thus v I = v O + i × 1 k = 4.7 V For v I > 0.043 mA 100 To ensure that the transistor remains in the active mode for β in the range 50 to 150, we need to select RC so that for the highest collector current possible, the BJT reaches the edge of saturation, that is, VCE = 0.3 V. This figure belongs to Problem 1.45. (b) G = -R2 /R1 1 + R2 /R1 1 + R2A finite: $v_i = -v_0$, $v_0 = v_i - ii$ Rf A Rf $-v_0 v_0 = --ii$ Rf A Rf $-v_0 v_0 = --ii$ Rf \Rightarrow Rm = 1 A ii 1 + A Rf $v_i = Ri = ii$ 1 + A $\Rightarrow v_0 = 2.21$ Thus, 200 200 200 1 + = 200 + R1 5000 R1 0.96 × 200 = 200.04 R1 \Rightarrow R1 = 0.960 k This effective value can be realized by shunting R1 (1 k) with Ra , 1 1 1 = + \Rightarrow Ra = 24 k 0.960 1 Ra (c) From Appendix J, we find the closest available 1% resistor as either 23.7 k or 24.3 k. We want CR = 10-2 s (the time constant of the differentiator); thus, R= 10-2 = 1 M 0.01 µF From Eq. (2.33), the transfer function of the differentiator is Vo (j ω) = $-j\omega$ CR Vi (j ω) Thus, for $\omega = 10$ rad/s the differentiator transfer function has magnitude. Vo = $10 \times 10-2 = 0.1$ V/V i and phase $\varphi = -90^{\circ}$. Thus 1 W 2 VOV IREF = μ n Cox 2 L 1 2 × 400 × 10 × VOV 2 = VOV = 0.3 V 180 = 2 vx = (i3/gm3) + (i1/gm1) 1 gm3 1 i2 1 gm2 i1 1 gm1 VG3 = Vtn + VOV = 0.5 + 0.3 = 0.8 V (b) Q1 is operating at VDS = VGS = 1.6 V Thus, IREF - IO = VDS ro where Rin Here, we have applied a test voltage vx to determine Rin Here, we have applied a test voltage vx to $vx Rin \equiv ix Since all three transistors are identical and are operating at the same ID$, $gm1 = gm2 = gm3 Now from the figure we see that i1 = i2 and i2 + i3 = i2 + i3 VA 18 = 100 k = IREF 0.18 0.8 = 0.008 mA = 8 \muA IREF - IO = 100 IO = 180 - 8 = 172 \muA ro = (c) Refer to Fig. The$ pole due to CE will have frequency $\omega PE : \omega PE = 1$ 10, 000 25 + 101 $2\pi \times 100 = CE \Rightarrow CE = 12.83 \mu F$ Placing the pole due to CC at 10 Hz, we obtain $2\pi \times 10 = 1 \text{ CC} (10 + 10) \times 103 \Rightarrow CC = 0.8 \mu F$ (f) A Bode plot for the gain magnitude is shown in Fig. 7.33(a). 6 dB 1 $2\pi CC2$ (RD + RL) f 10 Hz f 100 Hz 1 = 10.8 Hz $2\pi \times 1 \times 10-6$ (4.7 + 10) × 103 Since fP2 fP1, fP3, fZ, fL fP2 = 87.5 Hz Figure 2 Observe that the dc gain is 6 dB, i.e. 2 V/V. R1 R3 R4 R2 = 0.99 R1 R3 Now for this case, Acm can be found from Eq. (2.19) R v 2 only: Ri = 0V v2 = 2R I R Chapter 2-17 R Since R v0 R2 R4 = : R1 R3 Rs Rs +1 = + 1 \Rightarrow R1 = R3 \Rightarrow R2 = R4 R1 R3 2.60 I v2 R R2 Ri 1 v between 2 terminals: v Ri = = 2R I R1 vO vicm R Ricm i 2 R 0V v R3 R4 vO I R R When R2 /R1 = R4 /R3, the output voltage v O will be zero. and substitute Y1 = (1/R1) + sC1 and Y2 = (1/R2) + sC2 to obtain C1 = C1 + C2 R1 + R2 1 20 log 1+ (1) R1 C2 = 1+ C1 R2 1000 10, 000 2 = -0.04 dB The gain drops by 3 dB at the corner frequencies of the two STC networks, that

is, at f = 10 Hz and f = 10 Hz. or 1.74 Use the expression in Eq. (1.2), with C1 R1 = C2 R2 B = 7.3×1015 cm-3 K -3/2; When this condition applies, the attenuator is said to be compensated, and its transfer function is given by $k = 8.62 \times 10-5$ eV/K; and Eg = 1.12 V Vo C1 = Vi C1 + C2 we have T = -55° C = 218 K: Chapter 1-27 ni = 2.68×106 K -3/2; When this condition applies, the attenuator is said to be compensated, and its transfer function is given by $k = 8.62 \times 10-5$ eV/K; and Eg = 1.12 V Vo C1 = Vi C1 + C2 we have T = -55° C = 218 K: Chapter 1-27 ni = 2.68×106 K -3/2; When this condition applies, the attenuator is said to be compensated, and its transfer function is given by $k = 8.62 \times 10-5$ eV/K; and Eg = 1.12 V Vo C1 = Vi C1 + C2 we have T = -55° C = 218 K: Chapter 1-27 ni = 2.68×106 Hz m 1-27 m 1-2cm-3; N = 1.9 × 1016 ni That is, one out of every 1.9 × 1016 silicon atoms is ionized at this temperature. Input needed is 14 mVrms . 6.3 Bias point Q: VOV = 0.2 V and VDS = 1 V. Thus the condition in (a) above is not satisfied and the MOSFET is operating in the triode region. Now making the assumption that D1 is off and D2 is on, we obtain the results shown in Fig. Therefore, we shall use the first design. P7.54. P7.5, we obtain For I3 = 40 μ A = 2IREF, we obtain (W/L)3 = 2 (W/L)1 W = 20 L 3 W3 = 10 μ m We next consider Q4 and Q5. For the given data, re = IC1 β VT 25 mV = 250 = IE 0.1 mA This figure belongs to Problem 7.20, part (b). 2 on the next page. Also because all have equal |VA| = 4 V, all ro 's will be equal: To obtain the largest possible signal swing at the output, we maximize the allowable positive signal swing by setting VD4 at its highest possible value of VDD - |VOV| = 3.3 - 0.2 = 3.1 V. That is Ro = 0. Since VAn the channel lengths are equal, VAn = |VAp| and ro1 = ro2 = ro. $\sqrt{gm1} = gm2 = 2 \times 0.4 \times 25 \times 0.1 = 1000$ 1.41 mA/V 1.8 VA ro1 = ro2 = = 18 k I 0.1 Gm = gm1 = 1.41 mA/V Q6 Q3 Q5 Q2 (gm2 ro2)ro1 ro1 Q4 Q1 Ro = gm2 ro2 ro1 = 1.41 × 457 = -644 V/V From the figure we see that We observe that the circuit with a cascode transistor provides higher gain. Rsig 200 k vo vsig vgs 10 M 5 M gmvgs 200 k Rin Figure 2 16 k 16 k Chapter 6-12 (d) Rin = 10 M 5 M = 3.33 M 6.32 v gs Rin 3.33 = v sig Rin + Rsig 3.33 + 0.2 5 V = 0.94 V/V v gs vo v = $\times = -0.94 \times 15.38 \text{ v}$ sig v sig v gs vBE = -14.5 V/V 6.31 (a) Using the exponential characteristic: ic = IC ev be /VT - IC giving VC = VCC - RC IC For v BE = 705 mV \Rightarrow v be = 5 mV iC = IC ev be /VT (b) Using small-signal approximation: Thus, With v BE = 0.700 V = 5 - 5 × 0.5 = 2.5 V ic = ev be /VT - 1 IC ic = gm v be = 5 k = 0.5 × 0.5 = 2.5 V ic = ev be /VT - 1 IC ic = gm v be = 5 k = 0.5 × 0.5 = 2.5 V ic = ev be /VT (b) Using small-signal approximation: Thus, With v BE = 0.700 V = 5 - 5 × 0.5 = 2.5 V ic = ev be /VT - 1 IC ic = gm v be = 5 k = 0.5 × 0.5 = 2.5 V ic = ev be /VT - 1 IC ic = gm v be = 5 k = 0.5 × 0.5 = 2.5 V ic = ev be /VT + 0.5 = 0.611 mA IC · v be VT v C = VCC - RC iC = 5 - 5 × 0.611 = 1.95 V v ce = v C - VC = 1.95 - 2.5 = -0.55 V v ce 0.55 V Voltage gain, Av = -v be 5 mV ic v be = IC VT See table below. Q5 Q3 Q6 Q4 io6 io5 ro6 vo ro8 ro5 Ro1 vicm 2RSS Ro2 1 (gm7 // ro7 (io8 Q7 Q8 and since the output resistance is Ro = ro6 ro8 = 1 |VA | $\times \times v$ id 2|VOV | 2 I Thus Ad = vo |VA | = v id |VOV | Q.E.D. (c) See figure. = Ad = 2(|VA |/ VOV |) 2 Q.E.D. This figure belongs to Problem 8.84. Then replace the 9-V source and the two 20-k resistors by their Thévenin equivalent, namely, a 4.5-V source and a 10-k series resistance. (a) DC analysis of each of the two stages: VBB = VCC 47 R2 = 4.8 V = 15 R1 + R2 = 100 47 = 32 k IE = VBB - VBE RB RE + β + $14.8 - 0.7 = 0.97 \text{ mA} 1 \text{ mA} 32 3.9 + 100 \text{ mA} 1 \text{ mA} 32 \text$ $101 \text{ IC} = \alpha \text{IE} 1 \text{ mA} = 6.118 \text{ Refer to the circuit of Fig. Rsig Ro vsig}$ Rin vi Av ovi RL (c) Gv = 10 = = vo Rin RL Av o Rin + Rsig RL + Ro To determine Gm (at least conceptually), we short-circuit the output of the equivalent circuit in Fig. +1 + 0.040 + 2.4 + 2 + 0.083 + 0.080 + 3.6 + 2 - 0.077 + 0.080 + 3.9 + 5 + 0.221 $+0.200 - 9.7 - 5 - 0.181 - 0.200 + 10.3 \text{ re} = +8 + 0.377 + 0.320 - 15.2 \text{ where} - 8 - 0.274 - 0.320 + 16.8 \alpha = +10 + 0.492 + 0.400 - 18.7 - 10 - 0.330 - 0.400 + 21.3 + 12 + 0.616 + 0.480 + 25.9 \text{ gm} = 6.33 \text{ At IC} = 0.5 \text{ mA}$, IC 0.5 mA = 20 mA/V = VT 0.025 V β 100 = 5 k = r π = gm 20 mA/V $gm = VT \alpha VT = IE IC 100 \beta = = 0.99 \beta + 1100 + 1 re = IC 0.05 = 2 mA/V VT 0.025 Chapter 6-13 \beta 100 = 50 k = gm 2 mA/V \alpha VT 0.99 \times 25 mV re = 500 = IC 0.5 mA and r\pi = |Av| = gm RC = then 6.34 For gm = 30 mA/V, IC gm = 30 mA/V,$ iI (b) Rin = 0 (because of the virtual ground at the input). For signal current to be limited to $\pm 10\%$ of I (I is the biasing current), the change in diode voltage can be obtained from the equation $v^{1} = v^{0} + 5 \text{ mV} = 1.005 \text{ V}$. P4.25(c) and use IB = 0.0215 mA IC = 0 - (-10) = 0.5 mA IC = 20 Assuming active-mode operation, and utilizing the fact that β is large, IB 0 and V4 2 V IC = 1 mA Thus, $\beta \equiv 1$ IC = 46.5 = IB 0.0215 (b) Since VC < VB, the transistor is indeed operating in the active region. v O (100 μ s) = -0.02 × 106 × 100 × 10-6 = -2 V and the output voltage then remains constant at this value. The collector currents are RE = 3.1 k RB = 119.2 k ICnominal = 0.99 × 0.96 = -2 V and the output voltage then remains constant at this value. 0.95 mA ICmin = $0.99 \times 0.86 = 0.85$ mA ICmax = $0.99 \times 0.86 = 0.85$ mA and the collector voltages are Substituting these values in Eqs. 2.5 are R2 - and R1, respectively. Using 2 I2 = I1 e(V2 - V1)/VT = 2e(0.65 - 0.7)/0.025 = 0.2707 mA. P6.123. which is 1.8% higher than IE 6.100 5 V nominal 6.99 3 V RC IC VC IB RC VC VE RB RE 0.7 V RE 0.4 mA IE 5 V 3 V -0.7 - (-3) RE = 0.4 = 5.75 k To maximize gain while allowing for ± 1 V signal swing at the collector, design for the lowest possible VC consistent with VC -1 = -0.7 + 0.3 = -0.4 V VC = 0.6 V VCC - VC 3 - 0.6 = 6.2 k = RC = IC 0.39 As temperature increases from $25 \circ$ C to $125 \circ$ C, (i.e., by $100 \circ$ C), VBE decreases by 2 mV × 100 = 0.2 V - 200 mV. 7.43(b), we have Ro = ro2 = ro = 10 M Exercise 7-7 For the current source in Fig. 1 1 5.14 iD = k n v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus v DS for various values of v OV . Gv = Av = -20 V/V v^{2} i = 0.1 × 2VOV = ro = 10 M Exercise 7-7 For the current source in Fig. 1 1 5.14 iD = k n v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus v DS for various values of v OV . Gv = Av = -20 V/V v^{2} i = 0.1 × 2VOV = ro = 10 M Exercise 7-7 For the current source in Fig. 1 1 5.14 iD = k n v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus v DS for various values of v OV . Gv = Av = -20 V/V v^{2} i = 0.1 × 2VOV = ro = 10 M Exercise 7-7 For the current source in Fig. 1 1 5.14 iD = k n v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus v DS for various values of v OV . Gv = Av = -20 V/V v^{2} i = 0.1 × 2VOV = ro = 10 M Exercise 7-7 For the current source in Fig. 1 1 5.14 iD = k n v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus v DS for various values of v OV . Gv = Av = -20 V/V v^{2} i = 0.1 × 2VOV = ro = 10 M Exercise 7-7 For the current source in Fig. 1 1 5.14 iD = k n v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus v DS for various values of v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus v DS for various values of v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus v DS for various values of v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus v DS for various values of v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus values of v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus values of v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus values of v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus values of v OV v DS - v 2DS kn 2 (1) Figure 1 shows graphs for iD /k n versus values of v OV v DS - v $0.2 \times 2 \times 0.25 = 0.05 \text{ V} \text{ v}^{\circ} 0 = 0.05 \times 20 = 1 \text{ V} \text{ Exercise } 6-6 \text{ Ex: } 6.22 \text{ IC} = 0.5 \text{ mA gm} = \text{IC } 0.5 \text{ mA} = 20 \text{ mA/V} = \text{VT } 0.025 \text{ V} \text{ rn} = \beta 100 = 5 \text{ k} = \text{gm } 20 \text{ Rn} = \pi = 5 \text{ k} \text{ Av } 0 = -200 \text{ V/V} \text{ Ro} = \text{RC} = -200 \text{ × RL} + \text{Ro } 5 + 10 = -66.7 \text{ V/V} \text{ Gv} = \text{Rin } 5 \text{ Av} = \times -66.7 \text{ Rin} + \text{Rsig } 5+5 = -33.3 \text{ V/V} \text{ For IC} = 0.5 \text{ mA}$ and $\beta = 100$, $v^{\alpha} \pi = 5 \text{ mV} \Rightarrow v^{\beta}$ sig = 2 × 5 = 10 mV re = $v^{\alpha} o = 10 \times 33.3 = 0.33 \text{ V}$ VT α VT $0.99 \times 25 = = 50$ IE IC $0.5 \text{ rm} = (\beta + 1)\text{re} 5 \text{ k}$ Although a larger fraction of the input signal to be in fact smaller than in the original design! For v^{β} sig = 10 mV, Rsig = 10 k and with v^{π} limited to 10 mV, the value of Re required can be found from 10 Re + 100 = 101 + 505 Ex: 6.23 Refer to the solution to Exercise 6.21. Thus for both devices, 0.2 = 8 mA/V 0.025 1 = 0.125 k re gm gm = rn = β 100 = = 12.5 k gm 8 ro = VA 50 = 250 k = IC 0.2 IE2 = 10 mA IE1 = IE2 10 = 0.1 mA β 2 + 1 100 re2 = VT 25 mV = 2.5 = IE2 10 mA re1 = VT 25 mV = 250 IE1 0.1 mA The Darlington follower circuit prepared for small-signal analysis is shown in the figure. 3.25 For 2VD Vs VO, avg = 1 2 Vs - 1.4 π m (a) For VO, avg = 2 2 Vs - 2VD = Vs - 1.4 π m (b)
V° s = 11.4 = 17.9 V 2 $\sqrt{1202}$ = 9.5 to 1 Turns ratio = 17.9 V 2 $\sqrt{1202}$ π where we have assumed Vs 0.7 V and thus the conduction angle (in each half cycle) is almost π. To obtain I = 100 μA when V = 10 V, we select 10 = 100 k R = 0.1 mA The meter resistance does not affect the voltmeter calibration. Also, each will have ro = roa . AM = 2rπ 1 × × gm RL 2rπ + Rsig 2 where gm = 20 mA/V 100 = 5 k rπ = 20 10 1 × × 20 $\times 10 = 50 \text{ V/V AM} = 10 + 10 2 \text{ fP} 1 = 2\pi = 1 \text{ C}\pi + \text{C}\mu (2\pi \text{ Rsig}) 21 6 2\pi + 2 \times 10 - 12 (10 10) \times 103 2 = 6.4 \text{ MHz s} 1 + \omega \text{P} 1 50 1 + s \omega \text{P} 2 50 |T (j \omega)| = 2 \omega 21 + \omega 1 + \omega \text{P} 1 \omega \text{P} 2 \sqrt{\text{At }\omega} = \omega \text{H}, |T| = 50/2, \text{ thus} \quad \omega \text{H} 2 \omega \text{H} 2 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + \omega \text{H} \omega \text{P} 1 \omega \text{P} 2 2 \text{ fH} 4 2 2 \text{ fP} 1 \text{fP} 2 + \text{fH} 2 2 + \omega \text{H} \omega \text{P} 2 2 + 11 + 2 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega \text{P} 2 = 1 + 1 + \omega \text{P} 1 \omega$ $1 \omega P 2 1 fP 21 + 1 fP 22 \omega H \omega P 1 2 \omega H \omega P 2 2 -1=0 -1=0 1 fH 4 1 2 + f + -1=0 H 6.42 \times 82 6.42 82 \Rightarrow fH = 4.6 MHz$ (Exact value) Using Eq. (9.164), an approximate value for fH can be obtained: $1 1 fH 1/+2 fP 21 fP 2 = 1/11+2 = 5 MHz 6.42 8 Chapter 9-19.1 Refer to Fig. (a) For the circuit in (a), <math>1 W 2 I = \mu n Cox VOVa 2 L$ For the circuit in (b), 1 W I = μ Cox V2 2 4L OVb Comparing Eqs. 1, we can write 3 - 1.5 RC = 1.5 k + 0.01 RB + 0.7 = 0.01 RB + 0.01 Standard 5% resistors: RC = 3.3 k RB = 120 k If the actual BJT has β = 50, then 3 - 0.7 VCC - VBE = 0.41 mA = IE = RB 120 RC + 3.3 + β + 1 51 VC = 3 - 1.5 V Allowable negative signal swing at the collector is as follows: VC - VCEsat = 1.65 - 0.3 = 1.35 V VC = 3 - 1.5 × 0.99 = 1.52 V (c) β = ∞: VCC - VBE 3 - 0.7 IC = IE = 1.53 mA = RC 1.5 VC = 0.7 V Chapter 6-38 (d) From the circuit diagram of Fig. Thus, for the v 1 transconductance amplifier, we want 0.25v 1 to appear at the input. Suffice it to say that the dc voltage drop across RC is 5 V and that each collector swings ± 1 V. P6.124. v O, avg = 2 $2\pi \pi - \theta \theta \sqrt{10.25v}$ d ϕ Chapter 3-27 $\pi - \theta \sqrt{1-12}$ $2 \cos \varphi - 1.4 \varphi \theta \pi \sqrt{2}(12 \ 2 \cos \theta) 1.4 (\pi - 2\theta) - \pi \pi = (b)$ For VO, avg = 100 V = 7.65 V 2 · Vs - 1.4 \pi \pi \Rightarrow Vs = 101.4 = 159 V 2 \sqrt{120} 2 = 1.07 to 1 Turns ratio = 159 iR, avg = 100 V = v O, avg 7.65 = 7.65 mA R 1 3.69 vS vS 120 Vrms R vO 3.71 The circuit is a full-wave rectifier with center tapped secondary winding. Observe that the controlled source gm1 vn1 appears across its controlling voltage vn1; thus the controlled source can be replaced with a resistance (1/gm1). This in turn occurs when R2 and R3 are at their highest possible values (each one percent below nominal), resulting in Acm R4 R3 + R4 | Acm | $1 - 1.01 \times 1.01 \ 0.99 \times 0.99$ The corresponding CMRR is $10 \ V O = 10 \ \text{mA} \ 1 \ \text{k} \ 1 \ \text{c} = 11 \ \text{mA} \ \text{R4} \ 200 \times 0.04 \ \times 0.04 \ \text{V/V} \ \text{R3} + \text{R4} \ 202 \ \text{v} \ O = v \ 1 + i \ 2 = 11 \ \text{mA} \ \text{R4} \ 200 \times 0.04 \ \text{v} \ \text{O} \ \text{R7} \ \text{mA} \ \text{R4} \ 200 \ \text{mA} \ \text{R4} \ \text{R4} \ 200 \ \text{mA} \ \text{R4} \ \text{R4} \ 200 \ \text{mA} \ \text{R4} \ 1 \ \text{mA} \ \text{R4} \ 200 \ \text{mA} \ \text{mA} \ \text{R4} \ 200 \ \text{mA} \ \text{mA} \ \text{mA} \ 1 \ \text{mA} \ \text{mA$ Peak current in diode is 10 - 0.7 = 9.3 mA 1 t1 T 4 t2 T 2 t T 2.5 (e) PIV occurs when v S is at its the peak and v O = 0. Hence Then For the Wilson current mirror, we have Ron = (gm2 ro2) rm 3 = β 3 ro3 100 × 100 k β ro = = 5 M 2 2 and for the simple mirror, Ro = ro = 100 k. For the 10-mA source: Since IL varies from 2 to 7 mA, the current ID will varry from 8 to 3 mA. 7.15(a). In order to have 3.3 V across the 4 series-connected diodes, each diode drop must be \leq V 1 mA \geq The voltage drop across each pair of diodes is 1.3 V. On 1 M the other hand, if VOS is negative, then -0.1 V of the output 0.3 V is due to VOV, with the result that IOS must be causing 0.4 V of output offset. For each supply, VO = 12 V Vr = 1 V (peak to peak) Thus v O = 12 ± 0.5 V It follows that the peak value of v S must be 12.5 + 0.7 = 13.2 V and the total rms voltage across the secondary will be = $2 \times 13.2 = 18.7$ V (rms) $\sqrt{2}$ 120 = 6.43:1 18.7 To deliver 100-mA dc current to each load, Transformer turns ratio = 12 = 120 0.1 Now, the value of C can be found from R= Vr = 1 = Vp - 0.7 2fCR $12.5 2 \times 60 \times C \times 120$ iDmax = IL $(1 + 2\pi (Vp - 0.7)/2 Vr) = 0.1(1 + 2\pi 12.5/2) = 1.671$ A To determine the required PIV rating of each diode, we determine the maximum reverse voltage that appears across one of the diodes, say D1. At this time, v O = VO and the maximum reverse voltage will be PIV Maximum reverse voltage = VO + Vp = 12 + 13.7 = 25.7 V (b) Vr = Using a factor of safety of 1.5 we obtain $2 = PIV = 1.5 \times 25.7 = 38.5 V$ (d) iDav = IL $1 + \pi 2(Vp - VD)$ (e) iDmax = IL $1 + \pi 2(Vp - VD)$ (e) iDmax = IL $1 + \pi 2(Vp - VD)$ (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (e) iDmax = IL $1 + \pi 2(Vp - VD)$ (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for
the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety of about 1.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety 0.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety 0.5, 2(Vp - VD) (for the diodes, one usually uses a factor of safety 0.5, 2(Vp - VD) (for the diodes, one use 1.5, 2(Vp - VD) (for the diodes, one use 1.5, 2(Vp - VD) (for the diodes, one use 1.5, 2(Vp - VD) (for the diodes, one use 1.5, 2(Vp - VD) (for the diodes, one use 1.5, 2(Vp - VD) (for the diodes, one use 1.5, 2(Vp - VD) (for the diodes, one use 1.5, 2(Vp - VD) (for the diodes, one use 1.5, 2(Vp - VD) (for the diodes, one use 1.5, 2(Vp - VD) (for 2(13.7 - 0.7) 12 1 + 2 π = 0.2 2 PIV = 1.5 × 25.7 = 38.5 V Vp - VD (d) iDav = IL 1 + π 2 Vr 13.7 - 0.7 12 1 + π = 0.2 2×2 = 399 mA = 1.42 A D1 120 Vrms 60 Hz C R D2 (a) VO = Vp - VD - 1 = Vp = VO + VD + 1 = 13 + 0.7 = 13.7 V Vrms 13.7 = $\sqrt{2}$ = 9.7 V 2 Vp - VD (d) iDav = IL 1 + π 2 Vr 13.7 - 0.7 12 1 + π = 0.2 2×2 = 399 mA = 1.42 A D1 120 Vrms 60 Hz C R D2 (a) VO = Vp - VD - 1 = Vp = VO + VD + 1 = 13 + 0.7 = 13.7 V Vrms 13.7 = $\sqrt{2}$ = 9.7 V 2 Vp - VD (d) iDav = IL 1 + π 2 Vr 13.7 - 0.7 12 1 + π = 0.2 2×2 = 399 mA = 1.42 A D1 120 Vrms 60 Hz C R D2 (a) VO = Vp - VD - 1 = Vp = VO + VD + 1 = 13 + 0.7 = 13.7 V Vrms 13.7 = $\sqrt{2}$ = 9.7 V 2 Vp - VD (d) iDav = IL 1 + π 2 Vr 13.7 - 0.7 12 1 + π = 0.2 2×2 = 399 mA = 1.42 A D1 120 Vrms 60 Hz C R D2 (a) VO = Vp - VD + 1 = 13 + 0.7 = 13.7 V Vrms 13.7 = $\sqrt{2}$ = 9.7 V 2 Vp - VD (d) iDav = IL 1 + π 2 Vr 13.7 - 0.7 12 1 + π = 0.2 2×2 = 399 mA = 1.42 A D1 120 Vrms 60 Hz C R D2 (a) VO = Vp - VD + 1 = 13 + 0.7 = 13.7 V Vrms 13.7 = \sqrt{2} $Vs 0.7 V 12 = 271 \mu F 2 \times 2 \times 60 \times 200$ (c) Maximum reverse voltage across D1 occurs when v S = -Vp . Thus R2 = 10 k, and R1 = 20 k. The short-circuit output current of the Q3 - Q5 mirror will be ro5 . The capacitor voltage, which is v O will rise linearly according to vO = 1 1 It = t C CR Thus, at t = T (the end of the pulse) the output voltage reaches 1 V and then stays constant at this value. Thus ic1 = gm1 v i = 20.8v i Ri2 = rm2 = β gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = β gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = β gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = β gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = \beta gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = \beta gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = \beta gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = \beta gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = \beta gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = \beta gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = \beta gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = \beta gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = \beta gm2 where gm2 = IC2 1.04 mA = 41.6 mA = VT 0.025 V rm2 = 100 = 2.4 k 41.6 ib2 = gm1 v i = 20.8v i Ri2 = rm2 = 30.8v i = 100 v rm2 = $16.1v i = 1610v i = Ri3 = (\beta + 1)(re3 + 2.4 k) = 101(0.0119 + 2.4) = 243.6 k gm2 gm1 1 1 gm1 ro1 1 + Since gm1 ro1, gm2 1 1 - Ais gm1 gm1 ro1 1 = 36.18v i ib3 = ic2 × ie3 = (\beta + 1)ib3 = 101 × 36.18 = 3654v i v o = ie3 × 2.4 k where = 3654 × 2.4v i = 8770v i Ais |ideal 1 - gm1 ro1 1 + Since gm1 ro1, gm2 1 1 - Ais gm1 gm1 ro1 1 = Ais |ideal 1 - gm1 ro1 5.6 = 0.0225 × 1610v i = 36.18v i ib3 = ic2 × ie3 = (\beta + 1)ib3 = 101 × 36.18 = 3654v i v o = ie3 × 2.4 k where = 3654 × 2.4v i = 8770v i Ais |ideal 1 - gm1 ro1 1 + Since gm1 ro1 1 + Since gm1 ro1 = 36.18v i ib3 = ic2 × ie3 = (\beta + 1)ib3 = 101 × 36.18 = 3654v i v o = ie3 × 2.4 k where = 3654 × 2.4v i = 8770v i Ais |ideal 1 - gm1 ro1 1 + Since gm1 ro1 = 36.18v i ib3 = ic2 × ie3 = (\beta + 1)ib3 = 101 × 36.18 = 3654v i v o = ie3 × 2.4 k where = 3654v i v o = ie3 × 2.4 k$ = Thus vo = 8770 V/V vi Finally, from inspection, Ro = ro2 8.115 From the figure we observe that the controlled source gm1 v gs1 = ii ro1 gm1 v gs1 = ii ro1 gm1 v gs1 = im v gs1 = m2 v gs1 = gm2 v gs1 = gm2 v gs1 = gm2 v gs1 = gm2 v gs1 = m2 v gs $0.7 + 2.3 \times 25 \times 10 - 3 \log = 0.679 V$ Second iteration 5 - 0.679 = 0.432 mA I2 = 10 kV2 = 0.7 + 2.3 \times 25.3 \times 10 - 3 \log for i = 0.1 mA, we get almost the same voltage. 6.56(a). Using Eq. (8.48), we obtain iE1 = 1 (mA) = 0.599 mA 1 + e - 10/25 = RC (iC1 - iC2) iE2 = I - iE1 = 1 -0.599 = 0.401 mA Using Eqs. Since ro5 = ∞ , RC5 is simply the input resistance of the emitter follower Q6, we have RC5 = Ri6 = (β + 1)(re6 + RL) where re6 = VT 25 mV = 25 = IE6 1 mA Ri6 = (100 + 1)(0.025 + 1) = 103.5 k Q4 ic1 Thus the voltage gain of the first stage is given by A1 = 5 k 25 ib1 vid 25 Q2 Q1 50 50 Rin Rin = (β + 1)(4 β + $\times 50$ = 101 $\times 200$ 20 k ic1 = β 1 = 100 ib1 ib3 (5 + 5) 10 = = 0.5 ic1 (5 + 5) + Rin2 10 + 10 ic3 = β 3 = 100 ib3 Thus Thus A2 = $-20 \times 103.5 = -2070$ V/V ic3 ic3 ib3 ic1 = $\times \times = 100 \times 0.5 \times 100$ ib1 ib3 ic1
= $\times \times = 100 \times 0.5 \times 100$ ib1 ib3 ic1 = $\times \times = 100 \times 0.5 \times 100$ ib1 ib3 ic1 = $\times \times = 100 \times 100$ now be obtained as A0 = 50 vo = A1 A2 A3 v id = $-40 \times -2070 \times 0.976 = 8.07 \times 104$ V/V 8.112 Refer to Fig. As v id increases, the transfer characteristic bends and the gain is reduced. Thus the throughput or speed will be 44, $100 \times 16 = 7.056 \times 105$ bits per second. Thus VOS becomes VOS = 2 mV VCC RS 2 = - IRS Ir e I RS + $+4(\beta + 1) 2(\beta + 1) 2(\beta$ 1) 2 Combining terms, we have IRS I RS = + Ire 2 (β + 1) (β + 1) RS I RS so that + re = I 2 (β + 1) (β + 1) 8.72 RS IRS I re I RS - - 4 (β + 1) 2 (β + 1) 2 I = RC VC Q1 RC RS RS 2 Q2 IB1 IB2 I 2 2 I I RS · 2 (β + 1) I 1 2 2 VC = IC RC . 8.13(b), Ron = (gm3 ro3) ro1 = (1 × 36) × 36 = 1.296 M IC2 RC 5 k I 0.4 mA 2.5 V VEE IC1 = IC2 IE1 = IE2 $= I 0.4 \text{ mA} = 2 2 = 0.2 \text{ mA VCM max VC} + 0.4 \text{ V} = VCC - IC \text{ RC} + 0.4 \text{ V} = 2.5 - 0.2 \text{ mA} (5 \text{ k}) + 0.4 \text{ V} = +1.9 \text{ V VCM min} = -2.5 \text{ V} + 0.3 \text{ V} + 0.7 \text{ V} = -1.5 \text{ V} \text{ Input common-mode range is } -1.5 \text{ V to } +1.9 \text{ V Ex: } 8.9 \text{ Substituting iE1} + iE2 = I \text{ in Eqn. Thus, } \Rightarrow CC1 = 20 \text{ nF } 5 \times 10 - 3 + (1/1.8 \times 103) = 88.4 \text{ Hz } 2\pi \times 10 \times 10^{-1} \text{ Hz} = 1.5 \text{ V to } +1.9 \text{ V Ex: } 8.9 \text{ Substituting iE1} + iE2 = I \text{ in Eqn. Thus, } \Rightarrow CC1 = 20 \text{ nF } 5 \times 10 - 3 + (1/1.8 \times 103) = 88.4 \text{ Hz } 2\pi \times 10 \times 10^{-1} \text{ Hz} = 1.5 \text{ V to } +1.9 \text{ V Ex: } 8.9 \text{ Substituting iE1} + iE2 = I \text{ in Eqn. Thus, } \Rightarrow CC1 = 20 \text{ nF } 5 \times 10 - 3 + (1/1.8 \times 103) = 88.4 \text{ Hz } 2\pi \times 10 \times 10^{-1} \text{ Hz} = 1.5 \text{ V to } +1.9 \text{ V Ex: } 8.9 \text{ Substituting iE1} + iE2 = I \text{ in Eqn. Thus, } \Rightarrow CC1 = 20 \text{ nF } 5 \times 10 - 3 + (1/1.8 \times 103) = 88.4 \text{ Hz} 2\pi \times 10 \times 10^{-1} \text{ Hz} = 1.5 \text{ V to } +1.9 \text{ V Ex: } 8.9 \text{ Substituting iE1} + iE2 = I \text{ in Eqn. Thus, } \Rightarrow CC1 = 20 \text{ nF } 5 \times 10 - 3 + (1/1.8 \times 103) = 88.4 \text{ Hz} 2\pi \times 10 \times 10^{-1} \text{ Hz} = 1.5 \text{ V to } +1.9 \text{ V Ex: } 8.9 \text{ Substituting iE1} + iE2 = I \text{ in Eqn. Thus, } \Rightarrow CC1 = 20 \text{ nF } 5 \times 10 - 3 + (1/1.8 \times 103) = 88.4 \text{ Hz} 2\pi \times 10^{-1} \text{ Hz} = 1.5 \text{ H$ 10-6 fP2 = 9.2 Refer to Fig. aiE The collector current β iB changes from β IB to β (IB + ib). P5.52(a): The MOSFET is operating in saturation. Between the two collectors, the signal will be 400 mV. v = 0.7 + 2.3 × 0.025 log 1 R= 3.36 Constant voltage drop model: = 0.6882 V 1 - 0.6882 = 0.6235 mA 3 i = 0.5 k 0.6235 4.20 mA = vp = vO 20 vO + \Rightarrow vO = 4V 200 100 k 5.01 4 = 0.04 V = 40 mV 100 (c) RL = ?, iOmax = 20 mA = 2.111 The peak value of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that can be applied at the input vibration of the largest possible sine wave that the input vibration of the largest possible sine wave that the input vibration of the largest possible sine wave that the input vibration of the largest possible sine wave that the input vibration of the largest possible sine wave that the input vibration of the largest possible sine wave that the input vibration of the largest possible sine wave that the input vibration of the largest possible sine wave that the input vibration of the largest possible sine wave that the input vibration of the largest possible sine wave that the input vibration of the largest possible sine wave that the input vibration of the largest possible sine wave the largest possibl both sides of (1) relative to vI : ID3 25 = $|VOV 3| = 1011 W \times 50 \times kp 212 L 3$ For vO = 1.65 V, from 1 we have \Rightarrow ID3 = 100 μ A (d) vO = VDD 3.3 = 1.65 V 22 2 (vI - 0.8) = 0.11 \times (-0.03) \Rightarrow 2 \partial vO \partial vI \partial vO = -606.1 (vI - 0.8) 2 = 0.11 (1 - 0.03 \times 1.65) \Rightarrow vI VOA = 3.3 - 0.32 = 2.98V = 1.123 V \partial vO = -195.8 $V/V \partial vI = 1.123$ At point B: VOB = VIB - Vtn Now we find the transfer equation for the linear section: (Refer to Example 7.4) iD1 = iD2 = (Note that |VOV 2| = |VOV 3|) vO 1 W kn (vI - Vtn)2 1 + 2 L 1 VAn W VDD - vO 1 2 VOV 1 + = k p 3 |VAP| 2 L 2 vO 20 1 × 100 × (vI - 0.8)2 1 + 2 L 1 100 40 3.3 - vO 1 × 0.322 1 + = × 50 × 2 1 50 vO vO $1 + (vI - 0.8)2 = 0.322 \ 1.066 - 50 \ 100 \ 1 - 0.019v \ O (vI - 0.8)2 = 0.111 + 0.01vO \ 0.11(1 - 0.03vO) (e) \ Rout = ro1 \ ro2 \ ro1 = VAn \ 100 \ V = = 1 \ M \ ID1 \ 0.1 \ mA \ ro2 = VAp \ 50 \ V = 500 \ k = ID2 \ 0.1 \ mA \ ro2 = VAp \ 0.1 \ ro2 \ ro2 \ ro2 = VAp \ ro2 \ ro$ mA/V Av = -gm1 (ro1 ro2) = -210.6 V/V (1) Now if we solve for VOB = VIB - 0.8 2 + 0.0033VOB - 0.11 = 0 \Rightarrow VOB = 0.33 V VOB Comment: The three estimates of voltage gain obtained in (c), (d) and (e) are all reasonably close; about -200 V/V. 7.41(c). v 100 k v 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k 100 k 100 k 50 k r 2.37 (a) v O = -(v 1 + 2v 2 + 3v 3) 100 k Rf = 2 \Rightarrow R2 = 50 k R2 R1 = 100 k $Ri1 = 100 \text{ k} R2 = Rf 100 \text{ k} = 1 \Rightarrow R3 = R3 3 \text{ Ri2} = 20 \text{ k} 100 \text{ k} \text{ v} (d) \text{ v} O = -6v 1 \text{ R} 100 \text{ k} 100$ 5v 4, we can arbitrarily select Rc = Rb, then Suggested configurations: Ra = 1 R1 v O = -(2v 1 + 2v 2 + 2v 3) 100 k Ra = 2 R2 If we select R2 = 10 k, then Ra = 20 k and R1 = 20 k. The change in output voltage is -22 mV. (a): I = 0 V = -1 V 3 V 3.13 6 k 3 - 0 0.5 mA 6 0V 0.25 mA 10 N D2 ON 0 - (-3) 12 0.25 mA V0 12 k 3 V (b) (b) In (b), the two resistors are interchanged. The limit on v sig can be obtained by dividing the 10 mV by v b /v sig = $13.4 \times 15 = 200 \text{ mV} = 0.2 \text{ V} 6.121$ (a) 0.5 mA VC 0.495 mA 200 ki = 200 50.5 = 40.3 k vb Rin 40.3 = 0.668 V/V = = v sig Rin + Rsig 40.3 + 20 vo Total resistancein collector = $-\alpha$ vb Total resistance
in emitter 20 20 - = -20 V/V 0.25 + 0.25 vo Gv = = $-0.668 \times 20 = -13.4$ V/V v sig i 200 k vi = 200 [101 × (0.25 + 0.25)] vo vo vi 200 IE = 0.1 mA VT 25 mV re = = 250 IE 0.1 m 2.18 (a) Choose R1 = 1 k and R2 = 200 k. 1 $|T(j\omega)| = 1 + \omega \omega 0.21 = -1 \omega 1 dB 2.1 + \omega 0.20 log \Rightarrow 1 + \omega 1 dB \omega 0$ This will place the corner frequency at f02 = 1 = 80 Hz $2\pi \times 10-6 \times 2 \times 103$ T (s) = 100 s $1 + s 2\pi f01$ s 1 $2\pi C1$ (Rs + Ri) 1.68 Since when C is connected to node A the 3-dB frequency is reduced by a large factor, the value of C must be much larger than whatever parasitic capacitance originally existed at node A (i.e., between A and ground). Now, if RB is increased to 100 k, the loop equation [Eq. (1)] yields IE = 3 - 0.7 = 0.5 mA 100 2.2 + 41 VE = 3 - 0.7 mA 100 2.2 + 41 VE = 3 - 0.7 mA 100 2.2 + 0.5 mA 100 2.5 mA 100 2.5 m $0.5 \times 2.2 = +1.9 \text{ V}$ VB = VE - VEB = 1.9 - 0.7 = +1.2 V Assuming active-mode operation, we obtain IC = $-3 + 0.48 \times 2.2 = -1.9 \text{ V}$ Since VC < VB + 0.4, the transistor is operating in the active mode, as assumed. At v I = 2.5 V, v O = 2.5 V and the diode begins to conduct. Thus, this alone increases ro by a factor of 4. VSG = 2 V 100 k VSD 10 V VG = 8 V VD = VG + IR = 8 + 1 = 9 V 0.1 mA VSD = 1 V (iii) R = 30 k Fig. Correspondingly v i will be a sine wave with a peak value of $10/(83.3 \times 2) = 0.085 \sqrt{V}$. factor = 0.5 (b) W is doubled \rightarrow rDS is halved. P6.109. 5000 Thus the virtual ground will depart by a maximum of $\pm 2 \text{ mV}$. 7.16(d), you notice that in Segment III, both Q1 and Q2 are in saturation and the transfer characteristic is quite linear. $\beta 100 = 2 \times (\beta + 1)(50 + 150) = 2 \times 101 \times 0.2$ (k) = 40.4 k = 2.5 × 10 - 4 V/V (b) Rid = 2r\pi = 2.25 \times 0.012 \times 500 Chapter 8-21 (d) CMRR = 100 | Ad | = 2REE RC Rid = 2 \times (\beta + 1)(50 + 150) = = 2 \times 101 \times 0.2 (k) = 40.4 k = 2.5 × 10 - 4 V/V (b) Rid = 2r\pi = 2.25 \times 0.012 \times 500 Chapter 8-21 (d) CMRR = 100 | Ad | = 2REE RC Rid = 2 \times (\beta + 1)(50 + 150) = = 2 \times 101 \times 0.2 (k) = 40.4 k = 2.5 × 10 - 4 V/V (b) Rid = 2r\pi = 2.5 \times 10 - 4 V/V (b) Rid = 2rm = 2.5 × 0.012 × 500 Chapter 8-21 (d) CMRR = 100 | Ad | = 2REE RC Rid = 2 \times (\beta + 1)(50 + 150) = = 2 \times 101 \times 0.2 (k) = 40.4 k = 2.5 × 10 - 4 V/V (b) Rid = 2rm = 2.5 × 0.012 × 500 Chapter 8-21 (d) CMRR = 100 | Ad | = 2REE RC Rid = 2 \times (\beta + 1)(50 + 150) = = 2 \times 101 \times 0.2 (k) = 40.4 k = 2.5 × 10 - 4 V/V (b) Rid = 2rm = 2.5 × 0.012 × 500 Chapter 8-21 (d) CMRR = 100 | Ad | = 2REE RC Rid = 2 \times (\beta + 1)(50 + 150) = = 2 \times 101 \times 0.2 (k) = 40.4 k = 2.5 × 10 - 4 V/V (b) Rid = 2rm = 2.5 × 0.012 × 500 Chapter 8-21 (d) CMRR = 100 | Ad | = 2REE RC Rid = 2 \times (\beta + 1)(50 + 150) = = 2 \times 101 \times 0.2 (k) = 40.4 k = 2.5 × 10 - 4 V/V (b) Rid = 2rm = 2.5 × 0.012 × 500 Chapter 8-21 (d) CMRR = 100 | Ad | = 2REE RC Rid = 2 \times (\beta + 1)(50 + 150) = = 2 \times 101 \times 0.2 (k) = 40.4 k = 2.5 × 10 - 4 V/V (b) Rid = 2rm = 2.5 × 0.012 × 500 Chapter 8-21 (d) CMR = 100 | Ad | = 2REE RC Rid = 2 \times (\beta + 1)(50 + 150) = = 2 \times 100 \times 10 $4 \times 105 = |\text{Acm}| 2.5 \times 10 - 4 \text{ or } 112 \text{ dB VA } 100 \text{ (e) } ro = = 100 \text{ k I } (2.1 \text{ Ricm } \beta \text{REE } 1 + (\text{RC} / \beta \text{ro}) \text{ RC} + 2 \text{REE } 1 + ro 1 + (25/(100 \times 1000)) = 100 \times 500 25 + 1000 1 + 1000 25 \text{ M } 20 \text{ VA} = = 100 \text{ k I } (2.5 \times 10 - 4 \text{ or } 112 \text{ dB VA } 100 \text{ (e) } ro = = 200 \text{ k I } / 2 \text{ 0.1 Ricm } \beta \text{REE } 1 + (\text{RC} / \beta \text{ro}) \text{ RC} + 2 \text{REE } 1 + ro \text{ For } \text{RC}$ ro, 2REE Ricm β REE 1+ ro = 50 × 100 = 2.5 M 2 × 100 1+ 200 (c) If the bias current I is generated using a Wilson mirror, REE = Ro | Wilson mirror, then = 50 = 100 k 0.5 1 REE = × 100 × 100 = 5 M 2 5 | Acm | = × 0.1 2 × 5,000 ro = = 5 × 10-5 V/V 50 CMRR = = 106 5 × 10-5 V/V 50 CMRR = 106 or 120 dB 8.60 See figure on next page. (d) To maintain the BJT in the active mode at all times, the maximum allowable VCM is limited to VCM max = 0.4 + v Cmin = 0.4 + v C required input common-mode range (which is not specified). = 9.4 4.7 = Chapter 1-4 This figure belongs to 1.9. that the current through it will be 0.8I; thus 15 V 157 k R 4 The input resistance of the divider, Rin , is $0.2IR = 0.8IR1 \Rightarrow R1 = 10 \text{ k R } 1 = R 4.5 \text{ Now if R1}$ is 10% too high, that is, if Rin = R R1 = R 200 R 4 the problem can be solved in two ways: R1 = 1.1 VO 4.7 k RO (a) Connect a resistor R2 across R1 of value such that R2 R1 = R/4, thus R R2 (1.1R/4) = R2 + (1.1R/4) 4 1.10 I1 I R1 I2 V R2 1.1R2 = R2 + 11R = 2.75 R 4 1.1R 11R Rin = R 4 4 R R = R = 4 5 \Rightarrow R2 = V = I (R1 R2) R1 R2 = I R1 + R2 V R2 I1 = =I R1 R1 + R2 V R1 I2 = =I R2 R1 + R2 0.2I I 2 I 3 I 3 RL 10 k R 4 (b) Connect a resistor in series with the load resistor R so as to raise the resistance of the load branch by 10%, thereby restoring the current division ratio to its desired value. Vs = $12 + 0.7 \pi = 19.95 \text{ V} 2$ Thus voltage across secondary winding = 2VS 40 V Chapter 3-28 (b) (i) Using Eq (3.30), we have the conduction angle = Looking at D4, PIV = VS - $VO-\omega t \sim = VS + (VS - 0.7) = 2VS - 0.7 = 39.2 V = If$ choosing a diode, allow a safety margin by moving a factor of 1.5, thus $\sqrt{2Vr}/Vp - VD 2 \times 0.1 Vp - 0.7 Vp - 0.7 0.2 = 0.447$ rad PIV 60 V \therefore Fraction of cycle = Vp Vr VpVD T (i) $Vr \sim = Vp - VD CR [Eq. (3.28)] T 0.1 Vp - VD = Vp - VD CR C = 1 = 166.7 \mu F 0.1 \times 60 \times 103 (ii) \omega t 2 \times 0.01 Vp - 0.7 = 0.141 rad Vp - 0.7 = 0.141 rad Vp - 0.7 = 0.141 rad Vp - VD = 12.77 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 103 = 192 mA (ii) For Vr = 0.01 Vp - VD T = CR C = 1.277 2 1 + \pi 0.1 T03 = 1.$ $= 1667 \,\mu\text{F} 1$ (a) (i) v O, avg = Vp - VD - VF 2 $\sqrt{1} \sqrt{102 - 0.70.1} = 102 - 0.71 - 2$ (ii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi
0.1103 = 371 \text{ mA} (ii) iD, peak (ii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (ii) iD, peak (ii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (ii) iD, peak (ii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (ii) iD, peak (ii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (ii) iD, peak (ii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (ii) iD, peak (ii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (ii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (ii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak = IL (1 + 2\pi Vr 2 12.77 = 1 + 2\pi 0.1103 = 371 \text{ mA} (iii) iD, peak $13.37\ 2\ 1 + 2\pi = 0.01\ 103 = 1201\ \text{mA}\ 1.2\ \text{A}\ \text{Chapter}\ 3-29\ \text{Vp} - \text{VD}\ 3.73\ (i)\ \text{Vr} = 0.1\ \text{Vp} - \text{VD} = 2\text{fCR}\ \text{The factor of}\ 2 \Rightarrow \text{VOV} = 2\ \text{CR}\ \text{The factor of}\ 2 \Rightarrow \text{VOV}\ 2 \Rightarrow \text{VOV}\$ $0.2 \text{ V v GS1} = \text{v GS2} = 0.2 + 0.4 = 0.6 \text{ V v S} = -0.6 \text{ V 1} \times 0.4 \times 10$ (v id + 0.4 - 0.4) $2 \Rightarrow \text{v id} = 0.283 \text{ V v which is } 2\text{VOV}$, as derived in the text. Chapter 2-36 $2.107 \text{ 1} + \text{R2} = 10 \Rightarrow \text{R1} = 1 \text{ k and } \text{R2} = 9 \text{ k R1 When a } 100\text{-mV}$ (i.e., 0.1-V) step is applied at the input, the output will be v O = $0.1 \times 10(1 - e - t/\tau)$, V 1+ f3dB f1 f3dB = f1 $2 = \sqrt{\sqrt{2} 2 - 1}$ Q.E.D (b) 40 dB = 20 log G0 = G0 = 100 = 1 + R2 R1 where $\tau = f3dB = 1 \omega 3dB v$ O reaches 1% of the 1-V final value at time t, ft R2 1 + R1 = 2 MHz = 20 kHz 100 1 - e - t/\tau = 0.99 (c) Each stage should have 20-dB gain or R2 1 + = 10 and therefore a 3-dB frequency of R1 e - t/\tau = 0.01 f1 = 2 × 106 = 2 × 105 Hz 10 t = 4.6 \tau The overall f3dB = 2 × 105 Hz 10 t = 4.6 \tau Hz 10 t = 4.6 \tau f1 + 0.0 t = 4.6 \tau f1 + 0. $\sqrt{2-1}$ For t to be 200 ns, = 128.7 kHz, 200 = 43.49 ns $\tau = 4.6$ Thus we require a closed-loop 3-dB frequency 1 or $\tau \omega 3dB = f3dB = 1.1 = 3.66$ MHz 2.108 (a) Assume two identical stages, each with a gain function: G = G0 $\omega = jf1+j1+\omega 1$ f1 G0 $2.109 \text{ ft} = 100 \times 5 = 500 \text{ MHz}$ if a single op amp is used. Thus, the new bias current is $16 = 20 \ 20 = 1 + \text{gm Rs} + 2\text{Rs} \Rightarrow \text{Rs} = 125 \text{ IC} = \text{gm} \times \text{VT} = 3.33 \times 0.025 = 0.083 \text{ mA}$ Gv = 25 V/V 6.68 gm = 6.65 (a) See figure below. The slope of each straight line is equal to this value divided by 100 V (VA). Thus, ID = 1 mA. Thus the total variation in the output voltage can be $\pm 3\%$, resulting in VO in the range 4.85 V to 5.15 V. Av = -k n VOV RD Coordinates of point A: Vt and VDD; thus But ro1 |VA | 5 = ro2 = IREF IREF VOV 1 = 0.2 V Since ID2 = ID3 = ID1 = 50 μ A Thus, Av = -gm1 Ro 1 2, we have μ Cox (W/L) VOV 2 p W 2ID2 W = = L 2 L 3 µp COX (VOV) 2 -40 = -gm1 × 100 = 100 = 51 × 2 IREF and ID = \Rightarrow IREF = 25 µA 2 (50 µA) = 29.1 86 µA/V2 (0.2 V) 2 \Rightarrow gm1 = 0.4 mA/V But gm1 = 2µn Cox W L ID1 1 W \Rightarrow =8 L 1 1 W ID1 = µn Cox V2 2 L 1 OV 1 1 2 × 400 × 8 × VOV 1 2 \Rightarrow VOV 1 = 0.125 V 25 = If Q2 and Q3 are operated at |VOV| = 0.125 V, $1 W |VOV| 2 ID2 = ID3 = \mu p Cox 2 L 2,3$ $1 W 25 = x 100 \times x 0.1252 2 L 2,3$ $W \Rightarrow = 32 L 2,3$ For Q1, $2 (50 \mu A) W = = 6.46 L 1 387 \mu A/V2 (0.2 V) 2$ Av must be at least -10 V/V and Av = -gm (rol ro2) $gm1 = 2ID 2 \times 0.05 = 0.5 mA/V = VOV 1 0.2$ rol ro2 = 10 = 20 k 0.5 But rol = VA1 V L 5L = 100L = An = ID1 ID1 0.05 ro2 = |VAp|L|VA2| 6L = 120L = ID2 ID2 0.05 Thus, 100L 120L = 20 k \Rightarrow L = 0.367 µm If L is to be an integer multiple of 0.18 µm, then L = 0.54 µm 7.43 To raise the gain to 20 V/V, ro1 ro2 has to be raised to 40 k, which requires L = 2 × 0.367 = 0.734 Again, to use a multiple of 0.18 µm we select L = 0.9 µm. P7.95(b). (b) For 5.1-V zeners we use 4 diodes to provide 20.4 V with $4 \times 30 = 120$ - resistance. v O = Vp e-t/RC During conduction, the diode current is given by T/2 Vp - Vr = Vp e- RC \leftarrow discharge is only half T the period. This is because with B1 and B2 3 grounded the two transistors will have equal VBE 's. 1.16(a), we assumed that the amplifier is unilateral (i.e., has no internal feedback, or that the input side does not know what happens at the output side). 8.13. When v I < 0, D1 is cut off and the circuit becomes a voltage divider. (2) and (3) to compute IEmin and IEmax, IEnominal = IEmax (3) If we set IEmin = 0.9 mA and solve Eqs. Not a good design! Nevertheless, if the source were connected directly to the load, (This takes into ower dissipated in the internal resistance of the source.) 1.44 (a) Case S-A-B-L (see figure on next page): vo vo v ib v ia = $\times \times =$ vs v ib v ia vs 10 100 \times 100 7.236 mA. As before, the voltage at X, VX, will be equal to V. IC 10 mA = 400 mA/V gm = VT 0.025 V β 200 rm = = 0.5 k = gm 400 Rib = rm = 0.5 k = 0.476 + 1 vo = $-gm RC = -400 \times 0.1 = -40 V/V v\pi$ vo = $-40 \times 0.322 = -12.9 V/V v$ sig ie = -vivivi = -8.56 V/V v sig ie = $-vivivi = -0.99 \times 6 \times vo = \pm 0.4 V/V \pm 0.4 = \pm 0.01 V = \pm 0.4 V/V \pm 0.4 = \pm 0.4 V$ vi This figure belongs to Problem 6.49. Thus, IRC = Ad VT 2 Substituting from (2) into (1), we obtain vⁱ d v C1min = VCC - Ad VT + 2 \Rightarrow Ad = 63.2 V/V (2) Ad = gm1,2 (ro1,2 ro3,4) For (3) ro1,2 = ro3,4 = VA 2VA Ad = 2VT I 1 gm1,2 = VA VA I × = 2VT I 2VT = 20 = 400 V/V 2 × 0.025 Chapter 8-16 This figure belongs to Problem 8.41. P8.51. = -A2va
Obviously, the cascode delivers a much greater gain than that achieved by quadrupling the channel length of the CS amplifier. A3 = $-\alpha$ (b) The output resistance now becomes very large resistance Ro = 3 k re8 + β + 1 3 k When the amplifier is loaded with RL = 100, RL = RL + Ro 100 1.73 × 105 × 3000 + $100 \text{ Gv} = 1.73 \times 105 \text{ Gv} = 5581 \text{ V/V}$ If the original amplifier is loaded in RL = 100, Gv = 8513 \times The gain of the second stage will now be A2 = v o2 3 k Ri3 = -a v o1 2 \times 0.025 + 2 \times 0.025 + 2 \times 0.025 From Example 8.8, Ri3 = 234.8 k, thus A2 - 3 234.8 = -29.6 V/V 0.1 which is about half the value without the two 25- emitter resistances. Credit for these goes to the problem solvers listed therein. (d) v I = -3 V, v = 0 V, v O = 0 V, and v A = -13 V. (6.7) and (6.8) as follows: $\sqrt{2 \times 4 \times 17.5 \times 1.8 + 1 - 1} = 4 \times 17.5 \times 1.8 + 1 - 1 = 4 \times 17.5 \times 10^{-1}$ $0.142 = 0.04 \text{ mA } 2 \text{ RD} = 17.5 \text{ k} = \text{Thus}, \text{ VGS } B = \text{Vt} + \text{VOV } B = 0.4 + 0.213 = 0.613 \text{ V} \text{ and } \text{VDS} = \text{VDD} - \text{RD ID} \text{ VDS } B = \text{VOV } B = 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ and } 0.213 \text{ V} = 1.8 - 17.5 \times 0.04 = 1.1 \text{ V} \text{ Thus}, \text{ coordinates of } B \text{ are } 0.613 \text{ V} \text{ are } 0.613 \text{$ $10-13 \text{ e}0.5/0.025 = 48.5 \mu A 4.18 \text{ Dividing Eq.}$ (4.14) by Eq. (4.15) and substituting iC /iB = β forced gives β forced = IS ev BC /VT - 1 ISC β forced = IS ev BC /VT - 1 ISC β forced = 1 IS eVCEsat /VT + 1 β ISC This equation can be used to obtain eVCEsat /VT and hence VCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC /IS = 100, we can use this equation can be used to obtain eVCEsat /VT = ISC 1 - β forced / $\beta = 100$ and ISC / $\beta = 1$ to obtain VCEsat corresponding to the given values of β forced. Thus 1 ID = k p v SD |VOV | - v 2SD 2 1 = 6.25 0.02 × 0.4 - (0.02)2 2 = 0.05 mA For VD = -2 V, the transistor will be operating in saturation, thus ID = 1 1 k p |VOV | 2 = × 6.25 × 0.42 = 0.5 mA 2 2 5.10 iD = 1 W k |VOV | 2 2 nL For equal drain currents: μ Cox Wp Wn = μ p Cox L L Wp $\mu 1 = 2.5 = n = Wn \mu p 0.4 kn = \mu Cox Chapter 5-3 5.11$ For small v DS, iD kn $1 = 2.645 1 \times 2 - \times 1 = 4 mA 2$ and v DS = 1.5 V (b) v GS = 2 V W (VGS - Vt) VDS, L1 1 W kn (VGS - Vt) VDS, L1 1 W kn (VGS - Vt) L 1 = $100 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 116.3 \text{ mV rDS} = 116.3 \text{ mV rDS} = 116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 20 \times (5-0.7)$ rDS = $116.3 \text{ mV rDS} = 10 \times 10-6 \times 10-6 \times 10^{-1}$ rDS = 100×10^{-1} rDS = 1saturation region, 1 1 iD = k n v 2OV =
 $\times 2.645 \times 1.52$ 2 = 3 mA For the same performance of a p-channel device: Wp Wp μ Wn = n = $2.5 \Rightarrow = \times 2.5$ Wn μ p L L (c) v GS = 2.5 V v OV = 2.5 - 0.5 = 2 V 5.12 tox = 6 nm, μ n = 460 cm2 /V·s, Vt = 0.5 V, and W/L = 10. case, IOS = 2.98 200 = 20 nA 10 1 M The offset current alone will result in an output offset voltage of 10 nF 10 k IOS × R2 = $20 \times 10-9 \times 1 \times 106 = 20$ mV R3 (d) VO = 200 mV + 20 mV = 220 mV = 0.22 V IB1 Vos Vo IB2 2.96 At $0 \circ C$, we expect $\pm 20 \times 50 \times 1000$ μ V = ± 500 mV = ± 1 V We expect $\pm 20 \times 25 \times 1000$ μ V = ± 500 mV = ± 20 mV = 20 mV = 2R2 = 40 k. P5.53(a). Similarly, the minimum number of pins required by quad op amp is 14: $4 \times 2 + 4 \times 1 + 2 = 14$ Gain A = $= 1 \times 106 \times 40 \times 10 - 3 = 40,000 \text{ V/V}$ v1 Gmv1 i 2.2 Refer to Fig. The result is the circuit shown in Fig. First, we use Thévenin's theorem to replace the voltage divider feeding the base with VBB and RB : $6 \times 300 = +0.75 \text{ V} = -10.75 \text{ V}$ -3 + 480 Since VC = 2 V is lower than VB, which is +2.3 V, the transistor will be operating in the active mode. 8.85 Gm = gm1,2 = ro2 = 2(I/2) 0.2 = 1 mA/V = VOV 1,2 0.2 20 VAn = = 200 k I/2 0.1 Chapter 8-30 ro4 = |VAp | 12 = = 120 k I/2 0.1 Thus, IO = ID4 - ID2 Ro = ro2 ro4 = 200 120 = 75 k = ID1 - ID2 Ad = Gm Ro = 1 × 75 = 75 V/V The gain is reduced by a factor of 2 with RL = Ro = 75 k. R 10 k C T, dB 40 37 30 20 dB/decade 3 dB 20 V R 100 k R 1 k V R 100V 1 k V For f01 \leq 100 2 π C1 (10 + 100) × 103 \Rightarrow C1 \geq 1.66 Since the overall transfer function is that of three identical STC LP circuits in cascade (but with no loading the control of the effects, since the buffer amplifiers have infinite input and zero output resistances) the overall gain will drop by 3 dB below the value at dc at the frequency for which the gain of each STC circuit is 1 dB down. Thus (W/L)M ID4 = ID3 1 + (W/L)M At the output node, we have (a) Let WW 1W = -L2LA 2LA WW 1W = -L2LA 2LA QIand Q2 have equal values of VGS and thus of VOV, thus 1 W 1 W + V2 ID1 = k n 2 L A 2 L A OV 1 W 1 (W/L)A 2 = k n 1 + VOV 2 L A 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = = k n V2 2 2 L A OV 1 U (W/L)A ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = = k n V2 2 2 L A OV 1 W 1 (W/L)A ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = = k n V2 2 2 L A OV 1 W 1 (W/L)A ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = = k n V2 2 2 L A OV 1 U (W/L)A ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = = k n V2 2 2 L A OV 1 W 1 (W/L)A ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = = k n V2 2 2 L A OV 1 W 1 (W/L)A ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = = k n V2 2 2 L A OV 1 W 1 (W/L)A ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 I W ID1 = 1 + 2 2 (W/L)A Since, in the ideal case <math>1 W IUID4 - ID2 (W/L)M = ID3 1 + - ID2 (W/L)M = ID1 1 + - ID2 (W/L)M = I (W/L)M mA IC1 = IC2 0.25 mA gm1,2 = IC1,2 0.25 mA = 10 mA/V VT 0.025 V Chapter 8-31 ro = |VA| 10 V = 40 k = IC 0.25 mA Rid = 2 rII = 2 two input terminals and determine the output current i as follows: $\beta 100 = 2 \times = 20 k \text{ gm } 10 \text{ i} = IC2 - IC4 II1 - \alpha 2 21 + (2/\beta p2)$ 1 I 1 - $\alpha 2 21 + (2/\beta p2)$ Ro = ro2 ro4 = 40 40 = 20 k = α Gm = gm1,2 = 10 mA/V VT 0.025 V Chapter 8-31 ro = |VA| 10 V = 40 k = IC 0.25 mA Rid = 2 rII = 2 two input terminals and determine the output current i as follows: $\beta 100 = 2 \times = 20 k \text{ gm } 10 \text{ i} = IC2 - IC4 II1 - \alpha 2 21 + (2/\beta p2)$ 1 I 1 - $\alpha 2 21 + (2/\beta p2)$ Ro = ro2 ro4 = 40 40 = 20 k = α Gm = gm1,2 = 10 mA/V VT 0.025 V Chapter 8-31 ro = |VA| 10 V = 40 k = IC 0.25 mA Rid = 2 rII = 2 two input terminals and determine the output current i as follows: $\beta 100 = 2 \times = 20 k \text{ gm } 10 \text{ i} = IC2 - IC4 II1 - \alpha 2 21 + (2/\beta p2)$ 1 I 1 - $\alpha 2 1 + (2/\beta p2)$ Ro = ro2 ro4 = 40 40 = 20 k = α Gm = gm1,2 = 10 mA/V VT 0.025 V Chapter 8-31 ro = |VA| 10 V = 40 k = IC 0.25 mA Rid = 2 rII = 2 two input terminals and determine the output current i as follows: $\beta 100 = 2 \times = 20 k \text{ gm } 10 \text{ i} = IC2 - IC4 II1 - \alpha 2 21 + (2/\beta p2)$ Ro = ro2 ro4 = 40 40 = 20 k = \alpha Gm = gm1,2 = 10 mA/V VT 0.025 V Chapter 8-31 ro = |VA| 10 V = 40 k = IC 0.25 mA Rid = 2 rII = 2 two input terminals and determine the output current i as follows: $\beta 100 = 2 \times = 20 k \text{ gm} = 10 \text{ m} 10 \text{ i} = IC2 + IC4 II 1 - \alpha 2 21 + (2/\beta p2)$ 2 (1 Q5 i 2) bP2 aI/2 aI/2 Q2 Q1 I/2 I/2 I The figure shows a BJT differential amplifier loaded in a base-current mirror. 7.59 Refer to Fig. Note for instance that although we find the current mirror. 7.59 Refer to Fig. Note for instance that although we find the current mirror. 7.59 Refer to Fig. Note for instance that although we find the current mirror. 7.59 Refer to Fig. Note for instance that although we find the current mirror. 7.59 Refer to Fig. Note for instance that although we find the current mirror. 7.59 Refer to Fig. Note for instance that although we find the current mirror. 7.59 Refer to Fig. Note for instance that although we find the current mirror. 7.59 Refer to Fig. Note for instance that although we find the current mirror. which is approximately 2 4 1 gm v id . (1) and (2) to obtain (W/L)3 W3 = gm1 vi (W/L)3 W3 = gm1 vi (W/L)2 W2 Rin 1/gm1 which flows through RL and produces the output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is given by S2 id 3 = gm1 vi (1) The short-circuit output current io is gi The intercept of the iC -v CE straight line on the iC axis will be at v CE = $5 + iC = 1.1 - 5 \times 0.02 = 1$ mA Thus, the Early voltage is obtained as iC (at v CE = 0) VA 1 = $50 \text{ V} \Rightarrow VA = 0.02 \text{ VA}$ 50 V = = 50 k ro = IC 1 mA Slope = 4.39 ro = VA 50 V = IC IC Thus, At IC = 1 mA, ro = At IC = $100 \mu A$, 50 V = 50 k 1 mA ro = 50 V = 500 k 0.1 mA 4.40 ro = $100 \mu A$, $50 \text{ V} = 100 \mu A$, 50 V = 50 k 1 mA ro = 50 V = 500 k 0.1 mA 4.40 ro = $100 \mu A$, 50 V = 50 k 1 mA ro = 50 V = 500 k 0.1 mA 4.40 ro = $100 \mu A$, 50 V = 50 k 1 mA ro = 50 V = 500 k 0.1 mA 4.40 ro = $100 \mu A$, 50 V = 50 k 1 mA ro = 50 V = 500 k 0.1 mA 4.40 ro = $100 \mu A$, $50 \text{ V} = 100 \mu A$, 50 V = 50 k 1 mA ro = 50 V = 500 k 0.1 mA 4.40 ro = $100 \mu A$, 50 V = 50 k 1 mA ro = 50 V = 500 k 0.1 mA 4.40 ro = $100 \mu A$, $50 \text{ V} = 100 \mu A$, 50 V = 50 k 1 mA ro = 50 V = 500 k 0.1 mA 4.40 ro = $100 \mu A$, $50 \text{ V} = 100 \mu A$, 50 V = 50 k 1 mA ro = 50 V = 500 k 0.1 mA 4.40 ro = $100 \mu A$, $50 \text{ V} = 100 \mu A$, 50 $1/\text{slope} = 1/(0.8 \times 10-5) = 125 \text{ k}$ ro = VA IC 125 k = VA =
125 V 1 mA At IC = 10 mA, ro = which is the inverse of the slope of the iC -v CE line. This gives IS = $9.36 \times 10-17 \text{ A}$. (1.51) and (1.52), respectively: xn = W NA xn = W · = 0.1 µm NA + ND 10 + 1016 = 0.228 × 17 NA + ND 10 + 1016 = 0.228 µm ND 1016 = 0.228 × 10-17 \text{ A}. $17 \text{ NA} + \text{ND } 10 + 1016 = 0.03 \ \mu\text{m ND} = 0.1 \ \mu\text{m NA} + \text{ND } \text{Since both regions are doped equally, the depletion region is symmetric.}$ P7.39. Thus all transistors have $|\text{VOV}| = 161 \times 60 \times (1.6 - 1) \times 20.8 \ \text{ID} = 216 \ \mu\text{A} = 2 \ \text{ID} \times 216 = 102 \times 216 \times 216$ $720 \mu A/V |VOV| 1.6 - 1 = 0.72 mA/V \lambda = 0.04 \Rightarrow VA = ro = 2 ID VOV 1 1 = 25 V/\mu m \lambda 0.04 VA \times L 25 \times 0.8 = 92.6 k = ID 0.216 ID = 1 W 2 1 k V = × 60 \times 40 \times (1.5 - 1)2 2 n L OV 2 ID = 300 \mu A = 0.3 mA, VOV = 0.5 V Ex: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA 15 = 50 k = ro = ID 0.3 VA \times L = VA gm = (b) ID = 300 \mu A = 0.3 mA, VOV = 0.5 V Ex: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA 15 = 50 k = ro = ID 0.3 VA \times L = VA gm = (b) ID = 300 \mu A = 0.3 mA, VOV = 0.5 V Ex: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA 15 = 50 k = ro = ID 0.3 VA \times L = VA gm = (b) ID = 300 \mu A = 0.3 mA, VOV = 0.5 V Ex: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA 15 = 50 k = ro = ID 0.3 VA \times L = VA gm = (b) ID = 300 \mu A = 0.3 mA, VOV = 0.5 V Ex: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA 15 = 50 k = ro = ID 0.3 VA \times L = VA gm = (b) ID = 300 \mu A = 0.3 mA, VOV = 0.5 V Ex: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA 15 = 50 k = ro = ID 0.3 VA \times L = VA gm = (b) ID = 300 \mu A = 0.3 mA, VOV = 0.5 VEX: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA 15 = 50 k = ro = ID 0.3 VA \times L = VA gm = (b) ID = 300 \mu A = 0.3 mA, VOV = 0.5 VEX: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA 15 = 50 k = ro = ID 0.3 VA \times L = VA gm = (b) ID = 300 \mu A = 0.3 mA, VOV = 0.5 VEX: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA 15 = 50 k = ro = ID 0.3 VA \times L = VA gm = (b) ID = 300 \mu A = 0.3 mA, VOV = 0.5 VEX: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA 15 = 50 k = ro = ID 0.3 VA \times L = VA gm = (b) ID = 300 \mu A = 0.3 mA, VOV = 0.5 VEX: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA = 0.5 VEX: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA = 0.5 VEX: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA = 0.5 VEX: 6.11 2 ID VA 2VA \times = gm ro = VOV ID VOV 2 \times 0.3 = 1.2 mA/V 0.5 VA = 0.5 VA = 0.5 VA = 0.5 VA = 0.5 VA$ $0.5 \text{ mA} \Rightarrow \text{gm} = = 100 \text{ V/V Ex}: 6.12 \text{ Given}: \text{gm} = \text{gm} = 1.55 \text{ mA/V VA} 15 = 30 \text{ k} = \text{ID} 0.5 \text{ } \partial \text{C} \text{ } \partial \text{v} \text{ BE iC} = \text{IC where IC} = \text{IS eVBE /VT} \partial \text{iC IS eVBE /VT} \text{ } \partial \text{iC} \text{ } av = 1 \text{ } \text{mA/V}, \text{ } \text{ } \text{ } n = 50 \text{ } \mu\text{A/V2} \text{ } \text{ } \text{ } \text{ } \text{ } \text{mA} \text{ } \text{ } \text{ } \text{gm} = 2 \text{ } \text{ID} 2 \times 0.1 = 0.2 \text{ } \text{V} \Rightarrow \text{VOV} = \text{VOV} 1 \text{ } \text{gm} = \text{ID} = 1 \text{ } \text{W} 2 \text{ } \text{W} 2 \text{ } \text{ID} \text{ } \text{k} \text{ } \text{n} \text{ } \text{VOV} \Rightarrow = 2 2 \text{ } \text{L} \text{ } \text{k} \text{ } \text{ } \text{VOV} = 2 \times 12.5 \times 0.8 \text{ } 0.2 \text{ } \text{W}$ $2 \mu n \text{ Cox ID L} 2 \times 60 \times 40 \times 0.5 \times 103 \text{ ro} = L = 0.8 \mu m \Rightarrow gm \text{ ro} = 2 \times 0.1 = 100 50 \times 0.22 1000 \text{ IC VT Ex: } 6.13 \text{ IC } 0.5 \text{ mA} = 20 \text{ mA/V} = gm = \text{VT } 25 \text{ mV Ex: } 6.14 \text{ Ex: } 6.9 \text{ W VOV L} \text{ Same bias conditions, so same VOV and also same L and gm for both PMOS and NMOS. (a) } \beta = \infty \text{ VB} = 0 \text{ VE} = -0.7 \text{ V VE} - (-5) 4.3 \text{ IE} = 0.5 = = \text{RE RE} \Rightarrow \text{RE} = 8.6 \text{ k VC}$ $= VE + 2 = -0.7 + 2 = +1.3 VVCC - VC 5 - 1.3 RC = = 7.4 k IC 0.5 (b) \beta min = 50 IE 0.5 IBmax = 0.01 mA 51 51 IE RE = 0.5 \times 8.6 = 4.3 V IBmax RBmax = 0.01 mA 51 51 IE RE = 0.43 V 0.43 RBmax = 4.3 k RC = 7.5 k (d) \beta = \infty$: VB = 0, VE = -0.7 V Chapter 6-37 - 0.7 - (-5) = 0.52 mA 8.2 IC = 0.52 mA 0.52 mA An equal positive swing is just possible. Now, VE = VB - 0.7 If = VE - (-10) 3 Observe that with VC at 3 V and VB at 4.3 V, the transistor is operating in the active region. VCC Now, gm is reduced by a factor of 5 and ro is increased by a factor of 5, keeping Av o unchanged at -4000 V/V. The maximum gain magnitude is obtained when x = 0, $R2 vO = -vIR1 \Rightarrow 1 + R4 R4 1 + + = -100 R2 R3 100 100 = 100 + 100 R3 \Rightarrow R3 = 100 = 1.02 k 98$ When the potentiometer is set exactly in the middle, x = 0.5 and $R2 vO = -vIR1 = -100 100 0.5R4 0.5R4 + 1 + R2 R3 + 0.5R4 0.5 \times 100 0.5 \times 100 1 + 100 R3 \Rightarrow R3 = 100 = -2.48 V/V 10 k Rf 50 k 10 k v1 10 k v2 vO Rf$ Rf Rf v1 + v1 + v2 R1 R2 R3 50 50 50 = -v1 + v1 + v2 R1 R2 v2 For v1 and v2 = -1 V v O = $-(10 \times 1 + 5v2)$ vO = -2v1 + 2v1 v2 i1 = and i2 = R1 R2 Since i1, i2 ≤ 50 μ A for 1-V input signals (1x) R4 vI vO i2 R3 R2 vO Chapter 2-10 (b) vO = $-(v 1 + v 2 + 2v 3 + 2v 4) v 2 = 1.5 V 100 k v 1 = 3 sin \omega t v v 100 k vO v vO = -3 sin \omega t - 3 100 k v t 0 3 Rf R1 Rf R2 Rf R3 Rf R4 100 k = 1 \Rightarrow R1 = 100 k = 1 \Rightarrow R2 = 100 k 100 k 2 100 k = 2 \Rightarrow R4 = 2 = 2 \Rightarrow R3 = Ri1 = 100 k$ Ri2 = 100 k, Ri3 = 50 k, Ri4 = 50 k For the summer circuit, we should have (c) vO = -(v1 + 5v2) Rf Rf = 1 and = 2 R1 R2 100 k Select Rf = 2 R2 = 20 k. Transistor Q3 will be operating in the triode region and its drain-source resistance rDS will be given by rDS = $\mu n \cos 1 W VOV 3 L 3 Now$, W VOV 1, 2 L 1, 2 W $gm3 = (\mu n \cos) VOV 3 L 3$ WW For = , L 3 L 1,2 W gm1,2 = $\mu n \cos L VOV 1,2$ gm1,2 = $(\mu n \cos L VOV 1,2)$ gm1,2 = ($40 \text{ mA/V Av} = -\text{gm RC} = -40 \times 5 = -200 \text{ V/V } 6.35 \text{ gm} = v^{\circ} = |\text{Av}|v^{\circ} \text{be} = 200 \times 5 \text{ mV} = 1 \text{ V VC} = 1 \text{ V}, 6.36 \text{ VCC} = 3 \text{ V}, 3-1 \text{ IC} = = 1 \text{ mA } 2 \text{ IC } 1 \text{ mA} = 40 \text{ mA/V} = \text{gm } v \text{ be} = 0.005 \text{ sin } \omega t, \text{ mA } v \text{ C} (t) = \text{VC} - \text{RC } i \text{ C} = 3 - 2(1 + 0.2 \text{ sin } \omega t) \text{ V}^{\circ} \text{ be IC RC} = 0.3 \text{ VT}$ which can be manipulated to yield VCC - 0.3 IC RC $= V^{\circ}$ be 1 + VT Since the voltage gain is given by IC RC Av = -VT then VCC - 0.3 Av $= VT + V^{\circ}$ be 0.005 6.37 Since V^o be is the maximum value for acceptable linearity, the largest signal at the collector will be obtained by designing for maximum gain magnitude. -4 - (-10) = 2.5 mA 2.4 k IC IC = 2.5 mA $IE = \alpha V3 = +12 - IE \times 5.6 = 12 - 2.5 \times 5.6 = -2 \text{ V}$ Since VC is lower than VB, the transistor is operating in the active region. = 54.6 mA Similarly, for VD = 0.69 V we obtain I = $10-3 \times e(0.69 - 0.7)/0.025 = 0.67 \text{ mA } 3.22$ and for VD = 0.67 mA 3.22 and for VD = $0.67 \text{ mA } 3.22 \text{ mA } 1.2 \text{ mA$ have I I = $10-3 e(0.6 - 0.7)/0.025 = 18.3 \mu$ A To increase the current by a factor of 10, VD must be increased by VD, 10 = e ID1 D1 VD / 0.025 - VD / VT ID = IS eVD / VT ID = $/VT \Rightarrow V 60 \text{ mV}$ Thus the result in each case is a decrease in the diode voltage by 60 mV. Thus 2.102 The gain drops by 20 dB at f 10fb. In specifying the PIV rating for the diode we use a factor of safety of 1.5 to obtain where C = 100 μ F and R = 100, thus PIV = 1.5 × 13.7 = 20.5 V Vp - 2 VD (d) iDav = IL 1 + π 2 Vr 14.4 - 1.4 12 1+ π = 0.2 2×2 At the end of the discharge interval, t T and = 400 mA Vp - 2 VD 2 Vr $14.4 - 0.7 12 1 + 2\pi = 0.2 2 \times 2 CR = 100 \times 10 - 6 \times 100 = 0.01 \text{ s}$ is much smaller than CR, T v O 11.3 1 - CR (e) iDmax = IL 1 + $2\pi 11.3 \times 0.001 11.3T = 1.13 VCR$ 0.01 The average dc output voltage is = 740 mA 1.13 Vr = 11.3 - 10.74 V 2 2 To obtain the interval during which the diode conducts, t, refer to Fig. factor = 1.0 (d) If oxide thickness tox is halved, and ox tox Cox = Two conditions need to met for v OV and rDS Condition 1: rDS, 1 = $250 \Rightarrow (W/L)$ v OV, 1 = 10 then Cox is doubled. Thus 1 W 100 = $\times 100 \times (VSG - 0.6)2\ 2\ 1\ \mu m\ 2 \Rightarrow VSG = 0.6 + W\ (\mu m)$ For the six cases above we obtain (1) With Q1 diode connected, 20 (W/L)2 = 200 μA = 100 μA 10 (2) With Q2 diode connected, and W = 20 μm , 10 = 50 μA I1 = 100 μA 20 (3) If Q3 with W = 40 μm is diode connected, $10 = 25 \ \mu A \ I1 = 100 \ \mu A \ 40$ $20 = 50 \ \mu A \ I2 = 100 \ \mu A \ 40$ So, with only one transistor diode connected, we can get $25 \ \mu A$, $50 \ \mu A$, $200 \ \mu A$, and $400 \ \mu A$, or four different currents. 1. Now, for R1 = 10 k, R2 = 40 k and C = 1 \mu F, f (Hz) |T | (dB) \arrow T (\circs) 0 40 0 100 40 0 100 40 0 104 37 - 45 \circs 105 20 - 90 \circs 106 0 - 90 \circs Chapter 1-23 This figure belongs to 1.65. 10 Chapter 2-38 \therefore The minimum pulse width = W = 0.2 µs dv O = SR \Rightarrow 10 ω max = 40 × 10+6 \Rightarrow ω max dt max The output will be a triangular with 2-V peak and 10 V/µs slopes. = -110 V/V Using small-signal approximation, we write Av = -gm RC where IC 0.5 mA = 20 mA/V = VT 0.025 V gm = Av = -20 × 5 = -100 V/V v be i c /I
C i c /I C Error (mV) Exponential Small signal (%) Thus, the small-signal approximation at this signal level (v be = 5 mV) introduces an error of -9.1% in the gain magnitude. vsig $10 + 101 \times 0.05$ = ic1 = $\beta 1$ ib1 = 100 vsig $10 + 101 \times 0.05$ = ic1 = $\alpha i c_1 = \alpha i c_2 = \alpha i c_2 = \alpha i c_1 = \alpha i c_2 = \alpha$ 100×10 vsig $10 + 101 \times 0.05$ vsig 10 + re1 + re2 $\beta 1 + 1$ vsig 10 + 0.05 + 0.05 101 ic 2 = 0.99 vsig 10 + 0.05 + 0.05 101 vsig 10 + 0.05for both Ad = vod αRC re + Re Rid = (β + 1)(2re + 2Re) = 2(β + 1)(re + Re) With v id = 0, the dc voltage appearing at the top end of the bias current source will be I RC (a) VCM - VBE - 2 (b) VCM - VBE Since circuit (b) results in a larger voltage across the current source and given that the minimum value of VCM is limited by the need to keep a certain specified minimum voltage across the current source, we see that circuit (b) will allow a larger negative VCM. Chapter 7-17 7.45 (a) 2ID 2 × 0.125 = 0.5 mA/V = VOV 1 - 0.5 gm = 1.0 V Q2 ID 2 R VG Av = 1 - 2 × 0.5 × 1000 = -999 V/V (c) VD ii ID 1 0 R Q1 vi 1.0 V Figure 1 vgs 2gmvgs ro/2 vo vi Rin i i vgs vi From Fig. VD = 0.025 ln 10-12 ID = 1 - 0.6635 = 0.3365 mA 1 k Stop here as we are getting almost same value of ID and VD ID = 3.35 We first find the value of IS for the diode, given by IS = ID e-VD /VT with ID = 1 mA and VD = 0.75 V. The corresponding value of V I v I = v O - iR = 2.3 - 1 × 1 = +1.3 V v I < 0: D1 cutoff, vO = -1 D2 conducts ~ vI As v I decreases below 1.3 V, the diode current increases, but the diode voltage remains constant at 0.7 V. Since β is very large, the dc base current can be neglected. (a) To obtain operation, RC must be increased to the value that results in VCE = 0.3 V: IC = VCC - VC 10 - 5 = 0.5 mA = RC 10 RC = IB = IC 0.5 = 0.01 mA β 50 = VBB = VBB = 0.01 mA β 50 = 0.01 mA β 50 = VBB = 0.01 mA β 50 = 0.01 mA β 50 = VBB = 0.01 mA β 50 = 0.01 mA VBE + IB RB VCC - 0.3 IC 10 - 0.3 = 1.94 k 5 (b) For operation at the edge of saturation, (b) Further increasing RC results in the transistor operating in saturation. Gv = = vo $\alpha \times$ Total resistance in collectors = vsig Total resistance in collectors = vsig Total resistance in emitters For $\alpha = 100 \beta = = 0.99 \beta + 1.101 \text{ Gv} = -\alpha \times 10 \text{ k} 10 \text{ k} + \text{re} \beta + 1.01 \text{ Gv}$ $-0.99 \times 10 = -66.4 \text{ V/V} 10 + 0.05 101 \text{ (b)}$ Refer to Fig. The maximum value of VCM is limited by the need to keep Q1 and Q2 in the active mode. Only I depends on the value of R: (a) R = 10 k \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ k} \Rightarrow I = 4 = 0.4 \text{ mA } 10 \text{ (b)} R = 100 \text{ mA } 10 \text{ (b)} R = 100 \text{ mA } 10 \text{ (b)} R = 100 \text{ mA } 10 \text{ suppose that Q1 has $W = 10 \mu m$, Q2 has $W = 20 \mu m$, and Q3 has $W = 40 \mu m$. 10 Exercise 3-1 Ex: 3.1 Refer to Fig. For instance, v Id = -5.5 mV results in v O = -5 V; v Id = -5.5 mV results in v O = -5 V; v Id = -5.5 mV results in v O = -10 V, at which point the op amp saturates at the negative level of -10 V. Thus ID1 1 W = k n (1 - 0.6)22 L ID2 = 1 W kn (1 - 0.6)22 L and ID2 (1 - 0.6)22 L and ID2 (1 - 0.6)2 That is, a 10-mV mismatch in the threshold voltage results in a 5% mismatch in the thr iD k n (v GS C - Vt) v DS C = 4(1.8 - 0.4) v DS C = 5.6 v DS C, mA Ex: 6.3 But iD = VDD - v DS C VDD 1.8 = 0.1 mA = 0.1 mA, iD = $5 \mu A$, iD = $5 \mu A$, iD = $5 \mu A$, iD = 10 mA iD = $20 \text{ k} \le \text{ro} \le 200 \text{ k}$ ro = $v \text{ DS } v \text{ DS } 1 \Rightarrow \text{iD} = = \text{iD ro ro At iD} = 0.1 \text{ mA}$, iD = $5 \mu A$, iD = 5% iD At iD = 1 mA, iD = 50 µA, iD = 50 µA, iD = 50 µA, iD = 5.2 kiD 0.52 mA 0.50 mA vDS 1V 5.26 (a) Let Q1 have a ratio (W/L) and Q2 have a ratio (W/L) and R2 have ±1% tolerance, then VO will exhibit ±2% variability and thus will be in the range of 5 × 1.02 = 5.1 V to 5 × 0.98 = 4.9 V. c + 1.0 + 2.5 + 1.5 + 0.5 Sat. P6.108. VIB = VOB + Vt = 0.33 + 0.8 = 1.13 V If we solve (1) for VOA = 2.98 V, then 7.44 Refer to Fig. For VO = 2.7 V, Eq. (1) yields 3 - 2.7 - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 3 - 2.7 - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (1) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (2) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (3) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (4) yields 1 + 3 - (-5) - 0.691 50 = 1.013
1.04 For VO = -5 V, Eq. (5) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (7) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (7) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (7) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (7) yields 1 + 3 - (-5) - 0.691 50 = 1.013 1.04 For VO = -5 V, Eq. (7) yields 1 + 3 - (-5) $= \Rightarrow I = gm1 VOV VOV VOV 2 1 \times 1 \times 0.25 = 0.125 mA 2$ All four transistors are operated at the same value of ID and the same value of ID and the same value of VOV |. Use Eq. (1.53) to calculate charge stored on either side: Using Eq. (1.53) and A = 20 μ m2 = 20 × 10-8 cm2, the charge magnitude on each side of the junction is QJ = Aq QJ = 1.6 × 10-14 C. vO (V) 3.7 3.5 3 V D i v I (V) v O v I R 1 k slope 1 3.5 4.7 (a) v O (V) 3 V slope 1 2.5 2.3 D i v O v I R 1 k 1.3 v I (V) 2.5 (b) v O (V) 2.5 v I R 1 k 1.3 v I (V) 2.5 (b) v O (V) 2.5 v I R 1 k 1.3 v I (V) v O i 2.3 D 2.5 3 V slope 1 3.5 3 V 3.7 (d) Chapter 3-35 This figure belongs to Problem 3.83, part b. Thus, 100 (1 - Vt) 2 \Rightarrow Vt = 0.5, = 400 (1.5 - Vt) 2 VGD \leq Vt IR \leq Vt = 0.5, = 400 (1.5 - Vt) 2 VGD \leq Vt Vt = sat; Rmax = Case b — same procedure, except use VSG and VSD. 7.42. Here D2 conducts at v I = -3.5 V and its voltage becomes 0.7 V, at i = 1 mA (in the direction into v I) at v I = -4.2 V. P4.61(c), we denote the voltage at the emitter of Q3 as V and then obtain the voltages at all other nodes in terms of V, utilizing the fact that a saturated transistor has |VCE| = 0.2 V and of course |VBE| = 0.7 V. From Eq. (1.2), we note that the amplitudes of these two harmonics will have the ratio 7 to 9, which is confirmed by the measurement reported. gm = $2ID \Rightarrow ID = 0.2 \text{ mA} 0.2 \text{ ID} = 100 \text{ µA} 4.0 \text{ mA/V} 25 \text{ k} 100 \text{ k} 400 \text{ V/V} 1 \text{ mA} 25 \times 4 (1000 \text{ k} 100 \text{ k}) 25 + 5 \text{ IC I } 0.5 \text{ mA} = = 20 \text{ mA/V} 100 \text{ k} 100$ = VT VT 0.025 V 1 W 2 k V 2 n L OV 1 W × 0.4 × × 0.22 2 L W = 25 L W = 12.5 µm This figure belongs to Problem 7.25. 9.9. In the midband, $3 = 0.1 \times 2\pi \times 50 \Rightarrow \tau C2 = 31.8$ ms Chapter 9-5 and Thus, $-3 CC2 (4.7 + 5.6) \times 10 = 31.8 \times 10.3$ fL = fP = $\Rightarrow CC2 = 3.09 \mu$ F 3 µF RB Rsig = CE RE re + β + 1 | AM | = For CE to contribute 80% of fL, we use 1 τ CE α RC re 1 1+ Re re Thus, including Re reduces the gain magnitude by Re the factor 1 + . P8.2. = 101 k ID = 0.25 mA = 8.48 (a) Refer to the circuit in Fig. Specifically: 6.21 Substituting v gs = Vgs sin ω t in Eq. (6.28), iD = Eq. of L1 = iC = IC (1 + v CE /VA) = 5 (1 + v CE /I00) VCC - v CE = 10 - v CE RC \therefore 10 - v CE = 5 + 0.05v CE VCE = v CE = 4.76 V Now for a signal of 30-µA peak superimposed on IB = 50 µA, the operating point moves along the load line between points N and M. 1.5 Shunting the 10 k by a resistor of value of R result in the combination having a resistance Req , 1 Thus, R should have a -W rating. Thus the bias calculations are all consistent. Correspondingly, the peak-to-peak value of vsig will be 2.85 = 32 mV vsig (peak to peak) = 89 7.52 Given Eq. (7.63): Rin re = 100 + 3 + 1 × 100 × 3 ro + RL RL ro + β + 1 = 403 k We can write 7.51 Refer to Fig. Thus, the high-frequency advantage of the CG amplifier is completely lost! = 1.73Cgs Rsig Ex: 9.21 (a) ACS = -gm (RL ro) fH = 1 = -gm (ro ro) = -gm ro $2 \text{ Thus}, 1 = - \times 40 = -20 \text{ V/V} 2 \text{ Acascode} = -gm (RL \text{ Ro}) \text{ ro} + \text{ ro} \text{ gm ro } 1 2\pi \times 1.73 \text{ Cgs Rsig } 6.25 \text{ fH} (cs) = -gm (ro \text{ gm ro ro}) - gm \text{ ro} = -40 \text{ V/V} \text{ Thus}, \text{ Acascode} = 2 \text{ ACS} (b) \text{ For the CS amplifier}, \\ \tau H = Cgs \text{ Rgs} + Cgd \text{ Rgd where } \text{Rgs} = \text{Rsig } \text{Rgd} = \text{Rsig} (1 + gm \text{ RL}) + \text{RL} \text{ Rsig} (1 + gm \text{ RL}) + \text{RL} \text{ Rsig} (1 + gm \text{ RL}) + \text{RL} \text{ Rsig} (1 + gm \text{ RL}) + (cs) + (cs) \text{ Rsig} (1 + gm \text{ RL}) + (cs) \text{ Rsig} (1 + gm$ gm RL) 1 = Rsig 1 + gm ro 2 $1 = \text{Rsig } 1 + \times 40 = 21 \text{Rsig } 2 \text{ Ex: } 9.22 \text{ gm} = 40 \text{ mA/V ru} = \beta 200 = 5 \text{ k} = \text{gm } 40 \text{ Rin} = ru + rx = 5 + 0.2 = 5.2 \text{ k} \text{ A0} = \text{gm ro} = 40 \times 130 = 5200 \text{ V/V} \text{ Ro } 1 = ro 1 = 130 \text{ k} \text{ Rin} 2 = re 2 = 25 \text{ ro } 2 + \text{RL ro } 2 + \text{R$ r = 1.53 GHz r = 1.53 GHz r = 1.27 K R r =not a bad estimate! = 130 k 35 $R\mu 1 = \text{Rsig}(1 + \text{gm}1 \text{ Rc} 1) + \text{Rc} 1 = 4.39(1 + 40 \times 0.035) + 0.035 = 10.6 \text{ k} \tau H = \text{Cm} 1 \text{ Rm} 1 + \text{Cm} 2 \text{ Rc} 1 + (\text{CL} + \text{Cm} 2)(\text{RL} \text{ Ro}) = 16 \times 4.39 + 0.3 \times 10.6 + 16 \times 0.035 + (5 + 0.3)(50 26,000) \text{ Ex: } 9.25 \text{ gm} = 40 \text{ mA/V}$ re = $25 \text{ rm} = \beta 100 = 2.5 \text{ k} = \text{gm} 40 = \text{Rsig} + \text{rx} = \text{Rsig} = 1 \text{ k}$ Rsig RL = RL ro = 1 100 = 0.99 k RL AM = RL + re + = 70.24 + 3.18 + 0.56 + 264.5 = 338.5 ns fH = 1 = 470 kHz and ft has increased from 175 V/V to 242 V/V, fH has increased from 73.5 kHz to 470 kHz, and ft has increased from 12.9 MHz to 113.8 MHz. To have fH equal to 1 MHz, 1 = 159.2 ns $\tau H = 2\pi$ fH $2\pi \times 1 \times 106$ 159.2 = 70.24 + 3.18 + 0.56 + (CL + C μ)(50 26000) \Rightarrow CL + C μ = 1.71 pF Thus, a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature of +30° C results in a change in temperature
of +30° C results in a change in temperature unchanged at α IE, the collector voltage does not change: 10 V VB = 1.0 V Thus, IE = 10 - 1.7 10 - VE = 1.66 IE = or $-0.2/5.2 \times 100 = -4\%$. Currently, the positive input terminal sees a resistance R3 = 5 k and the negative input terminal sees a resistance R3 = 5 k and t VC3 = V = 2.044 V This figure belongs to Problem 4.61, part (c). The latter causes the lower node of the 10-k base-biasing resistor to rise with the output voltage, thus causing a much reduced signal current in the 10-k resistor and a correspondingly larger effective resistance across the amplifier input. A node equation at the common anodes node yields a negative current in D1. vc -ic RC = v sig ib RB + ie (re + RE) = - ic ib RC ie RB + (re + RE) ib (1) (2) Chapter 6-28 = - β RC RB + (β + 1)(re + RE) = - v sig ib RB + ie (re given by gm VA 25 V = IC IC mA (2) 1 VT 0.025 V = = gm IC IC mA (3) I C (mA) 1/g m (k) r o (k) | Gv | (V/V) RE Y v sig re + RE ic = $-ic RC = -\alpha ie RC - ic RC vc RC = = \alpha v sig ie (re + RE) re + RE 6.81$ With the Early effect taken into account, the effective resistance in the collector is reduced from RC = 10 k to (RC ro), where ro = ro = (1) VA 100 V = = 100 k IC 1 mA (RC ro) = 10 100 = 9.1 k 0.1 0.250 250 27.5 0.2 0.125 125 41.2 0.5 0.020 20 55.6 1.0 0.025 25 57.1 1.25 0.020 20 55.6 Observe that initially | Gv | increases as IC is increased. 1 we see that since the dc currents into the gates are zero, Figure 3 VD = VG Also, since Q1 and Q2 are matched and carry equal drain currents, For the circuit in Fig. (2) and (3) gives VCnominal = $-5 + 0.95 \times 4 = -1.6$ V IEmin = 0.8 mA VCmin = $-5 + 0.95 \times 4 = -1.6$ V IEmin = 0.8 mA VCmin = $-5 + 0.95 \times 4 = -1.6$ V IEmin = 0.8 mA VCmin = $-5 + 0.85 \times 4 = -1.6$ V IEmin = $-5 + 0.85 \times 4 = -1.6$ V IE obtained for v GD $\ge -|Vtp|$, which includes v GD = 0. Specifically, I1 = I, Vx = -I1 R1, I2 = -Vx/R2 = I1 (R1/R2), thus iL vx vO (a) v x = -iI × 10 i = -v x/R = iI (10/R) 10 iL = iI + i = iI 1 + R Thus, 10 iL = 1 + iI R For iL = 11 \Rightarrow R = 1 k. Thus, ID 0.01 ID /ID SKID = = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10
Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 = 0.1 K/K 0.10 Substituting in the expression derived in (a), 0.1 Substit $\sqrt{11 + 20.1 \times 0.1 \text{RS}} \Rightarrow \text{RS} = 45 \text{ k}$ To find VGS, ID = K(VGS - Vt) 2 100 = 100(VGS - 1) 2 VGS = 2 V VGS + ID RS = VS 2 + 0.1 × 45 = 6.5 V (c) For VSS = 5 V and VGS = 2 V, ID RS = 3 V 3 = 30 \text{ k} RS = 0.1 1 1 = SKID = $\sqrt{71 + 20.1 \times 0.1 \times 301}$ K 1 ID = $\times = \times \pm 10\% = \pm 1.4\%$ ID 7 K 7 6.91 (a) With a fixed VGS, ID = 1 k n (VGS - Vt) 2 ∂ ID = 1 k n (VGS - Vt) $-k n (VGS - Vt) \partial Vt Q.E.D Vt = \pm 5\%$, and Vt VOV = 0.25 V, we have ID Vt = 0.5 V, Thus, $\partial ID Vt = 0.5 V$, Thus, $\partial ID Vt = -\partial Vt ID ID 2 \times 0.5 \times \pm 5\% 0.25 = \mp 20\% = -$ (b) For fixed bias at the gate VG and a resistance RS in the source lead, we have VG = VGS + ID RS where $II = -\partial Vt ID ID 2 \times 0.5 \times \pm 5\% 0.25 = \mp 20\% = -(b)$ For fixed bias at the gate VG and a resistance RS in the source lead, we have VG = VGS + ID RS where $II = -\partial Vt ID ID 2 \times 0.5 \times \pm 5\% 0.25 = \mp 20\% = -(b)$ For fixed bias at the gate VG and a resistance RS in the source lead, we have VG = VGS + ID RS where $II = -\partial Vt ID ID 2 \times 0.5 \times \pm 5\% 0.25 = \mp 20\% = -(b)$ For fixed bias at the gate VG and a resistance RS in the source lead, we have VG = VGS + ID RS where $II = -\partial Vt ID ID 2 \times 0.5 \times \pm 5\% 0.25 = \mp 20\% = -(b)$ For fixed bias at the gate VG and a resistance RS in the source lead, we have VG = VGS + ID RS where $II = -\partial Vt ID ID 2 \times 0.5 \times \pm 5\% 0.25 = \mp 20\% = -(b)$ For fixed bias at the gate VG and a resistance RS in the source lead, we have VG = VGS + ID RS where $II = -\partial Vt ID ID 2 \times 0.5 \times \pm 5\% 0.25 = \mp 20\% = -(b)$ For fixed bias at the gate VG and a resistance RS in the source lead, we have VG = VGS + ID RS where $II = -\partial Vt ID ID 2 \times 0.5 \times \pm 5\% 0.25 = \mp 20\% = -(b)$ For fixed bias at the gate VG and a resistance RS in the source lead, we have VG = VGS + ID RS where II = -(b) + (b) +VGS is obtained from 1 ID = k n (VGS - Vt) 2 2 ID \Rightarrow VGS = Vt + kn Thus Vt + 2ID + ID RS = VG kn Differentiating relative to Vt, we have 1 2 ∂ ID ∂ ID 1+ $\sqrt{+}$ RS = 0 ∂ Vt 2 2ID /k n k n ∂ Vt 1 ∂ ID + RS = -1 $\sqrt{-}$ ∂ Vt 2k n ID 1 ∂ ID + RS = -1 $\sqrt{-}$ $\sqrt{-}$ ∂ Vt 2k n ID 1 ∂ ID + RS = -1 $\sqrt{-}$ $\sqrt{-}$ Q.E.D VOV + 2ID RS Vt For Vt = 0.5 V, = $\pm 5\%$, and Vt ID VOV = 0.25 V, to limit to +5% we ID require SVIDt = - SVIDt = $1 \text{ Chapter } 6-33 1 \times 0.5(10 - 10 \text{ ID} - 1)2 2 \Rightarrow \text{ID } 2 = 3.75 \text{ k} 0.1$ The first root results in VD = 0.375 V - 1 = - ID = 1.11 mA or 0.73 mA For ID = 0.1 mA, 0.375 RS = 3.75 k 0.1 The first root results in VD = 0.25 V, to limit to +5% we ID require SVIDt = - SVIDt = $1 \text{ Chapter } 6-33 1 \times 0.5(10 - 10 \text{ ID} - 1)2 2 \Rightarrow \text{ID } 2 = 3.75 \text{ k} 0.1$ The first root results in VD = 0.25 V, to limit to +5% we ID require SVIDt = $- \text{ SVIDt} = 1 \text{ Chapter } 6-33 1 \times 0.5(10 - 10 \text{ ID} - 1)2 2 \Rightarrow \text{ID } 2 = 3.75 \text{ k} 0.1$ The first root results in VD = 0.25 V, to limit to +5% we ID require SVIDt = - ID = 1.11 mA or 0.73 mA For ID = 0.1 mA, 0.375 RS = 3.75 k 0.1 The first root results in VD = 0.25 V. -0.11 V, which is physically meaningless. 2.85 Vo = -sCR = -10-3 s Vi 2.86 R2 C = 10 nF = $10-3 \text{ s} = 100 \text{ k} 10-8 \text{ F} \omega$ Vo = -j 3 Vi 10 R1 C Vi Vo = $\omega \text{ V} 103 \text{ i} \varphi = 180^{\circ} + 90^{\circ}$ (an inversion + a phase lead of 90°) Vo Z2 = $- = -\text{Vi } Z1 \text{ R2 } R1 + 1 \text{ sC Vo Chapter } 2-29 \text{ Vo } R2 /R1 (j\omega) = -\text{Vi } [1 + (\omega 1 / j\omega)][1 + j(\omega / \omega 2)]$ Thus, (R2 /R1)s Vo = -1 Vi s+ CR1 where which is that of an STC high-pass type. VCC VBIAS Q3 Q4 vod Q2 Q1 vid VCM 2 vod /2 vid VCM 2 vid 2 A RC RC vod / 2 Q1 vid 2
A RC RC vod / 2 Q1 vid 2 A RC RC vod / 2 Q1 vid 2 A RC RC vod vO 1.5 V VO I IL R IL ID Vo ID RL IL varies from 2 to 7 mA To supply a load current of 2 to 7 mA, the current I must be greater than 7 mA. Thus, v icm i1 = R i2 = v icm R3 + R4 Thus, ii = v icm R3 + R4 and vI/2R vI/2 I vI vI 2 Ricm = (R1 + R2) (R3 + R4) (+ R4) vO vI/2R R 2.61 From Eq. (2.19), vO R4 R2 R3 = 1 - Acm = v Icm R4 + R3 R1 R4 R The second factor in this expression is the one that in effect determined: IC3 13.4 × 0.47 = × 0.47 = +6.36 V α 0.99 = VE3 + 0.7 = +7.06 V VE3 = VC2 IC = $0.98 \times 1.177 = 1.15$ mA Thus the current is reduced by Ex: 4.315 V IC = 1.28 - 1.15 = 0.13 mA which is a -10% change. Then, the maximum allowable value of VBIAS = 4.7 - 0.7 = +4 V. (d) pp \approx NA = 5×1016 cm-3; np = or n2i nn Or, alternatively, it can be shown as vn µn E 1350 µn = = vp µp E µp $480 = 2.8125 = 4.5 \times 103$ cm $-3\rho = 0.31$ - cm; R = 10.42 k (e) Since ρ is given to be 2.8 $\times 10-6$ - cm, we directly calculate R = 9.33 $\times 10-2$. 8.41 See figure on next page. P7.74(d). K G02 2 f 1 + f1 The gain will drop by 3 dB when which at f = 5 MHz becomes K 2 K 1 + 8 |G5MHz| = Chapter 2-37 | For overall gain of 100: 100 = | | | | | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | 2 | K | $1 + 8 2.112 i 100 k\Omega 1 k\Omega v I \Rightarrow K = 5.7 1 iO$ $3 v I \Rightarrow K = 5.7 1 iO$ 3 v O Thus for each cascade stage: f3dB = iL 40 5.7 RL f3dB = 7 MHz The 3-dB frequency of the overall amplifier, f1, can be calculated as $[1 | 1 | 1] 3 | 3 [5.7 | = (5.7) \Rightarrow f1 = 3.6 MHz \sqrt{2} 2] f 1 + 7 (a) RL = 1 k for v Omax = 10 V$. Vp = Vp = 0.1 V When the output is at its peak, 10 = 10 mA iL = 1 k for v Omax = 10 V. Vp = Vp = 0.1 V When the output is at its peak, 10 = 10 mA iL = 1 k i = 2.110 (a) R2 = K, f3dB = R1 ft R2 1 + R1 = ft 1 + K GBP = Gain × f3dB GBP = K (b) 1 + ft K = ft 1 + K K + 1 R2 = K, R1 GBP = K f3dB = ft K ft = ft K 10 100 - 10 = -0.1 mA; therefore 100 k iO = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC IB = VCC - 0.7 RB forced = IC IB Thus, β forced = VCC - 0.2 VCC - 0.2 RC IB = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 20 mA. IC = VCC - 0.2 RC = 10 + 0.1 = 10.1 mA is well under iOmax = 10 + 0.1 = 10.1 mA is well under iOmax = 10 + 0.1 = 10.1 mA is well under iOmax = 10 + 0.1 = 10.1 mA is well under iOmax = 10 + 0.1 = 10.1 mA is well under iOmax = 10 + 0.1 = 10.1 mA is well under iOmax = 10 + 0.1 = 10.1 mA is well under iOmax = 10 + 0.1 = 10.1 mA is well under iOmax = 10 + 0.(1) Pdissipated = VCC (IC + IB) 4.44 Refer to the circuit in Fig. Thus vOmax = 1.8 - 0.2 = +1.6 V IC 0.1 mA = = 4 mA/V VT 0.025 V ro = For the NMOS transistor, Rin = $r_{II} = 2ID 4 = 0.25 \Rightarrow ID = 0.5$ mA 2ID 2 × 0.1 = 1 mA/V = VOV 0.2 From Table K.1 (Appendix K), for the 0.18-µm process we have |VA| = 5 V/µm, µn Cox = 387 µA/V VA 100 V = IC IC A0 = gm ro = 2ID gm = VOV 7.30 gm = W = 4.21 L \Rightarrow W = 4.21 L \Rightarrow W = 4.21 L \Rightarrow W = 4.21 µm \Rightarrow 7.32 For the BJT cell: IC IC = gm = VT 0.025 V 7.29 For the npn transistor, gm = 1 W \times 100 V = VT 0.025 V 7.29 For the npn transistor, gm = 1 W \times 100 V = VT 0.025 V 7.29 For the npn transistor, gm = 1 W \times 100 V = VT 0.025 V β 100 = gm gm For the BJT cell: IC IC = gm = VT 0.025 V β 100 = gm gm For the BJT cell: W ID = 2 \times 0.2 \times 40 \times 1D gm = 2µn Cox L = 0.3 µm, VA 100 V = VT 0.025 V β 100 = gm gm For the BJT cell: W ID = 2 \times 0.2 \times 40 \times 1D gm = 2µn Cox L = 0.3 µm, VA 100 V = VT 0.025 V β 100 = gm gm For the BJT cell: IC IC = gm = VT 0.025 V β 100 = gm gm For the BJT cell: IC IC = 16ID = 4 ID mA/V (ID in mA) ro = VA 10 V = ID ID 40 A0 = gm ro = $\sqrt{V/V}$ (ID in mA) ID Rin = ∞ Chapter 7-12 BJT Cell Bias current MOSFET Cell IC = 0.1 IC = 1 ID = 0.1 I 100 10 A0 = $0.253 \times 18 = 4.55$ V/V A0 (V/V) 4000 4000 126 40 Rin (k) 25 $2.5 \propto \infty$ (c) If the device is redesigned with a new value of W so that it operates at ro = VOV = 0.25 V for ID = $100 \mu A$, 7.33 Using Eq. (7.46), VA 2(μ Cox) (WL) A0 = ID $\checkmark 52 \times 0.4 \times 8 \times 0.54 \times 0.5$ 0.15 1 W 2 VOV ID = k n 2 L A0 = 100 = 1 W × 400 × × 0.152 2 L W = 22.2 L Thus, \Rightarrow W = 22.2 × 0.5 = 11.1 µm gm = 2ID 2 × 0.1 = = 1.33 mA/V VOV 0.15 ro = VA L 5 × 0.36 = = 18 k ID 0.1 A0 = gm ro = 0.8 × 18 = 14.4 V/V (d) If the redesigned device in (c) is operated $\sqrt{10}$ at 10 μ A, VOV decreases by a factor of 10 to 0.08 \sqrt{V} , gm decreases by a factor of 10 to 0.253 mA/V, ro increases by a factor of $\sqrt{10}$. 5.22 (a) Refer to Fig. The transistor VBE can be found from 0.2 mA VBE = 0.8 + 0.025 ln 1 mA or equivalently. = 0.76 V 4.34 Since the BJT is operating at a constant emitter current, its |VBE | decreases by 2 mV for every \circ C rise in temperature. During the positive half of the sinusoid, the diode is forward biased, so it conducts resulting in v D = $0.1C \text{ gm} = 40 \text{ mA/V VT} \beta \text{ rm} = 2.5 \text{ k gm}$ (c) Rin1 = R1 R2 rm = RB rm = 32 2.5 = 2.32 k v b1 Rin 2.32 = 0.32 V/V= v sig Rin + Rsig 2.32 + 5 (b) IC = $\alpha IE 0.5 mA VC = 0.5 = 3 - 0.5RC$ (d) Rin2 = R1 R2 rn = Rin1 = 2.32 k v b2 v b2 = -qm (RC Rin2) v b1 v n1 = RC = 5 k IC 0.5 mA (c) qm = 20 mA/V = VT 0.025 V = -40(6.8 2.32) = -69.2 V/V This figure belongs to Problem 6.118. P7.91 we see that Each of Q1 and Q2 is operating at an IC approximately equal to 200 µA. Ro (b) As I is increased, gm increases and hence the current-driving capability of the amplifier, and as we will see later, its bandwidth. Despite all of our combined efforts, however, there is little doubt that some
errors remain, and for these I take full responsibility. 1.80 Cross-sectional area of Si bar 1.82 pn0 = 2 n2i (1.5 × 1010) = = 2.25×104 /cm3 ND 1016 From Fig. P4.30, we assume active-mode operation and verify that this is the case at the end of the solution. = I (W/L)A 2 (W/L)A The input offset voltage is VOS = 8.86 VDD IO Gm where Gm = gm1, 2 = 2(I/2) I = VOV VOV Thus, Q3 Q4 IO Q1 Q2 I VSS VOS = (VOV /2) (W/L)A (W/L)A (b) ID1 = ID2 = I 2 Q.E.D. ID3 = ID1 If the (W/L) ratios of the mirror transistors have a mismatch (WL)M, the current transfer ratio of the mirror will have an error of [(W/L)M/(W/L)M]. Thus we can write ID2 = IS eVD2 /VT 3.27 For a diode conducting a constant current, the diode voltage decreases by approximately 2 mV per increase of 1 ° C. (b) For VB = 0 V, 3 - (VB - 0.4) VB - 0.7 = $1 1 VE = 0 - VBE = -0.7 V \Rightarrow VB = 2.05 VIE = 3 VIC$ Assuming operation in the active mode, we have 1 k IB VB 0.5 VCEsat 0.2 V VB IE $-0.7 - (-3) = 2.3 \text{ mA VC} = +3 - IC \times 1 = 3 - 2.3 = +0.7 V$ Since VC > VB - 0.4, the BJT is operating in the active mode, as assumed. Ro = Ron Rop = 1 (gm ro)(ro rm) 2 Av $o = -gm1 Ro gm1 = gm2 = Av = -gm Ro 1 mA/V 1 = -(gm ro)gm (ro r\pi) 2 1 gm ro r\pi = -(gm ro) 2 r\pi + ro 1 1 = -(gm ro) 1 1 2 + gm ro gm r\pi |VA| Substituting gm ro = and gm r\pi = \beta, VT 1 |VA|/VT Av = -2 (VT/|VA|) + (1/\beta) ro 1 = ro 2 = 2ID 2I 2 × 0.1 = = |VOV| |VOV| 0.2 |VA| 5 |VA| = = 50 k = ID I 0.1 Rin = ∞ Ro = gm2 ro 2 ro 1 = 1 × 10 ro 1 = -(gm ro) 2 rm + ro 1 1 = -(gm ro) 1 1 2 + gm ro gm r\pi |VA| Substituting gm ro = and gm r\pi = -(gm ro) 2 rm + ro 1 1 = -(gm ro) 2 rm + ro 1 1 = -(gm ro) 2 rm + ro 1 1 = -(gm ro) 1 1 2 + gm ro gm r\pi |VA| Substituting gm ro = and gm r\pi = -(gm ro) 2 rm + ro 1 1 = -(gm ro) 2 rm + ro 1 = -(gm ro) 2 rm + ro 1 1 = -(gm ro) 2 rm + ro 1 = -(gm ro)$ $50 \times 50 = 2.5$ M Av o = -gm1 Ro $= -1 \times 2.5 \times 183 = -2500$ V/V (d) Refer to the circuit in Fig. Neglecting the base currents, we see that all three transistors are operating at IC = 10 μ A, and thus 1 mA VBE1 = VBE2 = VBE3 = 0.7 - 0.025 ln 10 μ A that we have set vi = 0 and applied a test voltage vx . 100 $\times 103 = fT$ fB = $\beta 0.9.24$ Cin = Cgs + Cgd $(1 + \text{gm R L}) = 1 + 0.1(1 + 39) = 5 \text{ pF fsdB} = 1 2\pi \text{Cin Rsig } 1 2\pi \times 5 \times 10 - 12 \text{ Rsig } \text{For fsdB} > 1 \text{ MHz}, \text{Rsig } (a) \text{ R1} = \text{ro } = ro \text{ gm ro } \text{ro } \text{R3} = 7.66$ (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R2 + ro gm ro R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R3 = 7.66 (b) i1 = gm vi vo I 0.2 mA VG2 R3 = 7.66 (c) i1 = gm vi vo I 0.2 mA VG2 R3 = 7.66 (c) i1 = gm vi vo I 0.2 mA VG2 R3 = 7.66 (c) i1 = gm vi vo I 0.2 mA VG2 R3 = 7.66 (c) i1 = gm vi vo I 0.2 mA VG2 R3 = 7.66 (c) $i1 = \text{gm vi } vo \text{$ 2 ro1 vi Q1 5.4/0.361 gm vi 2 i6 = 0 (because vsg4 = 0) i7 = i5 = 1 \text{ gm vi } 2 \text{ Chapter } 7-251 (c) v1 = -i2 ro = -(gm ro) vi 21 v2 = -i4 R2 = -gm (gm ro) vi 21 v2 = -i4 ra = -i4 ra0.121 W 22 For a 5% reduction, $R = 0.95 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 10\%}$ reduction, $R = 0.90 \Rightarrow R = 90 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ reduction, $R = 0.50 \Rightarrow R = 10 \text{ k} R + 10 \text{ For a 50\%}$ Since Q2 is to operate at the edge of saturation, VDS2 = VOV Thus, VOV = VGS - Vt VD2 = 0.25 V = 1.3 - 0.4 = 0.9 and To operate at the edge of saturation, we must have R2 = = VDD - VD2 ID2 1.8 - 0.25 = 3.1 k 0.5 VD = 1.3 - 0.4 = 0.9 and To operate at the edge of saturation, RD = 1.3 - 0.4 = 0.9 and To operate at the edge of saturation, RD = 1.3 - 0.9 = 4 k 0.1 Chapter 5-12 5.45 VDD 1.8 V VD ID 5.47 Refer to the circuit in Fig. Thus To find the average diode current, note that the charge supplied to C during conduction is equal to the charge lost during discharge. All transistors have the same channel length and are carrying a dc current I /2. P7.12 by substituting m = 1, replacing VO with the voltage across Q3, namely (3 - VO), replacing VBE with VEB, and VA2 with |VA|: IO = IREF 1 + [(3 - VO - VEB)/|VA|] 1 + (2/ β) (1) Now, substituting IO = 1 mA, VO = 1 V, β = 50, |VA| = 50 V, and -3 IO 10 = 0.691 V VEB = VT ln = 0.025 ln IS 10-15 results in 1 × (1 + 0.04) = 1.013 mA 3 - 1 - 0.691 I + 50 3 - 0.691 V VEB = VT ln = 0.025 ln IS 10-15 results in 1 × (1 + 0.04) = 1.013 mA 3 - 1 - 0.691 I + 50 3 - 0.691 V VEB = VT ln = 0.025 ln IS 10-15 results in 1 × (1 + 0.04) = 1.013 mA 3 - 1 - 0.691 I + 50 3 - 0.691 V CC - VEB = 2.28 k = R = IREF 1.013 IREF = Maximum allowed voltage VO = 3 - 0.3 = 2.7 V. Note that lowering the resistances of the voltage divider considerably decreases the dependence on the value of β , a highly desirable result obtained at the expense of increased current and hence power dissipation. Since β is very high, IC IE VC = $+3 - IC \times 1 = 3 - 1.3 = +1.7$ V Since VC > VB - 0.4, the transistor is operating in the
active mode as assumed. 104 fb = 10 $kHz \Rightarrow fb = 1$ Hz The unity-gain frequency ft will be two decades higher than 10 kHz, that is, vo ft = 100 × 10 kHz = 1 MHz 0 At a frequency f fb, tr | A| = ft /f tr = For f = 1 kHz, |A| = 1 MHz = 103 V/V or 60 dB 1 kHz Ex: 2.28 20 log A0 = 106 dB $\Rightarrow A0 = 106 dB \Rightarrow A0 = 106 dB$ 200,000 V/V ft = 2 MHz For a noninverting amplifier with a nominal dc gain of 100, R2 1+ = 100 R1 0.9 × 1.6 - 0.1 × 1.6 1 V/µs \Rightarrow tr = 1.28 µs Ex: 2.30 From Eq. (2.59) we have: fM = SR = 15.915 kHz 15.9 kHz 2 π VO max Using Eq. (2.60), for an input sinusoid with frequency f = 5 fM, the maximum possible amplitude that can be accommodated at the output without incurring SR distortion is: $fM 1 VO = VO max = 10 \times = 2 V$ (peak) 5fM 5 t Chapter 2-1 2.1 The minimum number of pins required by dual op amp is 8. Thus VCE = $VC - IC RC = 3 - 2.25 = 0.75 VV^{\circ} = VCE - 0.3 = 0.75 - 0.3$ = 0.45 V Av = -3 - 0.3 = -90 V/V 0.025 + 0.005 Check: Av = -gm RC = -IC RC 2.25 = -90 V/V = -VT 0.025 V^o $o = |\text{Av}| \times \text{V}^{\circ}$ be = $90 \times 5 = 450$ mV = 0.45 V 6.38 Transistor $\alpha = 1 - 0.4$ sin ωt , V a b 1.000 0.990 c d 0.980 1 50 ∞ e ∞ 100 IC (mA) 1.00 IB (mA) 0 0.010 0.020 0 gm (mA/V) 40 39.6 40 40 25 24.5 25 100 re () 25 10 $r\pi$ () ∞ 100 g 9 15.9 1.00 1.00 0.248 4.5 17.5 1.02 1.00 0.25 5 18.6 0.002 0.5 1.10 9.92 180 700 5 1.34 50 22.7 2.525 k 1.25 k ∞ 10.1 k 6.39 IC = 1 mA, f 0.990 0.900 0.940 β = 100, gm = IC 1 mA = 40 mA/V = VT 0.025 V rn = β 100 = 2.5 k gm 40 mA/V ro = VA 100 V = 100 k IC 1 mA where we have assumed VCEsat = 0.3 V. For I = 200 μ A, the bias current of the half-circuit is 100 μ A and, 25 mV = 250 re = 0.1 mA 10 RC = - Gain of half-circuit = - re 0.25 = -40 V/V At each collector we expect a signal of 40 × 5 mV = 200 mV. 1 v² = - × 202 × 5 = -1 V 2 Thus, v2 is a 1-V peak sine wave, 180° out of phase relative to vi . See figure on next page. Corresponding output power = (10/2)2 /500 = 0.1 W 1.42 Rs vs vi Ri Av ovi vo = 1 V × RL ×1×100 1vi vo 1 M 1 M + 200 k 100 100 + 20 100 1 × = 0.69 V/V or -3.2 dB Voltage gain = vs = Current gain = ro vi v 20 /500 = A2v × 104 = 1.39 × 107 W/W v 2i /1 M or 10 log (1.39 × 107) = 71.4 dB. Thus, the output voltage can range from -0.5 V to +0.5 V. Vp VpVD t Vp PIV (c) When the diode is cut off, the maximum reverse voltage across it will occur when v S = -Vp. Therefore, 10 µm W = \Rightarrow W = 50 µm 3 µm 5 µm 1 µm So the dimensions of the matched transistors Q1 and Q2 should be changed to W = $50 \mu m 5 \mu m 1 \mu m So$ the dimensions of the matched transistor is made 3 times larger than that of the NMOS transistor. 1), we can write R1 0.5 VD = VD = 0.5VD VGS = R1 + R2 0.5 + 0.5 Thus VD = 2VGS = 1.6 V 1 2 ID = k n VOV 2 1 = $\times 5 \times 0.22 = 0.1$ mA 2 VD 1.6 V = = 1.6 µA Idivider = 1 M 1 M IRD = 0.1 + 0.0016 0.102 mA RD RD = vy VDD - VD 10 - 1.6 = 82.4 k IRD 0.102 2ID 2 × 0.1 = 1 mA/V = VOV 0.2 (c) Replacing the MOSFET with its T model results in the amplifier equivalent circuit shown in Fig. 2.64 (a) Refer to Fig. 7.32 Ro = gm3 ro3 ro4 For identical transistors, Ro = (gm ro)ro 7.57 50 = gm2 ro2 = AO2 = 2VA VOV Thus, $VA = 50 \times VOV / 2 = 25 \times 0.2 = 5V5 = 5 \times L \Rightarrow L = 1 \mu m 7.58$ Refer to Fig. ID1 = V/R We can write the following equation for the diode voltages: 3.24 V = VD2 - VD1 We can write the following diode equations: I ID2 = IS eVD2 /VT ID1 e(VD2 - VD1)/VT = eV/VT = ID1 V/R To achieve V = 50 mV, we need 10 mA - 0.05/R ID2 = e0.05/0.025 = 7.39 = ID1 0.05/R Solving the above equation, we have R = 42 A4 = 2A3 = 4A2 = 8 A1 With I1 = 0.1 + 0.2 + 0.4 + 0.8 = 1.5 mA 3.25 We can write a node equation at the anodes: ID2 = I1 - I2 = 7 mA ID1 = I2 = 3 mA We can write the following equation for the diode voltages: V = VD2 - VD1 If D2 has saturation current IS, then D1, which is 10 times larger, has saturation current IS, then D1, which is 10 times larger, has saturation current IS as follows: IE = 5 - VE = 5 $= IB + IC (1) \text{ where results in } IE3 = 5 - (V + 0.2) = 0.48 - 0.1V 10 (2) \Rightarrow VE = +2.27 \text{ V IC4} = 5 - (V - 0.5) = 0.183 - 0.033V 30 (3) \text{ VC} = +2.07 \text{ V IB3} = 5 - (V - 0.5) = 0.1V - 0.05 10 (4) 5 - VE = VE - 0.2 + 0.1 \text{ V E} + 0.43 \text{ VB} = 1.57 \text{ V I} = 2.07 \text{ IC} = 2.07 \text{ mA} 1 \text{ IE4} = 1.57 - (-5) \text{ IB} = 0.657 \text{ mA} 10 \text{ βforced} = V = 0.05V 20 (5) \text{ V} - 0.7 = 0.1V - 0.05 10 (4) 5 - VE = VE - 0.2 + 0.1 \text{ V E} + 0.43 \text{ VB} = 1.57 \text{ V I} = 2.07 \text{ IC} = 2.07 \text{ mA} 1 \text{ IE4} = 1.57 - (-5) \text{ IB} = 0.657 \text{ mA} 10 \text{ βforced} = V = 0.05V 20 (5) \text{ V} - 0.7 = 0.1V - 0.05 10 (4) 5 - VE = VE - 0.2 + 0.1 \text{ VE} + 0.43 \text{ VB} = 1.57 \text{ V I} = 2.07 \text{ IC} = 2.07 \text{ mA} 1 \text{ IE4} = 1.57 - (-5) \text{ IB} = 0.657 \text{ mA} 10 \text{ βforced} = V = 0.05V 20 (5) \text{ V} - 0.7 = 0.1V - 0.05 10 (4) 5 - VE = VE - 0.2 + 0.1 \text{ VE} + 0.43 \text{ VB} = 1.57 \text{ V I} = 2.07 \text{ IC} = 2.07 \text{ mA} 1 \text{ IE4} = 1.57 - (-5) \text{ IB} = 0.657 \text{ mA} 10 \text{ βforced} = V = 0.05V 20 (5) \text{ V} - 0.7 = 0.1V - 0.05 10 (4) 5 - VE = VE - 0.2 + 0.1 \text{ VE} + 0.43 \text{ VB} = 1.57 \text{ V I} = 2.07 \text{ IC} = 2.07 \text{ mA} 1 \text{ IE4} = 1.57 - (-5) \text{ IB} = 0.657 \text{ mA} 10 \text{ βforced} = V = 0.05V 20 (5) \text{ V} - 0.7 = 0.1V - 0.05V 20 (5) \text{ V} = 0.05V 2$ $0.07\ 10\ (6)$ Substituting from Eqs. That is, v GS ranges from $1.5 - 0.11 = 1.39\ V$, at which W = $8.33\ L\ iD = 6.6\ 1 \times 1 \times (1.39 - 1)2 = 0.076\ mA\ 2$ and VDD v DS = $5 - 0.076\ \times 24 = 3.175\ V$ and v GS = $1.5 + 0.11 = 1.61\ V$ at which v DS = $0.61\ V$. Thus ro2 = ro4 = $100\ k = |VA| = I\ 2\ |VA| = I\ 2\$ Omin = VCM - Vtn = 0 - 0.5 = -0.5 V v Omax = VDD - |VOV| = 1 - 0.2 = 0.8 V Thus, -0.5 V ≤ v O ≤ 0.8 V |VA| 10 = = 50 k I 0.2 The CMRR can be obtained using Eq. (8.159): (d) RSS = CMRR = (gm ro)(gm RSS) = (1 × 100)(1 × 50) = 5000 or 74 dB Ad = Gm Ro = 1.13 × 75 = 85 V/V 8.96 The CMRR is given by Eq. (8.158): 8.95 (a) For Q1 and Q2, 1 W I = $\mu n \cos V2 2 2 L 1, 2 OV$ W 1 0.1 = × 0.4 × × 0.04 2 L 1,2 W W = = 12.5 ⇒ L 1 L 2 For Q3 and Q4, 1 W I | VOV | 2 = $\mu n \cos 2 2 L 3, 4$ 1 W 0.1 = × 0.1 × × 0.04 2 L 3,4 W W = = 50 ⇒ L 3 L 4 (b) Gm = gm1, 2 1 mA/V Ad = Gm Ro 50 = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro2 ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro4)] [2 gm3 RSS] = 1 × Ro ⇒ Ro = 50 k 2 (I/2) I 0.2 = = = VOV VOV 0.2 CMRR = [gm1, 2 (ro4)] [2 gm3 RS (a) Current source is implemented with a simple current mirror: |VA | RSS = ro | QS = I 2(I /2) I = gm3 = VOV VOV ro2 = ro4 = 2|VA | |VA | I × 2× × × × VOV 2 I VOV I 2 VA = 2 Q.E.D. VOV CMRR = (b) Current source is implemented with the modified Wilson mirror in Fig. (a) At midband, CE and CC act as short circuits. Use iteration: Diode has 0.7 V drop at 1 mA current. See figure at top of next page. Now we consider two cases: with and without RF. where gm7 = 2I 2 × 0.12 = VOV 0.35 = 0.7 mA/V 60 |VA | = = 500 k ro7 = ro5 = I 0.12 REE = $0.7 \times 5002 = 175 \text{ M}$ Acm = $-1 = 5.7 \times 10-5 \text{ V/V}$ 100 × 175 1200 | Ad | = 21 × 106 = CMRR = | Acm | 5.7 × 10-5 \text{ V/V} Acm = $-1 = 5.7 \times 10-5 \text{ V/V}$ 100 × 175 1200 | Ad | = 21 × 106 = CMRR = | Acm | 5.7 × 10-5 \text{ V/V} 100 × 175 1200 | Ad | = 21 × 106 = CMRR = | Acm | 5.7 × 10-5 \text{ V/V} 100 × 175 1200 | Ad | = 21 × 106 = CMRR = | Acm | 5.7 × 10-5 \text{ V/V} 100 × 175 1200 | Ad | = 21 × 106 = CMRR = | Acm | 5.7 × 10-5 \text{ V/V} 100 × 175 1200 | Ad | = 21 × 106 = CMRR = | Acm | 5.7 × 10-5 \text{ V/V}

10-5 or 146 dB 8.104 Refer to Fig. P5.52(e) with the Chapter 5-15 1-mA current source replaced with a 2.2-k resistor. We can write a loop equation for the loop containing the 1-k resistor. He EBJ of Q2 and the 1-k resistor. We can write a loop equation for the loop containing the 10-k resistor. He EBJ of Q2 and the 1-k resistor. He EBJ of Q2 and the 1-k resistor. Q1 will be saturated. 7.27. Since, for a fixed diode current, the diode current, the diode current, the diode current at a constant rate (-2 mV per \circ C temp. Thus V4 = VGSN = 1.232 V I3 = 3 1 × 270 × × 0.7322 = 217 μ A 2 1 (c) Refer to Fig. P5.53(b). Obviously ID and |VOV | will be the same as in (i) above. For Q1, ID = $0.5 = \Rightarrow 1$ W1 2 µn Cox V 2 L1 OV 1 W1 = $16 \times 0.25 = 4$ µm For Q2, we have 1 W2 2 ID = µn Cox VOV 2 2 L2 \Rightarrow W2 = $50 \times 0.5 = 25$ µm For Q3, ID = 1 W3 µn Cox (VGS3 - Vt) 2 2 L3 $\Rightarrow 0 \times (2.5 - 1.5 - 0.5)$ 2 L3 \Rightarrow W3 = 8 L3 $W3 = 8 \times 0.5 = 4 \ \mu m \ W1 \ 1 \times 0.25 \times (1 - 0.5) 2 \ L1 \ W1 = 16 \ L1 \ 0.5 = For \ Q2$, $W2 \ 1 \times 0.25 \times (1.8 - 1 - 0.5) 2 \ L2 \ W2 = 44.4 \ L2 \ 5.48 \ Refer$ to the circuits in Fig. P8.2. To determine VOV, $1 \times 4 \times |VOV| \ 2 \ 2 \Rightarrow |VOV| = 0.354 \ V \ 0.25 = With \ v \ G2 = 0$ and $v \ G1 = v \ id$, to steer the current from one side of the differential pair to the other, v id must be the ends of the range $\sqrt{\sqrt{-2}}$ |VOV| \leq v id \leq 2 |VOV| that is, -0.5 V \leq v id \leq +0.5 V For iD1 = 0.09 mA and iD2 = 0.07 mA, 1 W (v GS2 - 0.4)2 2 \Rightarrow v GS2 = 0.587 V and v S = -0.587 V 1 W iD1 = µn Cox (v GS1 - 0.4)2 2 \Rightarrow v GS1 = 0.612 V v id = v S + v GS1 = 0.612 GS1 = -0.587 + 0.612 At v id = -0.5 V, Q2 just cuts off, thus v S = |Vtp| = 0.8 V and v SG1 = 0.8 - (-0.5) = 1.3 V At this value of v SG1 , $1 \times 4 \times (1.3 - 0.8)2$ 2 = 0.5 mA iD1 = which is the entire bias current. Since this split of the current I is the complement of that in case (b) above, the value of v SG1 , $1 \times 4 \times (1.3 - 0.8)2$ 2 = 0.5 mA iD1 = which is the entire bias current. = 1.8 V so v OV,1 = 1.8 - 0.5 = 1.3 V, and W/L = vGS 1.5 V vGS 1.0 V $(v OV v DS) - 1/2 \partial v DS \partial v DS - 11 = k n VOV - v 2VDS 2 1 = k n (VOV - VDS) 1$ If VDS = 0.2VOV \Rightarrow rds = k n (VOV - 0.5VOV) 2 = 1/k n (0.2VOV) = k n VOV 1 If VDS = 0.2VOV \Rightarrow rds = k n (VOV - 0.5VOV) 2 = 1/k n (0.2VOV) = k n VOV 1 If VDS = 0.2VOV \Rightarrow rds = 0.5.6 rds = 1/2 dv DS $\partial v DS - 11 = k n VOV - 0.2VOV$ $VGS = 0.72 V VDS \ge 0.22 V (c) gDS = \therefore VOV = 0.47 V$. The gain is given by $1 = 4 = 1 |T| = \omega RC 10 \times 10 - 4$ Thus, $vO = -2 \sin(104 t - 90^{\circ})$ Figure 1 Chapter 2-25 (a) For an integrator without RF, the 0.1-mA current flows through C and the output voltage decreases linearly from 0 V as $vO(t) = -4 \tan(10 + 10)^{\circ}$. resistance of the first stage, Rin, is comparable to the source resistance Rs. (c) (d) 3 V IC 3 V 3.6 k IE V7 V 60.75 V 43 k 6.2 k V 8 IB IB IE /(b 1) 110 k V5 V9 4.7 k IE IC 3 V 10 k 3 V (c) (d) Writing an equation for the loop containing the BEJ of the transistor leads to IE = 3 - 0.7 = 0.449 mA 43 4.7 + 101 V 5 = -3 + 0.449 mA 43 4.7 = -0.9 V An equationfor the loop containing the EBJ of the transistor yields IE = 3 - 0.75 - 0.7 = 0.213 mA 110 6.2 + 101 V6 = $-0.9 \times 0.213 \times 6.2 = +1.7$ V IC = α IE = $0.99 \times 0.213 = 0.21$ mA V7 = $3 - 0.244 \times 3.6 = +1.4$ V V9 = $-3 + 0.21 \times 10 = -0.9$ V Chapter 4-21 This figure belongs to Problem 4.56, part (e). 6.45 C vn = rn Rin = ib rn vn = v sig v n v sig E v r x ix rn = $-gm RC vn + Rsig \beta RC rn + Rsig \beta RC rn + Rsig \beta RC rn + Rsig ix Since v x appears across re and ix = ie = small-signal resistance r is given by Q.E.D. r=$ vx, the re vxvx = re ix is 6.46 v ce = |Av|v be |Av| = gm RC = 50 × 2 = 100 V/V For v ce being 1 V peak to peak, 1V = 0.01 V peak, 1V = 0.01 V $10 - 0.3 = 1.5 \text{ k} 6.45 \text{ From the figure we see that IC3} \times 0.47 \alpha$ For the lowest β , VE3 = IC = β min IB IC3 $\times 0.47 + 0.7 (1) \alpha$ A node equation at the collector of Q2 yields = $50 \times 0.043 = 2.15 \text{ mA}$ and the corresponding VCE is VC2 = VE3 + $0.7 = 2.75 = IC3 \text{ VC2} + 2.7 \beta$ Substituting for VC2 from Eq. (1), we obtain 2.75 = Thus, VCE will range from 0.3 V to 6.8 V. Thus the second factor will have a maximum magnitude when R2 and R3 are at their highest values, that is, 2.59 For an ideal difference amp, we need: Rs + R1 Rs + R3 = R2 R4 Rs /R3 + 1 Rs /R1 + 1 = R2 /R1 R4 /R3 R2 = R3 = 10(1 - 0.01x) R1 = R4 (R - 0.01x) R1 = 10(1 + 0.01x) R2 v1 Rs R1 vO v2 Rs Q.E.D. Substituting in the expression for Acm, we have $(1 - 0.01x)2 10(1 + 0.01x) - Acm = 20 (1 + 0.01x) \times 0.04x$ R4 Acm 0.02x V/V Chapter 2-18 To obtain CMRR = 80 dB, Ad = 1 Ad 50 = CMRR = Acm x 50 or 20 log dB x x(%) 0.1 Acm (V/V) 1 5 0.002 0.02 0.1 CMRR (dB) 54 34 20 2.62 From Eq. (2.19), R4 R2 R3 Acm = 1 - R4 + R3 R1 R4 The second factor in this expression in effect determines Acm . 5.24 (page 338): VGS = 5 - 6ID ID = = 1 W k (VGS - Vt) 2 nL 1 × 1.5 × (5 - 6ID - 1.5) 2 which results in the following quadratic equation in ID : 36ID2 - 43.33ID + 12.25 = 0 W2 = 44.4 × 0.25 = 0 W 11.1 The physically meaningful root is 2.5 - 1.8 = 1.4 k R = 0.5 ID = 0.45 mA Chapter 5-13 This should be compared to the value of 0.5 mA found in Example 5.6. The difference of about 10% is relatively small, given the large variations in k n and Vt (50% increase in each). Using exponential model, we get iD2 = ev /VT = 0.9 to 1.1 iD1 iD2 and here $v = 25 \times 10-3 \ln iD1$ For 0.9, v = -2.63 mV For 1.1, v = 2.38 mV The variation is -2.63 mV to 2.38 mV for $\pm 10\%$ current variation. $R \Rightarrow IS = 3.46 \times 10-15 A$ IL (c) For m diodes connected in series we have VO ID = V + -0.7m R and rd = VO So now IL rd R VO 1 = -(R mrd) = -11 IL + R mrd = -11D ID + V + -0.7m mVT = -mV T ID Smallsignal model (a) From the small-signal model VO = -IL (rd R) VO = -(rd R)IL VT ID mV T + I - 0.7m WT + I - 0.7m WT + I - 0.7m VV = -V + -0.7m mVT + IDV - 0.7m + mVT Chapter 3-18 choose the 15-mA supply. P2.23. To ensure that the transistors remain in the active region, the maximum common-mode input voltage must be limited to (2 - 0.4) = +1.6 V. RL 200 vo = -IL (rd R) VO = -(rd R)IL VT ID mV T + 1 - 0.7m WT + -0.7m mVT + IDV - 0.7m + mVT Chapter 3-18 choose the 15-mA supply. P2.23. To ensure that the transistors remain in the active region, the maximum common-mode input voltage must be limited to (2 - 0.4) = +1.6 V. RL 200 vo = -IL (rd R) V $= 90.9 \text{ V} = \text{vi Rin } 2.2 \text{ vo} = 90.9 \times 0.98 = 89 \text{ V/V vsig } 7.54 \text{ Refer to Fig. Ex; } 6.4 \text{ 5 V Ex; } 6.2 \text{ Refer to Example } 6.1 \text{ and Fig. For our case, } Acm 2 = 0.5[1 - (1 \pm 0.04] = \pm 0.02 \text{ The common-mode gain of the first stage will remain approximately unity. } 1 \text{ mA} = 0.0099 \text{ mA } 101 \text{ Ip} = 1 - \text{In} = 0.9901 \text{ mA } 1.91 \text{ Eguation } (1.65); \text{ IS = Agn2i Dp Dn + Lp ND Ln NA}$ A = 100 μ m2 = 100 × 10-8 cm2 2 IS = 100 × 10-8 × 1.6 × 10-19 × 1.5 × 1010 1.89 Equation (1.55): 2 s 1 1 W = + (V0 + VR) q NA ND = 2 s q 1 1 + NA ND V0 1 + VR V0 VR 1 + V0 5 × 10-4 × 1016 + 18 10 × 10-4 × 1017 = 7.85 × 10-17 A I ~ = IS eV /VT ~ = 0.3 mA Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): A N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 ×
10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56): NA N D Qj = A 2 s q NA + ND 10 = 7.85 × 10-17 × 100 1.89 Equation (1.56) e750/25.9 = W0 = A 2 s q NA N D NA + ND = QJ 0 1 + (V0 + VR) VR V0 + VR V 0 + VR V1016 1 2 1017 + 1016 0.754 n2i (at 305 K) = $4.631 \times 1020 = 31.6$ fF ni = $7.3 \times 1015 \times (305)$ so $3/2 \times e - 1.12/(2 \times 8.62 \times 10) - 5 \times 305$ n2i (at 300 K) Thus IS approximately doubles for every $5 \circ$ C rise in temperature. The diode does not conduct, resulting in no current flowing in the circuit. 7.78 Refer to Eq. (7.95), (W/L)2 (W/L)1 = $1.12/(2 \times 8.62 \times 10) - 5 \times 305$ n2i (at 300 K) Thus IS approximately doubles for every $5 \circ$ C rise in temperature. $40/1 = 200 \ \mu\text{A} = 204/1$ 1 W ID1 = μn Cox V2 2 L 1 OV 1 Ro = β 3 ro3 /2 IO = IREF 1 4 2 20 = \times 160 × × VOV 1 2 1 = 0.25 V VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VOV 1 = 0.25 V VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VG2 = VGS1 = Vt + VOV 1 = 0.25 \text{ V} VG2 = VG2 = VG2 \text{ V} VG2 = VG2 = VG2 \text{ V} VG2 = VG2 = VG2 \text{ V} VG2 = VG2 = VC2 \text{ V} VG2 = VG2 VGS4 = VGS1 = $0.85 \vee VG3 = 0.85 + 0.85 = 1.7 \vee 7.79$ (a) IO1 = IO2 = 1 IREF 2 2 1 + 2 β Chapter 7-29 (b) 1.1 + 2.5 = 36 k 0.1 VOmax is limited by Q3 saturating. 4.23(a) with the base voltage raised from 4 V to VB. The saturation-triode boundary is determined by v GD = Vt, and v DS = VDD = 1 V, and since v GS = v GD + v DS, one has v GS = v GD + v DS. 0.4 + 1.0 = 1.4 V at the boundary. Thus, almost the entire output range of ± 10 V will be available for signal swing, allowing a sine-wave input of approximately 10-mV peak without the risk of output clipping. P6.53 on next page. Thus VDS = 0.2 + VOV VDD - VDS $1 \times 10^{-10} = -0.5$ VOV Av = $-2(VDD - VDS) \times 10^{-10} = -0.5$ VOV VDS $1 \times 10^{-10} = -0.5$ VOV VDD - VDS $1 \times 10^{-10} = -0.5$ VOV Av = $-2(VDD - VDS) \times 10^{-10} = -0.5$ VOV VDS -10 = -0.5 VOV VD $2(v^i / VOV) = VOV + v^i + 2VDD (v^i / VOV) \Rightarrow VDS = Since VOV + v^i + 2VDD (v^i / VOV) = 0.576 V 2ID VOV Av = -2.5 V, v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i + 2VDD (v^i / VOV) = 0.576 V 2ID VOV Av = -2.5 V, v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = VOV + v^i = 20 mV and m = 15 VOV = 0.27 V VDS = The value of ID can be found from gm = 0.27 V VDS = The value of ID can be found from gm = 0.27 V VDS = 0.27 V VDS$ × ID 0.27 = ID = 0.067 mA 0.5 = 2(VDD - VDS) 2(2.5 - 0.576) = - VOV 0.3 = -12.82 V/V v^{o} = |Av|v^{i} = 12.82 × 20 mV = 0.256 V The required value of k n can be found from 1 2 k n VOV 2 ID = 1 2 k n VOV 2 ID = 5 ince k n = 0.2 mV = 0.276 V The required value of k n can be found from 1 2 k n VOV 2 ID = 1 2 k n VOV 2 ID = 5 ince k n = 0.2 mV = 0.276 V The required value of k n can be found from 1 2 k n VOV 2 ID = 5 ince k n = 0.2 mV = 0.276 V The required value of k n can be found from 1 2 k n VOV 2 ID = 5 ince k n = 0.2 mV = 0.276 V The required value of k n can be found from 1 2 k n VOV 2 ID = 1 2 k n VOV 2 ID = 1 2 k n VOV 2 ID = 5 ince k n = 0.2 mV = 0.276 V The required value of k n can be found from 1 2 k n VOV 2 ID = 1 2 k n VOV 2 ID = 1 2 k n VOV 2 ID = 5 ince k n = 0.2 mV = 0.276 V The required value of k n can be found from 1 2 k n VOV 2 ID = 5 ince k n = 0.2 mV = 0.276 V The required value of k n can be found from 1 2 k n VOV 2 ID = 1 2 k n VOV 2 ID = 1 2 k n VOV 2 ID = 5 ince k n = 0.2 mV = 0.276 V The required value of k n can be found from 1 2 k n VOV 2 ID = 1 2 k n VOV 2 ID = 5 ince k n = 0.2 mV = 0.276 V The required value of k n can be found from 1 2 k n VOV 2 ID = 1 2 k n VOV 2 ID = 5 ince k n = 0.2 mV = 0.276 V The required value of k n can be found from 1 2 k n VOV 2 ID = 1 2 k n VOV 2 ID = 5 ince k n = 0.2 mV = 0.276 V The required value of k n can be found from 1 2 k n VOV 2 ID = 1 2 k n VOV 2 mA/V2, the W/L ratio must be $0.2 = W 1.83 \text{ kn} = = 9.14 \text{ L kn} 0.21 \text{ k n} \times 0.322 \Rightarrow \text{ k n} = 4.44 \text{ mA/V2}$ Finally, The required W/L ratio can now be found as VGS = Vt + VOV = 0.4 + 0.27 = 0.67 V kn 4.44 W = = 44.4 L kn 0.1 6.25 Av = -gm RD Upon substituting for gm from Eq. (6.42), we can write 2ID RD Av = -VOV = -2(VDD - VDS) VOV Q.E.D v GS max = VGS + v^i = Vt + VOV + v^i v DS min = VDS - | Av | v^i (1) 6.26 Given μ n = 500 cm2 /V·s, and Cox = 0.4 fF/ μ m2, k n = μ n Cox = 20 μ A/V2 k p = 10 μ A/V2 See table on next page. 8.108 If (W/L)7 becomes 48/0.8, ID7 will become ID7 = ID8 VO A0 (W/L)7 (W/L)8 This figure belongs to Problem 8.109. Now, for I2 $= 100 \ \mu A = 5IREF$, we have (W/L)2 = 5 (W/L)1 W = 5 × 10 = 50 L 2 W 2 = 50 × 0.5 = 25 \ \mu m Chapter 7-3 7.7 Referring to Fig. (d) VCM = $-0.1 \ V VS = -0.1 - VGS = -0.1$ $-2.5 + 0.25 \times 4 = -1.5$ V Since for each of Q1 and Q2, VSD = 1.15 - (-1.5) = 2.65 V which is greater than |VOV|, Q1 and Q2 are operating in saturation as implicitly assumed. $1 \le 10$ 2π CC2 (RD + RL) \Rightarrow CC2 $1 \ge = 0.8$ μ F $2\pi \times 10 \times (10 + 10) \times 103$ Select, CC2 = 0.8 μ F. I v C1 = (VCC + v r) - α RC 2 I = (VCC - α RC) + v r 2 I v C2 = (VCC + v r) $) - \alpha \text{ RC } 2 \text{ I} = (\text{VCC} - \alpha \text{ RC}) + v \text{ r} 2 \text{ v} \text{ od} \equiv v \text{ C2} - v \text{ C1} = 0$ Thus, while v C1 and v C2 will include a ripple component v r, the difference output voltage v od will be ripple free. Chapter 7-18 7.46 (a) IREF = IC3 = 3 - VBE3 46 \text{ k} 7.48 \text{ io} 3 - 0.7 46 = 0.05 \text{ mA} \text{ IREF} = \Rightarrow \text{IC2} = 5\text{IC3} \text{ RL} 20 \text{ k} \text{ IC2} = \text{I} = 0.25 \text{ mA} \Rightarrow \text{I Q1 vi vo 46 k Rin I Q3 Q2 Rin = r o + RL 20 + 20 = 980 = 1 + gm ro 1 + 2 × 20 Since is = io, (b) $|VA| = 50 V \Rightarrow ro1 = |VA| 30 = I 0.25 = 120 k 30 = 120 k ro2 = 0.25 Total resistance at the collector of Q1 is equal to ro1 ro2, thus rtot = 120 k 120 k = 60 k (c) gm 1 rm 1 = IC1 0.25 = = 10 mA/V VT 0.025 \beta 50 = = 5 k gm 10 Rs 20 io = = 0.95$ A/A isig Rs + Rin 20 + 0.98 If RL increases by a factor of 10, Rin becomes Rin = 20 + 200 = 5.37 k 1 + 2 × 20 and the current gain from 0.95 A/A to 0.79 A/A, a change of only -17%. The latter is equal to VT /IE, which is re To obtain the corresponding input signal, we divide this by (v o /v i): $v^s = 2.38 \text{ mV v} \circ /v$ i (2) Now for the given values of v o /v i calculate I and $v^s s$ in mV 0.5
0.1 0.001 0.0025 0.225 0.2475 2.4975 vo = 900 × 10-3 = 0.9 V/V vi vo = 990 × 10-3 = 0.99 V/V I = 990 μ A, vi I = 900 1000μ A, vo = $1000 \times 10-3 = 1 \text{ V/V}$ vi 3.48 4.76 23.8 238 2380 I D1 D3 3.47 vo 1 mA C 2 vo C1 D1 vi R D2 D2 10 k D4 vi I I When both D1 and D2 are conducting, the small-signal model is rd1 vi vo rd2 where we have replaced the large capacitors C1 and C2 by short circuits: rd 2 vo = vi rd 1 + rd 2 Thus vo = I, vi VT I 1 m - I = = VT VT 1m + I 1m - I where I is in mA Now I = 0 μ A, vo = 0 vi vo = 1 × 10-3 = 0.001 V/V vi vo = 10 × 10-3 = 0.01 V/V = 10 μ A, vi vo = 500 × 10-3 = 0.6 V/V = 500 μ A, vi vo = 500 × 10-3 = 0.6 V/V = 500 μ A, vi vo = 500 × 10-3 = 0.6 V/V = 500 μ A, vi vo = 500 × 10-3 = 0.5 V/V = 500 μ A, vi vo = 500 × 10-3 = 0.6 V/V = 500 μ A, vi vo = 5 frequency gain to 100, we should have: 1 M R R = = 10 k = 100 \Rightarrow R1 = R1 100 100 Ex: 2.20 Ex: 2.21 Refer to the model in Fig. Thus, from the point of view of reducing the change in VO as IL changes, we = 6.8 mV With RL = 1 k, Chapter 3-19 IL 1.5 V = 1.5 mA 1 IL = IL = 0.5 mA 5 - 1.4 5 - VO = = 18 mA R 0.2 ID = I - IL = 18 - IL = 18 - IL = 10 + IL = 10 $9.33 = 8.67 \text{ mA VO} = -0.5 \times 2 \times 3.4 \text{ Iteration } \#2: = -3.4 \text{ mV}$ $8.67 = 0.696 \text{ V VD} = 0.7 + 0.025 \ln 10 \text{ With } \text{RL} = 750$, IL VO $1.4 = 9.33 \text{ mA} = \text{RL } 0.15 1.5 = 2 \text{ mA } 0.75 \text{ VO} = 1.393 \text{ V IL} = 9.287 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{ID} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{IL} = 1 \text{ mA } \text{IL} = 1 \text{ mA } \text{IL} = -1 \text{ mA } \text{IL} = 1 \text{ mA } \text{I$ $8.753 = 0.697 \text{ VD} = 0.7 + 0.025 \ln 10 1.5 = 3 \text{ mA } 0.5 \text{ VO} = 1.393 \text{ VIL} = 2.0 \text{ mA } \text{IL} = 9.287 \text{ ID} = -2.0 \text{ mA } \text{IL} = 9.287 \text{ ID} = -2.0 \text{ mA } \text{IL} = 9.287 \text{ ID} = -2.0 \text{ mA } \text{IL} = 9.287 \text{ ID} = -2.0 \text{ mA } \text{IL} = 9.287 \text{ ID} = -2.0 \text{ mA } \text{IL} = 9.287 \text{ ID} = -2.0 \text{ mA } \text{IL} = 9.287 \text{ ID} = -13.6 \text{ mV} \text{ No further iterations are necessary and } \text{VO} = -2 \times 2 \times 3.4 \text{ ID} = 8.753 = -13.6 \text{ mV} \text{ No further iterations are necessary and } \text{VO} = -2.0 \text{ mA } \text{IL} = 9.287 \text{ ID} = -2.0 \text{ mA } \text{IL} = -2.0 \text{ mA } \text{I$ mA Iteration #2: 18 VD = $0.7 + 0.025 \ln = 0.715 V 10$ (a) Iteration #1: VO = $1.429 V VD = 0.7 V I = 17.85 mA VO = 2VD = 1.4 V ID = 17.85 mA VO = <math>0.7 + 0.025 \ln = 0.714 V 10 VO = 1.428 V I = 17.86 mA No$ further iterations are needed and ID = 17.86 mA VO = 1.43 V No further iterations are warranted and (e) From the above we see that as VSupply changes from 5 V to 3.232 V (a change of -35.4%) the output voltage changes from 1.39 V to 1.29 V (a change of -35.4%) the output voltage changes from 1.39 V to 3.232 V (a change of -35.4%) the output voltage changes from 1.39 V to 3.232 V (a change of -35.4%) the output voltage changes from 5.40 V (a change of -35.4%) the output voltage changes from 5.40 V (a change of -35.4%) the output voltage changes from 1.39 V to 3.232 V (a change of -35.4%) the output voltage changes from 5.40 V (a change on next page: v B = v A = 3 + 0.05 sin ωt , V Two possibilities: v C = v D = 3 - 0.05 sin ωt , V 25 k A 25 k v O D i = (v B - v C)/2R1 A Current through R2, 2R1, and R2 is C C 25 k vi O vO 25 k D B C O D vO (ii) = +1 V/V vi vO 25 k A 25 k B O vO 1 = + V/V vi vO 25 k A 25 k B O vO 1 = + V/V vi 2 vO = -1 V/V vi A vI 25 k C A (b) (i) = 0.05 sin ωt , mA v
E = v B + iR2 = v $3 + 2.55 \sin \omega t$, $V v F = v C - iR2 = 3 - 2.55 \sin \omega t$, V v O Chapter 2-21 This figure belongs to Problem 2.68. $\Rightarrow IR = 4 V R = V1 = -0.7 1 - 0.7 = -2.7 + IR 2$ Chapter 7-6 The current I splits equally between Q5 and Q6; thus V4 = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -2.7 + 1R = -0.7 V 2 I R = -0.7operating in the active mode as we have implicitly assumed. 8.28 Refer to Fig. Since VC = 0.5 V is greater than VB, the transistor will be operating in the active mode. The MOSFET is operating in the active mode. 10 Rs1 = 3 3 10 3 The value of Rp1 can be found from $\Rightarrow \text{Rp1} = 5 \text{ k}$ (Rp1 Ri1) + Rs1 The final circuit will be as follows: Chapter 1-19 For Rs varying in the range 1 k to 10 k Ro vs Ri vo Avo vi vi io RL 1 k to 10 k Ri \leq Rsmin 10 Ri = 1 k = 100 = 1 × 102 10 For RL varying in the range 1 k to 10 k and the load current variation limited to 10%, Ro is selected sufficiently large: Ro \geq 10 R Lmax Ri \geq 10 Rsmax Ro = 10 × 10 k Ri = 10 × 10 k = 1 × 105 For RL varying in the range 1 k to 10 k and v o limited to 10%, Ro is selected sufficiently large: For Rs varying in the range 1 k to 10 k and v o limited to 10%, Ro is selected sufficiently large: Ro \geq 10 R Lmax Ri \geq 10 R Lmax varying in the range 1 k to 10 k, the load voltage variation limited to 10%, select Ro sufficiently low: = $100 \text{ k} = 1 \times 105$ Now we find Ais : Rsmin + Ri Ro + RLmax RLmin 10 1 k = $100 \text{ k} = 1 \times 102$ Ro = 10 Now find Av o : Ri RLmin v omin = $10 \text{ mV} \times \times \text{Av o}$ Ri + Rsmax Ro + RLmin iomin = $10 \text{ \mu}\text{A} \times 100 \text{ k} + 10 \text$ $100 + 1 \text{ k} \Rightarrow \text{Av o} = 121 \text{ V/V} \Rightarrow \text{Ais} = 121 \text{ A/A Ro} \le 1 \times 10 - 3 = 10 \times 10 - 3 \times \text{io}$ Ri $100 \text{ k} + 100 \text{ k} + 100 \text{ k} + 100 \text{ k} = 1 \times 102$, Ais = 121 A/A, Values for the voltage amplifier equivalent circuit are Ro $= 1 \times 105$ Ri $= 1 \times 10 - 3 \times \text{io}$ Ri $100 \text{ k} + 100 \text{ k} + 100 \text{ k} + 100 \text{ k} = 1 \times 102$, Ais = 121 A/A, Values for the voltage amplifier equivalent circuit are Ro $= 1 \times 105 \text{ Ri} = 1 \times 102 \text{ k} + 100 \text{ k} + 100 \text{ k} + 100 \text{ k} = 1 \times 102 \text{ k} + 100 \text{ k}$ 102 1.56 Transconductance amplifier: 1.55 Current amplifier: ii is 10 A Rs 1 k to Ri 10 k io A Rs 1 k to 10 k Rs 1 to 10 k io vs Ri 10 mV nominal vi Gmvi Ro RL 1 to 10 k Rs 1 k to Ri 10 k Rs 1 to 10 k Rs 1 k to Ri 10 k Rs 1 to 10 k Rs 1 k to Ri 10 k Rs 1 to 10 k Rs 1 to 10 k Rs 1 to 10 k Rs 1 k to Ri 10 k /RL 5 V/2 k = = is 1 μ A 1 μ A = Ri = 100 k = 1 × 105 For RL varying in the range 1 to 10 k, the change in io can be kept to 10% if Ro is selected sufficiently large; 2.5 mA = 2500 A/A 1 μ A or 68 dB. Thus (a) A0 = 2 × 105 V/V ft = 100 kHz × 100 = 10 MHz fb = 200 Hz 10 ft = A0 fb = 2 × 105 V/V ft = 100 kHz × 100 = 10 MHz fb \times 50 = 107 Hz = 10 MHz 2.101 f = 10 kHz |A| = 20 × 103 (b) A0 = 20 × 105 V/V f = 100 kHz |A| = 4 × 103 fb = Thus, a change of a decade in f does not result in a factor of 5. (a) IE = 0.5 mA. (a) RC1 = 1.04 × 5 = 5.20 k RC2 = 0.96 × 5 = 4.80 k To equalize the total resistance in each collector, we adjust the potentiometer so that RC1 + x × 1 k = RC2 + $(1 - x) \times 1$ k 5.2 + x = 4.8 + 1 - x \Rightarrow x = 0.3 k RC RC RC 20 \Rightarrow RC = 1.6 k Thus a 2-mV offset can be nulled out by adjusting one of the collector resistances by 1.6 k. iC = iE - iB = 1000 - 50 = 950 µA \beta = iC 950 = 19 = iB 50 \alpha = \beta 19 = 0.95 \beta + 120 4.12 iC = IS ev BE /VT = 5 \times 1000 - 50 = 950 µA \beta = iC 950 = 19 = iB 50 \alpha = \beta 19 = 0.95 \beta + 120 4.12 iC = IS ev BE /VT = 5 \times 1000 - 50 = 950 µA \beta = iC 950 = 19 = iB 50 \alpha = \beta 19 = 0.95 \beta + 120 4.12 iC = IS ev BE /VT = 5 \times 1000 - 50 = 950 µA \beta = iC 950 = 19 = iB 50 \alpha = \beta 19 = 0.95 \beta + 120 4.12 iC = IS ev BE /VT = 5 \times 1000 - 50 = 950 µA \beta = iC 950 = 19 = iB 50 \alpha = \beta 19 = 0.95 \beta + 120 4.12 iC = IS ev BE /VT = 5 \times 1000 + $10-15 \text{ e}0.7/0.025 = 7.2 \text{ mA} 7.2 7.2 \text{ iB will be in the range mA to mA, that is, 50 200 144 } \mu \text{A to } 36 \mu \text{A} . 3 \text{ V5} = = 1.5 \text{ V } 2 \text{ (a)} \text{ Q1 and } \text{Q2 are matched. IE} = 0.5 \text{ mA} \text{ / A cm} \text{ / IC} = \alpha \text{ K} \text{ V1} \text{ and } \text{ Q2 are matched. IE} = 0.5 \text{ mA} \text{ A} \text{ A} \text{ A} \text{ C} \text{ and } \text{ Q2 are matched. IE} = 0.5 \text{ mA} \text{ A} \text{ A} \text{ A} \text{ A} \text{ and } \text{ Q2 are matched. IE} = 0.5 \text{ mA} \text{ A} \text{ A} \text{ A} \text{ B} \text{ and } \text{ Q2 are matched. IE} = 0.5 \text{ mA} \text{ A} \text{ A} \text{ A} \text{ B} \text{ and } \text{ Q2 are matched. IE} = 0.5 \text{ mA} \text{ A} \text{ A} \text{ B} \text{ and } \text{ Q2 are matched. IE} = 0.5 \text{ mA} \text{ A} \text{ A} \text{ B} \text{ and } \text{ Q2 are matched. IE} = 0.5 \text{ mA} \text{ A} \text{ A} \text{ B} \text{ and } \text{ Q2 are matched. IE} = 0.5 \text{ mA} \text{ A} \text{ A} \text{ B} \text{ and } \text{ A} \text{ A} \text{ B} \text{ and } \text{ A} \text{ A} \text{ and } \text{ A} \text{ A} \text{ and } \text{ A} \text{ A} \text{ and } \text{ and } \text{ A} \text{ and } \text{$ 10 k (50 + 150) Ad = Ricm $\beta REE 1 + (RC/\beta ro) RC + 2REE 1 + ro$ where 2REE = 200 k, thus REE = 100 k and $Ricm = 100 \times 1001 + (10/(100 \times 200)) 10 + 200 = 4.88$ M 8.57 (a) gm = IC 0.1 mA = 4 mA/V VT 0.025 V Ad = $gm RC = 4 \times 25 = 100$ V/V = 5 = 25 V/V 0.2 We have neglected ro because its equivalent value at the output will be ro [1 + (Re /re)] = 200[1 + (150/50)] = 800 k which is much greater than the effective load resistance of 5 k. Thus 0.3 V = 3 k 0.1 mA Rs = Now, for Q2 we have gm = 1 mA/V and VA = 10 V Thus, ro = VA 10 V = 100 k = ID 0.1 mA Rout = ro + Rs + gm ro Rs (f) The value of vo can range from VBIAS - Vt = 1.03 - 0.8 = 0.23 V to (VDD - VOV 2). The common-mode gain, however, undergoes dramatic change because of the significant effect of resistor tolerances on the operation of the difference amplifier in the second stage. Thus, IC = IE $1 + 1\beta = E 1 1 + 110 = 0.909$ mA IB = 0.091 mA For direction of flow, refer to the figure. 2. (a) we see that the transistor with twice the area (Q1) will carry twice the current in the other transistor (Q2). Thus, t R vO (V) C R1 Vi $0.2 \text{ ms Vo t } 100 \text{ k R2} = 1 \text{ k } 100 100 \text{ The circuit now has an STC high-pass response with a lower } 3-dB \text{ frequency R1} = 5 \text{ v } O = -CR 1 1 = -8 = 100 \text{ krad/s CR1 } 10 \times 103 100 \text{ s } 100 \text{$ $(105 / \omega) + j$ Therefore: For $0 \le t \le 0.2$ ms; v O = -1 ms × 1V = -5 V 0.2 ms and v O = 0 otherwise. P4.44 (with VBB = VCC) and to the BJT equivalent circuit of Fig. P8.6. For v G1 = v G2 = 0 V, ID1 = ID2 = 0.4 = 0.2 mA 2 To obtain VD1 = VD2 = +0.1 V VDD - ID1, 2 RD = 0.1 0.9 - 0.2 RD = 0.1 Thus, -0.2 V \le VICM \le +0.5 V 8.7 Refer to Eq. (8.23). 1.37 (a) Av = vO 10 V = 100 V/V = vI 100 mV or 20 log 100 = 40 dB Ai = 0.1 A iO v O /RL 10 V/100 = = iI iI 100 µA = 1000 A/A or 20 log 1000 = 60 dB Step Ap = v O iO vO iO = × = 100 × 1000 v I iI vI iI = 105 W/W or 10 log 105 = 50 dB 1 VFS 1 × step size = 2 2 2N - 1 This is known as the quantization error. 3 we can write at the output ID1 = ID2 = ID vo vo - vi + 2gm vgs + =0 ro /2 R VSG2 = VGS1 = 1 V Substituting vgs = vi and rearranging, we obtain and thus, 11 - vo 2gm R = -2gm 2 1 vi + R ro VG = 0 Thus, $ID = 1 \times 1 \times (1 - 0.5)2 = 0.125 \text{ mA } 2$ But 2gm R 1; thus vo ro -2gm R Av = vi 2 (b) G vgs D R 2gmvgs vi vo vgs ro = vgs vi Figure 2 From Fig. = iD = iC + 1000 Figure 2 From Fig. = iD = iC + 1000 Figure 2 From Figure 2 From Figure 2 From Fig. = iD = iC + 1000 Figure 2 From Figure 2 F iL Q.E.D. The output voltage, v O, can be expressed as v O = Vp - 2VD e - t/RC At the end of the discharge interval v O = Vp - 2VD - Vr The discharge occurs almost over half of the time period T/2. Using Eqs. Thus the voltage gain of Q1 will be Ais = vd 1 1 gm1 = -gm2 Rin ii
= gm2 Rin Q1, gm1 vi, will be mirror in the drain of Q3; 1 rm1 rm2 gm1 (2) For situations where β 1 and β 2 are large, we can neglect rm1 and rm2 in Eqs. The current through RL is determined by the input current and the ratio of the two resistors R1 and R2. When potentiometer is set to the bottom: $30 \times 25 = -10$ V v O = v + = -15 + 25 + 100 + 25 and to the top: $30 \times 25 = +10 \text{ V v O} = -15 + 25 + 100 + 25 = -10 \text{ V} \le v \text{ O} \le +10 \text{ V} 2 \times 10 = 10 \text{ Q} 1 - \text{ R3 R2} \times \text{R1 R4}$ R4 R3 1 - 0.99 × R3 R4 Acm = 0.0095 Neglecting the effect of resistance variation on Ad, R2 100 = 20 V V = R1 5 Ad CMRR = 20 log Acm 20 = 20 log 0.0095 Ad = = 66.4 dB 2.57 If we assume R3 = R1, R4 = R2, then Eq. (2.20): Rid = 2R1 \Rightarrow R1 = (b) Ad = 20 = 10 k 2 R2 = 1 V/V \Rightarrow R2 = 10 k R1 (c) Ad = R2 = 10 V/V \Rightarrow R2 = 1 M = R4 R1 R1 = R3 = 10 k From Eq. (2.20) 2.58 Refer to Fig. \Rightarrow k p = 1.137 mA/V2 5.36 PMOS with Vtp = -1 V Case VS VG VD 5.33 NMOS 14 = R2 = 0.5 V/V \Rightarrow R2 = 5 k = R4 R1 R1 = R3 = 10 k From Eq. (2.20) 2.58 Refer to Fig. \Rightarrow k p = 1.137 mA/V2 5.36 PMOS with Vtp = -1 V Case VS VG VD 5.33 NMOS 14 = R2 = 0.5 V/V \Rightarrow R2 = 5 k = R4 R1 R1 = R3 = 10 k From Eq. (2.20) 2.58 Refer to Fig. \Rightarrow k p = 1.137 mA/V2 5.36 PMOS with Vtp = -1 V Case VS VG VD 5.33 NMOS 14 = R2 = 0.5 V/V \Rightarrow R2 = 5 k = R4 R1 R1 = R3 = 10 k From Eq. (2.20) 2.58 Refer to Fig. \Rightarrow k p = 1.137 mA/V2 5.36 PMOS with Vtp = -1 V Case VS VG VD 5.33 NMOS 14 = R2 = 0.5 V/V \Rightarrow R2 = 5 k = R4 R1 R1 = R3 = 10 k From Eq. (2.20) 2.58 Refer to Fig. \Rightarrow k p = 1.137 mA/V2 5.36 PMOS with Vtp = -1 V Case VS VG VD 5.33 NMOS 14 = R2 = 0.5 V/V \Rightarrow R2 = 5 k = R4 R1 R1 = R3 = 10 k From Eq. 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(2.20) 2.58 Refer to Fig. \Rightarrow R4 R1 R1 = R3 = 10 k From Eq. (2.20) 2.58 Refer to Fig. \Rightarrow R4 R1 R1 = R3 = 10 k From Eq. (2.20) 2.58 Refer to Fig. \Rightarrow R4 R1 R1 = R3 = 10 k From Eq. (2.20) 2.58 Refer to Fig. \Rightarrow R4 R1 R1 = R 2 - 13 - 14 - 1 - 1a + 2 + 20002 Cutoff b + 2 + 10 + 102 Cutoff b + 2 + 10 + 102 Cutoff - Sat. 4.26(a). 1vF = 1.5 - 1.275 sin ωt , V vG = vH = R2 R2 1 = 1 + 1 + v Id R1 1 R2 (v O1 + v O2) = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 1 R2 (v O1 + v O2) = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 1 R2 (v O1 + v O2) = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 1 R2 (v O1 + v O2) = 1 + v Id R1 1 R2 (v O1 + v O2) = 1 + v Id R1 2 R1 R2 v Od = v O2 - v O1 = 1 + v Id R1 1 R2 (v O1 + v O2) = 1 + v Id R1 1 R2 (v O1 + do not depend on the value of R. Thus, iB will have the waveform shown in the figure. 8 (d) $P = I 2 R = (4 \times 10 - 3) 2 \times 10 \times 103 = 0.16 W$ Thus, the resistor should have a 1 -W rating. V2 VD = 700 mV, we have ID = 1 mA: $1.0 = 57.6 \text{ mV} 0.1 \Rightarrow VD = 757.6 \text{ mV} 0.1 \Rightarrow VD = 757.6 \text{ mV} 0.1 \Rightarrow VD = 785 \text{ mV} \Rightarrow VD =$ ID = 1 A and VD = 700 mV, we have ID = 1.0 mA: $0.001 V = VT ln = -173 mV 1 \Rightarrow VD = 527 mV$ Chapter 3-9 ID = 3 mA; $0.003 1 \Rightarrow VD = 555 mV = 0.661 V$ For i = 0.4 mA, v = 0.668 V = -145 mV V = VT ln Now we can refine the diagram to obtain a better estimate For both ID = 1.0 mA: $0.001 V = VT ln = -173 mV 1 \Rightarrow VD = 555 mV = 0.661 V$ For i = 0.4 mA, v = 0.668 V = -145 mV V = VT ln Now we can refine the diagram to obtain a better estimate For both ID = 1.0 mA: $0.001 V = VT ln = -173 mV 1 \Rightarrow VD = 555 mV = 0.661 V$ For i = 0.4 mA, v = 0.668 V = -145 mV V = VT lnvoltages is approximately 230 mV. We first attempt a cascade of the three stages in the order A, B, C (see figure above), and obtain 1.50 The equivalent circuit at the output side of a current amplifier loaded with a resistance RL is shown. (d) For VSupply = 5 + 1.786 = 6.786 V, Iteration #1: VD = 0.7 V VO = 1.4 V IL = 9.33 mA 6.768 - 1.4 I = 26.84 V IL = 9.33 mA 6.768 - 1.4 I = 26.84 V IL = 9.33 mA 6.768 - 1.4 I = 26.84 V IL = 9.33 mA 6.768 - 1.4 I = 26.84 V IL = 9.33 mA 6.768 - 1.4 I = 26.84 V IL = 9.33 mA 6.768 - 1.4 I = 26.84 V IL = 9.33 mA 6.768 - 1.4 I = 26.84 V IL = 9.33 mA 6.768 - 1.4 V IL = 9.33 mA 9.768 - 1.40.2 ID = I - IL = 26.84 - 9.33 = 17.51 mA Iteration #2: 17.51 VD = 0.7 + 0.025 ln = 0.714 V 10 Percentage change in VO per 1% change in 7.19 = 0.2% VSupply = 35.4 3.56 VZ = VZ0 + IZT rz (a) $10 = 9.6 + 0.05 \times \text{rz} \Rightarrow \text{rz} = 8$ For IZ = 2IZT = 100 mA, $\text{VZ} = 9.6 + 0.1 \times 8 = 10.4 \text{ VP} = 10.4 \times 0.1 = 1.04 \text{ W}$ (b) $9.1 = \text{VZ0} + 0.01 \times 30 \Rightarrow \text{VZ0} = 8.8 \text{ V}$ At IZ = 2IZT = 20 mA, VZ = 8.8 + 0.02 × 30 = 9.4 V P = 9.4 × 20 = 188 mW (c) $6.8 = 6.6 + IZT × 2 VO = 1.428 V \Rightarrow IZT = 0.1 A IL = 9.52 mA At IZ = 2IZT = 0.2 A, I = 26.70 mA VZ = 6.6 + 0.2 × 2 = 7 V ID = 17.18 mA P = 7 × 0.2 = 1.4 W Chapter 3-21 (d) 18 = 17.6 + 0.005 × rz At knee, \Rightarrow rz = 80 IZK = 0.25 mA At IZ = 2IZT = 0.01 A, VZ = 17.6 mA V$ $+ 0.01 \times 80 = 18.4 \text{ VP} = 18.4 \times 0.01 = 0.184 \text{ W} = 184 \text{ mW}$ (e) $7.5 = VZO + 0.2 \times 1.5 \text{ rz} = 750 \text{ FIRST DESIGN}$: $9 \cdot V$ supply can easily supply current Let IZ = 20 mA, well above knee. (W/L)1 (W/L)3 VOV = 0.2 V This is the same overdrive voltage at which Q4 will be operating. Assuming saturation-mode operation, we obtain VB = 1.3 V VE = VC + 1.3 V VE = 1.3 V VE = VC + 1.3 V VE = VECsat = -2.5 + 0.2 = -2.3 V - VE = 2.3 mA IE = 1 k VB = VE - 0.7 = -3 V - 3 - (-5) = 0.2 mA IB = 10 IC = IE - IB = 2.3 - 0.2 = 2.1 mA IC 2.1 = = 10.5 βforced = 10.2 = 2.3 0.185 which is less than the value of β 1 verifying saturation-mode operation. Transistor Q1 is operating in saturation. $_{,} = 0$. Neglecting R, we have Load regulation = -30 mV/mA. The latter value implies that the high- β transistor will leave the active region of operation and saturate. Acm = 0 From input loop: For vI 2 - vI 1 = vId, vId = 2i1 R1 v O = 10 v Id From the loop containing R2, +, -, R2: Thus, Ad = 10. Thus v Dmax = -1.1 + 0.7= -0.4 V Put differently, VSD must be at least equal to |VOV|, which in this case is 0.4 V. (b) RL = 200 If output is at its peak: iL = 10 V = 50 mA 0.2 which exceeds iOmax = 20 mA. vo (V) I 1 mA 10 I 0.5 mA 5 (a) 10.7 5.68 5.68 5 VO 10.7 v1 (V) = VO rd = = + V R + rd VT / I VT R + I VT IR + VT For no load, I = V + - 0.7 V + - VO = . Rin = 500 \Rightarrow gm1 = 2 mA/V gm1 = 2µn Cox Thus, 2= \Rightarrow 2 × 0.4 × W L W L = 25 1 W L ID1 1 × 0.2 1 Chapter 7-7 RO = ro2 = VA VL = A ID2 ID2 Thus, the small-signal voltage gain will be vo = gm1 RL (W3 /W2) vi Thus, 20 = 20 L 4 × 0.2 7.19 Replacing Q1 and Q2 with their small-signal voltage gain will be vo = gm1 RL (W3 /W2) vi Thus, 20 = 20 L 4 × 0.2 7.19 Replacing Q1 and Q2 with their small-signal hybrid- π models results in the equivalent circuit shown in the figure below. 6.125 (a) Applying Thévenin's theorem to the base-biasing circuit of Q1 results in the dc circuit shown below. Thus, the voltage gain becomes Av = $0.95 \ 0.95 + 1 \ 2.4 \ r\pi = 1.25 \ k$ Rin = $101[0.0125 + (1.25 \ 25)] = 121.5 \ k = 0.7 \ V/V$ Thus, Rin has been reduced by a factor of 10. Thus, we can write 200 kHz = 1 $2\pi C(Ro1 Ri2)$ Chapter 1-24 \Rightarrow (Ro1 Ri2) = 1 $2\pi \times 200 \times 103 \times 1
\times 10-9 = 0.8$ k A #1 #2 B #3 Av, dB 1 nF C The Bode plot for the overall transfer function can be obtained by summing the dB values of the two individual plots and then shifting the resulting plot vertically by 60 dB (corresponding to the factor 1000 in the numerator). (b) If L is halved, k n will be doubled and rDS will vary in the range of 1.25 k to 62.5. When the supply voltage is low, 160 = -35 mV/mA 4.6 3.62 (a) VZT = VZ0 + rz IZT 10 = VZ0 + rz IZ 38 Refer to Example 3.2. (a) (b) 10 V 5 I 1.861 10 k 0.86 mA 4 3 V 10 0 1 mA 10 10 k V0V 3 1 0.7 V 5 k V 2 0.7 10 5 1.86 mA Cutoff I 3 V 10 V I = 0A (b) V = 3 - I (10) = 3 V 10 V 5 k ID2 I0 V 0.7 V Cutoff 10 k (c) I V 10 k ID2 10 V 10 - (-10) - 0.7 = 1.29 mA 15 VD = -10 + 1.29 (10) + 0.7 = 3.6 V ID2 = 3 V 3 V V = 3 - 0.7 V 5 k ID2 I0 V 0.7 V Cutoff 10 k (c) I V 10 k ID2 10 V 10 - (-10) - 0.7 = 1.29 mA 15 VD = -10 + 1.29 (10) + 0.7 = 3.6 V ID2 = 3 V 3 V V = 3 - 0.7 V 5 k ID2 I0 V 0.7 V Cutoff 10 k (c) I V 10 k ID2 10 V 10 - (-10) - 0.7 = 1.29 mA 15 VD = -10 + 1.29 (10) + 0.7 = 3.6 V ID2 = 3 V 3 V V = 3 - 0.7 V 5 k ID2 I0 V 0.7 V Cutoff 10 k (c) I V 10 k ID2 10 V 10 - (-10) - 0.7 = 1.29 mA 15 VD = -10 + 1.29 (10) + 0.7 = 3.6 V ID2 = 3 V 3 V V = 3 - 0.7 V 5 k ID2 I0 V 0.7 V Cutoff 10 k (c) I V 10 k ID2 10 V 10 - (-10) - 0.7 = 1.29 mA 15 VD = -10 + 1.29 (10) + 0.7 = 3.6 V ID2 = 3 V 3 V V = 3 - 0.7 V 5 k ID2 I0 V 0.7 V Cutoff 10 k (c) I V 10 k ID2 10 V 10 - (-10) - 0.7 = 1.29 mA 15 VD = -10 + 1.29 (10) + 0.7 = 3.6 V ID2 = 3 V 3 V V = 3 - 0.7 V 5 k ID2 I0 V 10 k ID2 10 V ID2 $2.3 V 2.3 + 3 = 0.53 \text{ mA I} = 10 \text{ Chapter } 3 - 12 3.41 \text{ (d) } 3 V + 3 V \text{ I Cutoff ID2 } 12 \text{ k V I0 ON } 0.7 \text{ V D2 } V \text{ D1 ID2 Cutoff } 3 V 6 \text{ k I} = 0.43 V \text{ (a) } 30.7 0.383 \text{ mA 6 Cutoff } 1 V 0.7 V \text{ D2 } 2 \text{ k I } 0.383 0.25 0.133 \text{ mA ON } D2 \text{ D1 ON } 0(3) 12 0.25 \text{ mA I VOV } 12 \text{ k } 3 V 3 V \text{ (b) } 3 - 0.7 - (-3) = 0.294 \text{ mA } 12 + 6 \text{ V} = -3 + 0.294 \text{ mA } 12 + 6 \text{$ -1.23 VV = 2 - 0.7 (a) ID2 = = 1.3 V 1.3 - (-3) I = 2 = 2.15 mA Check that D1 is off: Voltage at the anode of D1 = V + VD2 = -1.23 + 0.7 = -0.53 V which keeps D1 off. 2 7.42 Refer to Fig. The result (after some manipulations) is the quadratic equation. vsig vsig = ib1 = $10 + (\beta + 1)\text{re} 1.0 + 101 \times 0.05 \alpha \text{RL}$ re1 = re2 = VT 25 mV = = 50 IE 0.52 NLmA VT 25 mV = = 50 IE 0.5 mA 10 = 50.2 V/V 10 + 0.05 + 0.05 101 ic1 = β ib1 = 100 vsig 10 + 101 × 0.05 ic2 = α ic1 = 0.99 × 100 vsig 10 + 101 × 0.05 vo = $-ic2 \times 10$ Gv = 7.94 vo 10 × 0.99 × 100 = $-ic2 \times 10$ Gv = 7.94 vo 10 × 0.99 × 100 vsig 10 + 101 × 0.05 (c) Refer to Fig. P7.69. VGS = 2 - 1 = 1 V VOV = VGS - Vt = 1 - 0.7 = 0.3 V Since VD at 2.5 V is 1.2 V higher than VS + VOV = 1 + 0.3 = 1.3 V, the transistor is indeed operating in saturation. 7.32. With a load resistance RL connected, Ex: 7.14 Use Eq. (7.63) Rin re ro + RL RL ro + β + 1 Exercise 7-4 Ex: 7.19 to obtain RL 0 ro (β + 1)ro ∞ Rin re 2 re 1 rn 2 rn VDD 1.8 V VG4 1.1 V Q4 VG3 0.8 V Ex: 7.15 Using Eq. (7.68), Q3 Rout ro + (gm ro)(Re rn) vO we obtain VG2 1.0 V Re 0 re Rout ro 2 ro $r\pi Q2 \propto ro \beta + 1$ ro ($\beta + 1$) ro Q1 VI 0.7 V Ex: 7.16 Ro = [1 + gm (Re rn)]ro where gm = 40 mA/V, $r\pi = \beta = 2.5 k$, gm Re = 0.5 k, and ro = If all transistors are matched and are obviously operating at the same ID, then all |VOV| will be equal and equal to that of Q1, namely, |VOV| = 0.7 - 0.5 = 0.2 V VA 10 = = 10 k IC 1 Thus, $VD1 = VS2 = VG2 - Vtn - VOV Ro = [1 + 40(0.5 2.5)] \times 10 = 1.0 - 0.5 - 0.2 = 0.3 V = 177 k$ The lowest vDS2 can go is |VOV| = 0.2 V Without emitter degeneration, $\therefore v O min = VDS1 + VDS2 = 0.3 + 0.2 = 0.5 V Ro = ro = 10 k IC 1$ Thus, $VD1 = VS2 = VG2 - Vtn - VOV Ro = [1 + 40(0.5 2.5)] \times 10 = 1.0 - 0.5 - 0.2 = 0.3 V = 177 k$ The lowest vDS2 can go is |VOV| = 0.2 V Without emitter degeneration. 10 k Similarly, $VSG4 = VSG3 = 0.7 V VD4 = VSG3 = 0.7 V VD4 = VS3 = VG3 + |Vt| + |VOV| Ex: 7.17 Since the CG transistor Q2 increases the output resistance by a factor approximately equal to gm2 ro2, = 0.8 + 0.5 + 0.2 = 1.5 V K gm2 ro2 vO max = VD4 - vSD3min = 1.5 - 0.2 = 1.3 V 0.55 \mu m and Ex: 7.18 If L is halved L = 2 |VA| = VA L, we obtain 0.55 \mu m$ output resistance] +4.5 V (b) +6V [two ways: (a) and (d) with (d) having a lower output resistance] R 10 k 5.00 V 1.9 15 V 4.7 k 10 k VO 4.7 k Thus 1 1 1 + = 10 R 9.4 \Rightarrow R = 156.7 \approx 157 k Now, VO = 15 4.7 = 4.80 V 10 + 4.7 To increase VO to 10.00 V, we shunt the 10-k resistor by a resistor R whose value is such that 10 R = 2 × 4.7. RO = 10 k R 4.7 k 9.4 = 3.133 k 3 To make RO = 3.33, we add a series resistance of approximately 200, as shown on the next page. To make IC1 = IC2, re2 IS1 e(VB2 - VE)/VT = 2 (b) From Fig. P5.56. The incremental quantities can be related by the equivalent circuit model shown in Fig. Of the two circuits with infinite input resistance (c and d), the circuit in (d) has the higher voltage gain. Observe that the linear range of the characteristic is now centered around v Id = -5 mV rather than the ideal situation of v Id = 0; this shift is obviously a result of the input offset voltage VOS. 4.5(b) and 4.5(d). For Q1, Weff = $20 + 10 = 30 \mu m$, so that $40 = 133 \mu A I3 = 100 \mu A$ $30 \text{ ID1} = \text{IREF} = 20 \ \mu\text{A}$ 1 W ID1 = $\mu\text{p} \cos |\text{VOV}| 2 2 \text{L} 1$ W 1 20 = $\times 100 \times \times 0.04 2 \text{L} 1$ W = 10 \Rightarrow L 1 (5) If Q2 and Q3 are diode connected, then For L = 0.5 μm , weff = 20 + 40 = 60 μm , so that 10 = 16.7 μA I1 = 100 μA 60 W1 = 5 μm Now, if two transistors are diode connected, the effective width is the sum of the two widths. Chapter 4-20 (b) 3 V a 0.5 0.495 mA 3.6 k IB 0.5 101 V3 3 0.495 3.6 1.218 V 0.005 mA VE 0.7 4.7 k I4 0.7 (3) 4.7 0.5 mA 3 V (b) See solution and answer on the figure, which corresponds to Fig. Vo = Vi - R2 /R1 1 + R2 /R1 1 $|A| A (b) Q.E.D A |G| R2 \le 0.001 = 100, = 0.1, |G| R1 A A \ge (1 + 100) \times 0.1/0.001 2.26$ From Example 2.2, vO R2 R4 R4 = -1+ + vI R1 R2 R3 Here R1 = R2 = R4 = 1 M 1 M v \therefore O = -1+1+ = -2+ vI R3 R3 That is, Amin 104 V/V. 9.42(b). So I can be only 10 mA or 15 mA. 2.97 R3 = R1 R2 = 10 k 1 M = 9.09 k Now, with the input grounded and assuming VOS = 0, the measured +0.3-V at the output is entirely due to IOS, that is, (a) R3 = R RF = 10 k 1 M \Rightarrow R3 = 9.9 k (b) As discussed in Section 2.8.2, the dc output voltage of the integrator when the input is RF grounded is VO = VOS 1 + + IOS RF R 1 M VO = 2 mV 1 + + 20 nA × 1 M 10 k = 0.202 V + 0.02 V VO = 0.222 V 0.3 = IOS R2 = IOS × 1 M Thus, IOS = $0.3 \mu A$ If VOS = $\pm 1 \text{ mV}$, then it alone will result in an output voltageof R2 VOS 1 + = VOS × 101 = $\pm 101 \text{ mV}$ or R1 + 0.1 V If VOS is positive, 0.1 V of the output 0.3-V offset will be due to VOS , leaving 0.2 V as the result of 0.2 V IOS ; thus in this case, IOS = $0.2 \mu A$. 0.5 mA 200 Figure 1 re 50 200 Figure 2 From Fig. Also observe that the mirror Q3 and Q4 is indeed functioning properly as the drain currents of Q3 1 and Q4 are equal (i12 = i2 = gm v id). If at this value of VB - 0.7 IO - VC = RC RE RE Exercise 4-5 10 - (VB - 0.5) 4.7 VB - 0.7 IE = 6IB = 3.3Dividing Eq. (1) by Eq. (2), we have Thus, IC = 5IB = VB - 0.7 10 - (VB - 0.4) = 4.7 3.3 \Rightarrow VB = +4.7 V (1) (2) 10.5 - VB 3.3 5 = × 6 VB - 0.7 4.7 Ex: 4.23 \Rightarrow VB = +5.18 V 10 V 0.5 mA RC VC 6 V Ex: 4.23 \Rightarrow VB = +5.18 V 10 V 0.5 mA RC VC 6 V Ex: 4.23 \Rightarrow VB = +5.18 V 10 V 0.5 mA RC VC 6 V Ex: 4.23 \Rightarrow VB = +5.18 V 10 V 0.5 mA RC VC 6 V Ex: 4.23 \Rightarrow VB = +5.18 V 10 V 0.5 mA RC VC 6 V Ex: 4.23 \Rightarrow VB = +5.18 V 10 V 0.5 mA RC VC 6 V Ex: 4.23 \Rightarrow VB = +5.18 V 10 V 0.5 mA RC VC 6 V Ex: 4.23 \Rightarrow VB = +5.18 V 10 V 0.5 mA RC VC 6 V Ex: 4.23 \Rightarrow VB = +5.18 V 10 V 0.5 mA RC VC 6 V Ex: 4.23 \Rightarrow VB = +5.18 V 10 V 0.5 mA RC VC 6 V Ex: 4.25 Refer to the circuit in Fig. See also the figure
below. RL RL + Rs ω 0 = 1 C(RL + Rs) For f0 \leq 100 Hz R1 V 1 \leq 100 2 π C(RL + Rs) C R2 V0 \Rightarrow C \geq 1 2 π × 100(20 + 5) × 103 Thus, the smallest value of C that will do the job is C = 0.064 µF or 64 nF. P5.52(b): The MOSFET is operating in saturation. P3.2. (a) Diode is conducting, thus 3.4 (a) V = -3 V I = Cutoff vO + 3 - (-3) = 0.6 mA 10 k 5V (b) Diode is reverse biased, thus 0 t I = 0 V = +3 V V p + = 5 V V p - = 0 V f = 1 kHz (c) Diode is conducting. conducting, thus (b) V = +3 V I = vO + 3 - (-3) = 0.6 mA 10 k (d) Diode is reverse biased, thus I = 0 V = -3 V 0 t 5 V V p + = 0 V V p - = -5 V f = 1 kHz Chapter 3-2 (c) D1 shorts to ground when v I < 0 whereby the output follows v I. Using Eq. (1) we can determine (RB /RC): $5 - 0.2 \text{ RB } 10 = 5 - 0.7 \text{ RC} \Rightarrow RB = 8.96 \text{ RC}$ Using Eq. (2), we can find IB : $(10 + 1) \times 5 \times IB \le 20 \text{ mW} \Rightarrow IB \le 0.36 \text{ mA Thus}$, VBB = IB RB + VBE VCC - $0.7 \le 0.36 \text{ mA RB} = 0.194 \times 10 + 0.7 = 2.64 \text{ V} \Rightarrow \text{RB} \ge 11.9 \text{ k}$ (3) Chapter 4-13 From the table of 1% resistors in Appendix J we select Thus, RB = $12.1 \text{ k IC} = 5 - 0.3 = 4.7 \text{ mA 1 RC} = 1.35 \text{ k IB} = 4.7 \text{ IC} = 0.094 \text{ mA } \beta$ 50 From the table of 1% resistors in Appendix J we select Thus, RB = $12.1 \text{ k IC} = 5 - 0.3 = 4.7 \text{ mA 1 RC} = 1.35 \text{ k IB} = 4.7 \text{ IC} = 0.094 \text{ mA } \beta$ 50 From the table of 1% resistors in Appendix J we select Thus, RB = $12.1 \text{ k IC} = 5 - 0.3 = 4.7 \text{ mA 1 RC} = 1.35 \text{ k IB} = 4.7 \text{ IC} = 0.094 \text{ mA } \beta$ 50 From the table of 1% resistors in Appendix J we select Thus, RB = $12.1 \text{ k IC} = 5 - 0.3 = 4.7 \text{ mA 1 RC} = 1.35 \text{ k IB} = 4.7 \text{ IC} = 0.094 \text{ mA } \beta$ 50 From the table of 1% resistors in Appendix J we select Thus, RB = $12.1 \text{ k IC} = 5 - 0.3 = 4.7 \text{ mA 1 RC} = 1.35 \text{ k IB} = 4.7 \text{ IC} = 0.094 \text{ mA } \beta$ 50 From the table of 1% resistors in Appendix J we select Thus, RB = $12.1 \text{ k IC} = 5 - 0.3 = 4.7 \text{ mA 1 RC} = 1.35 \text{ k IB} = 4.7 \text{ IC} = 0.094 \text{ mA } \beta$ 50 From the table of 1% resistors in Appendix J we select Thus, RB = 12.1 \text{ k IC} = 5 - 0.3 = 4.7 \text{ mA 1 RC} = 1.35 \text{ k IB} = 4.7 \text{ IC} = 0.094 \text{ mA } \beta 50 From the table of 1% resistors in Appendix J we select Thus, RB = 12.1 \text{ k IC} = 5 - 0.3 = 4.7 \text{ mA 1 RC} = 1.35 \text{ k IB} = 4.7 \text{ IC} = 1 19.2 mW 1 k 4.46 5 V VB 4.3 V RB 10 k V ECsat (a) 3 V 0.2 V VC 3 1 1 2 V VC 4.8 V IB 4 1.7 V IC 1 k VE 1.0 V 1 1.0 IE 1 1 mA 2 1 k Assume saturation-mode operation. It follows that that sensor internal resistance must be equal to RL, that is, 5 k. Since the gain decreases by 40 dB/decade or equivalently 12 dB/octave, it reaches 0 dB (unity magnitude) at f = fPC /2 = 5 Hz. Chapter 9-7 9.12 Cox = = ox tox 3.45 × 10-11 F/m = 0.43 × 10-2 F/m2 8 × 10-9 m = 0.43 × 10-2 F/m2 = 4.3 fF/µm2 = 1.33 mA/V = VOV 0.3 gm fT = 2\pi (Cgs + Cgd) 9.13 gm = = 1.33 × 10-3 = 7.1 GHz 2\pi × (25 + 5) × 10-15 k n = µn Cox = 450 × 108 (µm2 /V s) × 4.3 × 10-15 F/µm2 = 4.3 fF/µm2 = $193.5 \mu A/V \quad 1 \text{ W 2 ID} = \text{k n VOV} (1 + \lambda \text{VDS}) \\ 2 \text{ L 2 1 2 } \times 193.5 \times 20 \times \text{VOV} (1 + 0.05 \times 1.5) \\ 2 \Rightarrow \text{VOV} = 0.31 \text{ V 200} \\ = 2\text{ID 2 } \times 0.2 \\ = 1.3 \text{ mA/V} \\ = \text{VOV} \\ 0.31 \text{ V } \\ \chi \\ = 2 \\ \varphi f + \text{VSB gm} \\ = 0.5 \\ = \sqrt{(1 + \lambda \text{VDS})} \\ 2 \text{ L 2 1 2 } \times 193.5 \\ \times 20 \times \text{VOV} \\ (1 + 0.05 \times 1.5) \\ 2 \Rightarrow \text{VOV} \\ = 0.31 \text{ V 200} \\ = 2\text{ID 2 } \times 0.2 \\ = 1.3 \\ \text{mA/V} \\ = \text{VOV} \\ 0.31 \text{ V } \\ \chi \\ = 2 \\ \varphi f + \text{VSB gm} \\ = 0.5 \\ = \sqrt{(1 + \lambda \text{VDS})} \\ 2 \text{ L 2 1 2 } \times 193.5 \\ \times 20 \times 100 \\ = 2 \\ \text{VOV} \\ (1 + 0.05 \times 1.5) \\ 2 \\ \Rightarrow \text{VOV} \\ = 0.31 \text{ V 200} \\ = 2 \\ \text{ID 2 } \times 0.2 \\ = 1.3 \\ \text{mA/V} \\ = \text{VOV} \\ 0.31 \\ \gamma \\ \chi \\ = 2 \\ \varphi f + \text{VSB gm} \\ = 0.5 \\ = \sqrt{(1 + \lambda \text{VDS})} \\ 2 \\ \text{L 2 1 2 } \times 193.5 \\ \times 20 \\ \times 100 \\ = 2 \\ \text{VOV} \\ (1 + 0.05 \times 1.5) \\ 2 \\ \Rightarrow \text{VOV} \\ = 0.31 \\ \text{V 200} \\ = 2 \\ \text{ID 2 } \\ \times 0.2 \\ = 1.3 \\ \text{mA/V} \\ = 0.25 \\ \text$ 57.3 + 4.3 = 61.6 fF = 9.14 fT = gm 2π (Cgs + Cgd) For Cgs Cgd gm fT 2π Cgs 2 WLCox + WLov Cox 3 If the overlap component is small, we get Cgs = 2 WLCox (2) 3 The transconductance gm can be expressed as W gm = μ n Cox VOV (3) L Cgs Substituting from (2) and (3) into (1), we obtain W μ n Cox VOV L fT = 22π × WLCox 3 3μ n VOV = $4\pi L2$ We note that for a given channel length, fT can be increased by operating the MOSFET at a higher VOV. The result is that the poles caused by CE and CC do not interact. Transistor Q3 will have an overdrive voltage of VS1 = VS2 = -VGS1, 2 = -VGS= A = ID ID 0.36 To determine Av o, we note [refer to Fig. Thus the ±1% resistor tolerances will mainly affect the common-mode gain of the instrumentation amplifier, increasing it in the worst case to |Acm | = 0.02 Correspondingly, the CMRR will be reduced to CMRR = 20 log 20 log 21 0.02 | Ad | | Acm | = 60.4 dB as opposed to the ideal infinite value! vB 20 = 1 + = 3 V/V vA 10 30 vC = -3 V/V = -vA 10 (b) v O = v B -vC = 6 V/V vA Chapter 2-23 (c) v B and v C can be ±14 V, or 28 V P-P. The solutions are indicated on the corresponding circuit diagrams; the order of the steps is shown by the circled numbers. With Re included (i.e., left unbypassed), the input resistance becomes [refer to Fig. G = 1 + R2 R1 vO 2.53 For a non inverting amplifier [Eq. (2.11)]: G0 G0 1 + A G = 2.51 = G0 - G × 100 G0 for an inverting amplifier (Eq. 2.5): vO/A vO = vI G0 1 - G0 1 + A Case G 0 (V/V) a b c d e f g - 1 1 - 1 10 - 10 - 10 + 1 vO A vI vO = vI - G = vO A 1 1 A Error of gain magnitude vO - 1 v 1 I = -1 A + 1 = |G0| - |G| × 100 |G0| A (V/V) G (V/V) (%) 10 10 100 100 100 10 100 100 100 2 -0.83 0.91 -0.98 5 -9 -9.89 0.67 17 9 2 50 10 1.1 33 1 + 2.54 G = A (V/V) 1000 100 10 vO (V/V) vO 0.999 0.990 0.909 Gain error -0.1% -1% -9.1% 2.52 For an inverting amplifier Rin = R1 , R2 G = - R1 G0 G0 /A × 100 G0 - G × 100 = , $\leq x$ G0 G0 G0 1 + 1 + A A G0 A $\geq 100 \Rightarrow A \geq 100 \Rightarrow A \geq 100 = 100 \Rightarrow A \geq 100 = 100 \Rightarrow A \geq 100 \Rightarrow A$ 103 104 A (V/V) 10 102 103 104 105 2.55 Refer to Fig. Chapter 6-10 vi = gm v gs RS RD v s = +gm v gs RS V VA = 50 V Given VDS = VGS = 1 V. Thus, v O = v I. Thus, v O = v I. Thus, $R \le 15 - 9.825 + 7.25 \Rightarrow VZ = 10.32 V 25 - 10.32 = 70.9 m A IZmax = 0.207 PZ = 10.32 × 70.9 = 732 m W 3.63 \le 207$. Since VC < VB + 0.4, the transistor is operating in the active mode, as assumed. 8.2. $1 W I = \mu n Cox V2$ (a) $2 2 L 1.2 OV 0.08 = \Rightarrow VOV 1.2 \times 0.4 \times 10 \times VOV 2 = 0.2 V$ ID1,2 = 1 W kp |VOV |2 2 L 1 × 4 × |VOV |2 2 L 1 × 4 × |VOV |2 2 = |VOV | = 0.35 V 0.25 = VSG = |Vtp | + |VOV | VGS = Vtn + VOV = 0.4 + 0.2 = 0.6 V = 0.4 + 0.2 = 0.4 + 0.2 = 0.6 V = 0 $VVS = 0.4 - VGS = 0.4 - 0.6 = -0.2 VI = 0.08 mA 2 = VDD - ID1,2 RD ID1 = ID2 = VD1 = VD2 = 1 - 0.08 \times 5 = +0.6 V Since VCM = 0.4 V and VD = 0.6 V, VGD = -0.2 V, which is less than Vtn (0.4 V), indicating that our implicit assumption of saturation-mode operation is justified. Thus, I 1 W = µn Cox V2 2 2 L 4,5 OV 4,5 Q1 50 0.1 0.7 Q2 50$ gm, rn, and ro can be found as follows: Rin gm (ro RD RL) Rin + Rsig gm = IC 0.5 mA = 20 mA/V VT 0.025 V 1.67 × 2 × (2001820) 1.67 + 0.1 rn = β 100 = 5 k = gm 20 ro = VA 100 = 5 k = gm 20 ro = VA 100 = 200 k IC 0.5 Gv = - = - Ex: 6.40 Refer to Fig. Thus, Note: This large value of R is not desirable in integrated form; other designs may be move suitable. Therefore we need to redo the analysis assuming saturation-mode operation, as follows: VB = VE + 0.7 VC = VE + VCEsat = VE + 0.2 5 - VE - 0.2 = IC = RC 1 = 4.8 - VE IE = VE VE = VE = RE 1 (1) VC = 3.2 V Now checking the currents, IB = 5 - 3.7 = 1.3 mA 1 IC = 5 - 3.2 = 1.8 mA 1 Thus, the transistor is operating at a forced β of β forced = (2) IC 1.8 = 1.4 IB 1.3 which is much lower than the value of β , confirming operation in saturation. Observe that i11 = i7 = i3 (the current that enters a transistor exits at the other end!). Then for the circuit to behave as a difference amplifier with a gain of 10 and an input resistance of 20 k, we require R2 = 10 and R1 R RId = $2R1 = 20 \text{ k} \Rightarrow R1 = 10 \text{ k}$ and Ci Ad = Ex: 2.18 vi(t) i R2 = Ad R1 = $10 \times 10 \text{ k} = 100 \text{ k}$. For dc analysis, open-circuit the two coupling capacitors. vS vS D1 D3 Refer to Fig. Ex: 2.4 The gain and input resistance of the inverting amplifier circuit shown in Fig. re nominal (b) RC1 = RC2 = 10 k Rsig = 10 k IC 0.25 mA = 10 mA/V = VT 0.025 V rm 1 = rm 2 = β 100 = 10 k = gm 10 1 = 50 gm Rin = (β + 1)(re + Re) = 101(50 + 250) = 30.3 k
α RC 0.99 × 12 Av o = -40 V/V = -re + Re 0.3 Ro = RC = 12 k RL Av = Av o RL + Ro 12 = -20 V/V = -40 × 12 + 12 Rin Gv = × Av Rin + Rsig RL = 10 k $gm1 = gm2 = IC \ 0.5 = 20 \ mA/V = VT \ 0.025 \ rn \ 1 \ 10 \ vn1 = = 0.5 \ V/V \ vo \ sig \ rn \ 1 + Rsig \ 10 + 10 \ vn2 = -gm1 \ (RC1 \ rn \ 2) = -10(10 \ 10) \ vn1 = -50 \ V/V \ vo \ sig \ vn2 \ vn1 \ vo \ sig \ 30.3 \ + 10 = 6.65 \ mV \ 30.3 \ v^{0}$ $= v^{sig} \times |Gv| v^{sig} = 5 \times = -50 \times -50 \times 0.5 = 1250 V/V = 6.65 \times 15100 \text{ mV}$ 6.66 gm effective = gm 1 + gm Rs 6.69 Rin = (β + 1)(re + Re) 5 2= 1 + 5Rs \Rightarrow Rs = 0.3 k = 300 15 = 75(re + Re) 15 k re + Re = 200 75 Rin re $v^{\pi} = v^{sig}$ Rin + Rsig re + Re re 15 5 = 150 × 15 + 30 re + Re re = 0.1 \Rightarrow re + Re But re + Re = 200 , thus 6.67 Including Rs reduced the gain by a factor of 2, thus $1 + \text{gm Rs} = 211 = 2 \text{ mA/V} = \Rightarrow \text{gm} = \text{Rs } 0.5 \text{ The gain without Rs is} = 0.5 \text{ mA VC} = VCC - RC IC For VC = 1 V and VCC = 5 V, we have <math>1 = 5 - RC \times 0.5 \Rightarrow RC = 8 \text{ k To obtain the required value of RE}$, we note that the voltage drop across it is (VEE - VBE) = 4.3 V. 8.14.7.18(b), vo = iRL vsig = i(Rs + Rin) Thus, Since all transistors have the same 7.2 µm W = , L 0.36 µm RL vo = vsig Rs + Rin Q.E.D we have IREF = ID3 = ID2 = ID1 = 100 µA W gm1 = 2µn Cox ID1 L 1 7.2 = $2.387 \mu A/V2$ (100 µA) 0.36 Ex: 7.11 Since gm ro 1, we use Eq. (7.54), Rin RL 0 ro (gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA W gm1 = $2\mu n Cox ID1 L 1$ 7.2 = $2.387 \mu A/V2$ (100 µA) 0.36 Ex: 7.11 Since gm ro 1, we use Eq. (7.54), Rin RL 0 ro (gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA W gm1 = $2\mu n Cox ID1 L 1$ 7.2 = $2.387 \mu A/V2$ (100 µA) 0.36 Ex: 7.11 Since gm ro 1, we use Eq. (7.54), Rin RL 0 ro (gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA W gm1 = $2\mu n Cox ID1 L 1$ 7.2 = $2.387 \mu A/V2$ (100 µA) 0.36 Ex: 7.11 Since gm ro 1, we use Eq. (7.54), Rin RL 0 ro (gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA W gm1 = $2\mu n Cox ID1 L 1$ 7.2 = $2.387 \mu A/V2$ (100 µA) 0.36 Ex: 7.11 Since gm ro 1, we use Eq. (7.54), Rin RL 0 ro (gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA W gm1 = $2\mu n Cox ID1 L 1$ 7.2 = $2.387 \mu A/V2$ (100 µA) 0.36 Ex: 7.11 Since gm ro 1, we use Eq. (7.54), Rin RL 0 ro (gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA W gm1 = $2\mu n Cox ID1 L 1$ 7.2 = $2.387 \mu A/V2$ (100 µA) 0.36 Ex: 7.11 Since gm ro 1, we use Eq. (7.54), Rin RL 0 ro (gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA W gm1 = $2\mu n Cox ID1 L 1$ 7.2 = $2.387 \mu A/V2$ (100 µA) 0.36 Ex: 7.11 Since gm ro 1, we use Eq. (7.54), Rin RL 0 ro (gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA W gm1 = $2\mu n Cox ID1 L 1$ 7.2 = $2.387 \mu A/V2$ (100 µA) 0.36 Ex: 7.11 Since gm ro 1, we use Eq. (7.54), Rin RL 0 ro (gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA W gm1 = $2\mu n Cox ID1 L 1$ 7.2 = $2.387 \mu A/V2$ (100 µA) 0.36 Ex: 7.11 Since gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA (100 µA) 0.36 Ex: 7.11 Since gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA (100 µA) 0.36 Ex: 7.11 Since gm ro 1) we have IREF = ID3 = ID2 = ID1 = 100 µA (100 µA) 0.36 Ex: 7.11 ro)ro ∞ Rin 1 gm 2 gm ro $\infty = 1.24$ mA/V ro1 = ro2 = 1 RL + gm gm ro VAn 5 V/µm (0.36 µm) L1 = = 18 k ID1 0.1 mA Ex: 7.12 For gm ro 1, we use Eq. (7.58), [VAp |L2 Rout ro + (gm ro) Rs = ID2 6 V/µm (0.36 µm) = 21.6 k 0.1 mA to obtain Voltage gain is Av = -gm1 (ro1 ro2) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) ro ∞ ro (gm ro) ro ∞ ro (gm ro) Rs = ID2 6 V/µm (0.36 µm) = 21.6 k 0.1 mA to obtain Voltage gain is Av = -gm1 (ro1 ro2) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) ro ∞ ro (gm ro) ro ∞ ro (gm ro) Rs = ID2 6 V/µm (0.36 µm) = 21.6 k 0.1 mA to obtain Voltage gain is Av = -gm1 (ro1 ro2) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) ro ∞ ro (gm ro) Rs = ID2 6 V/µm (0.36 µm) = 21.6 k 0.1 mA to obtain Voltage gain is Av = -gm1 (ro1 ro2) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) ro ∞ ro (gm ro) Rs = ID2 6 V/µm (0.36 µm) = 21.6 k 0.1 mA to obtain Voltage gain is Av = -gm1 (ro1 ro2) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) ro ∞ ro (gm ro) Rs = ID2 6 V/µm (0.36 µm) = 21.6 k 0.1 mA to obtain Voltage gain is Av = -gm1 (ro1 ro2) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) ro ∞ ro (gm ro) Rs = ID2 6 V/µm (0.36 µm) = 21.6 k 0.1 mA to obtain Voltage gain is Av = -gm1 (ro1 ro2) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) ro ∞ ro (gm ro) Rs = ID2 6 V/µm (0.36 µm) = 21.6 k 0.1 mA to obtain Voltage gain is Av = -gm1 (ro1 ro2) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) Rs = ID2 6 V/µm (0.36 µm) = 21.6 k 0.1 mA to obtain Voltage gain is Av = -gm1 (ro1 ro2) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) Rs = ID2 6 V/µm (0.36 µm) = 21.6 k 0.1 mA to obtain Voltage gain is Av = -gm1 (ro1 ro2) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) Rs = ID2 6 V/µm (0.36 µm) = 21.6 k 0.1 mA to obtain Voltage gain is Av = -gm1 (ro1 ro2) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0 ro (gm ro) Rs Av = -(1.24 mA/V) (18 k 21.6 k) Rout 0)ro (gm ro) ro $\infty 2 = -12.2$ V/V Ex: 7.13 Av o remains unchanged at gm ro. IB VEB = VT ln ISB iB iE v EB DE (IS /a) B where IS 10-15 = 10-16 A β 10 0.091 × 10-3 = 0.025 ln 10-16 aiE ISB = VEB = 0.688 V Thus, VE = VB + VEB = 0 + 0.688 = 0.688 V If a transistor with β = 1000 is substituted, IC = IE 1 1 + β = 1 1 + 1 1000 = 0.999 mA + 10 v 20 0.252 = 6.25 mW = RL 10 0.25 V vo = 0.25 V/V = vs 1V Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 = 2 1 + + 9 25 49 π Voltage gain = Fraction of energy in first seven harmonics 1 1 1 8 + = 0.95 π Voltage gain = Fractin 1 + 9 25 49 π Voltage gain = F that is, in the fundamental and the third harmonic. (1) and (2) yields ix = ie1 [$\alpha + (1 - \alpha)(2 - \alpha)$] 2.5 V ix = ie1 [$2 - 2\alpha + \alpha 2$] (3) Chapter 7-30 Finally, vx can be expressed as the sum of the voltages across re3 and re1, Thus vx = ie3 re + ie1 re The voltage vx can be expressed as the sum of the voltages across 1/gm3 and 1/gm1 : ix = i2 Using Eq. (2) yields $vx = ie1 re(3 - \alpha)$ (4) Substituting i3 = i2 and i1 = i2, gm1 = gm3 = gm, and Dividing Eq. (4) by Eq. (3) yields Rin = $vx 3 - \alpha = re$ ix $2 - 2\alpha + \alpha 2vx = 2$ i2 /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 =
ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm But i2 = ix; thus For $\alpha 1$, Rin = 2re = 2 VT IREF vx = 2 iz /gm Bu Wilson current mirror in Fig. The current I splits equally between the two emitters. Assuming this to be the case, the analysis steps will be as follows: VCEsat = +4.8 V + 8 V + 8 WThus, IC 4.35 = 9.7 IB 0.45 VE = -3.9 V which is lower than β min, verifying that Q1 is indeed saturated. From our partial analysis on the figure, we can write IE1 = 0.1 mA IE2 = 5 mA Chapter 6-50 VB1 can be obtained as where VB1 $= 2.5 - 2 \mu$ A $\times 0.5$ M = 1.5 V re2 = and VB2 can be found as vo v b2 VB2 = VB1 - 0.7 = 0.8 V 25 mV = 55 mA 1000 = 0.995 V/V $1000 + 5 \text{ Rib2} = (\beta 2 + 1)(\text{re2} + \text{RL}) = 101 \times 1.005 = 101.5 \text{ k} 0.5 \text{ M} (c) \text{ Rin} = 1 \text{ M} 1 \text{ M} (\beta + 1)(\text{re1} + \text{Rib2}) 100 51 2.5 \text{ V} 2 \text{ A} 100 \text{ A} 0.1 \text{ mA where VT } 25 \text{ mV re} = = 250 = 0.25 \text{ k} \text{ IE1 } 0.1 \text{ mA } 0.05 \text{ mA } 50 \text{ A} 50 \text{ A} \text{ Rin} = 0.5 \text{ M} [51 \times (0.25 + 101.5)] \text{ k} 5 \text{ mA} = 0.5 \text{ M} 5.2 \text{ M} = 456 \text{ k v e1} \text{ Rib} 101.5 = \text{ v b1} \text{ Rib} + \text{ re1} 101.5 + 0.25 (b)$ Refer to the circuit in Fig. K= Rs + Ri Vs Vl = Vs For Rs = 10 k, Ri = 40 k, and Ci = 5 pF, $\omega 0 = f0 = C Rs 1 = 25$ Mrad/s 5 × 10-12 × (40 10) × 103 25 = 4 MHz $2\pi = RL Vl RL + Rs + RL RL + Rs + RL$ see that the current supplied through the 6-k resistor will exceed that drawn through the 12-k resistor, leaving sufficient current to keep D1 conducting. Consider first the diode-connected transistor Q2. Since re1 = re2, we obtain 1.8 V Q2 ie2 = ie1 Q1 (1) Node equation at node 1: ie3 + $\alpha ie2$ = ie1 + ie2 Using Eq. (1) yields 1.1 V ie3 = (2 - $\alpha)ie1$ Q3 ie2 = ie1 Q1 (1) Node equation at node 1: ie3 + $\alpha ie2$ = ie1 + ie2 Using Eq. (1) yields 1.1 V ie3 = (2 - $\alpha)ie1$ Q3 ie2 = ie1 Q1 (1) Node equation at node 1: ie3 + $\alpha ie2$ = ie1 + ie2 Using Eq. (1) yields 1.1 V ie3 = (2 - $\alpha)ie1$ Q3 ie2 = ie1 Q1 (1) Node equation at node 1: ie3 + $\alpha ie2$ = ie1 Q1 (1) Node equation at node 1: ie3 + $\alpha ie2$ = ie1 Q1 (1) Node equation at node 1: ie3 + $\alpha ie2$ = ie1 Q1 (1) Node equation at node 1: ie3 + $\alpha ie2$ = ie1 + ie2 Using Eq. (1) yields 1.1 V ie3 = (2 - $\alpha)ie1$ Q3 ie2 = ie1 Q1 (1) Node equation at node 1: ie3 + $\alpha ie2$ = ie1 Q1 (1) Node equation at node 1: ie3 + \alpha ie2 = ie1 Q1 (1) Node equation at node 1: ie3 + \alpha ie2 = ie1 Q1 (1) Node equation at node (2) Node equation at node 2: R 0.1 mA ix = α ie2 + (1 - α)ie3 IO VO Using Eqs. 6.56(b) and to the solution of Exercise 6.40 above. Denoting this resistance R, we gmb have 1 R = ro ro gmb 7.88 ro3 2ID 2 × 0.36 = = 2.4 mA/V VOV 0.3 gmb = χ gm = 0.2 × 2.4 = 0.48 mA/V \Rightarrow R = 3.3 k vgs vbs 1 20 × 0.2 × × 0.32 2 0.5 I = 0.36 mA = 360 μ A = gm = 0.2 × 0.4 = 0.48 mA/V \Rightarrow R = 3.3 k vgs vbs 1 20 × 0.2 × × 0.32 2 0.5 I = 0.36 mA = 360 μ A = gm = 0.2 × 0.4 = 0.48 mA/V \Rightarrow R = 3.3 k vgs vbs 1 20 × 0.2 × × 0.32 2 0.5 I = 0.36 mA = 360 μ A = gm = 0.2 × 0.4 = 0.48 mA/V \Rightarrow R = 3.3 k vgs vbs 1 20 × 0.2 × × 0.32 2 0.5 I = 0.36 mA = 360 μ A = gm = 0.2 × 0.4 = 0.48 mA/V \Rightarrow R = 3.3 k vgs vbs 1 20 × 0.2 × × 0.32 2 0.5 I = 0.36 mA = 360 μ A = gm = 0.2 × 0.4 = 0.48 mA/V \Rightarrow R = 3.3 k vgs vbs 1 20 × 0.2 × × 0.32 2 0.5 I = 0.36 mA = 360 μ A = gm = 0.2 × 0.4 = 0.48 mA/V \Rightarrow R = 3.3 k vgs vbs 1 20 × 0.2 × × 0.32 2 0.5 I = 0.36 mA = 360 μ A = gm = 0.2 × 0.4 = 0.48 mA/V \Rightarrow R = 3.3 k vgs vbs 1 20 × 0.2 × × 0.32 2 0.5 I = 0.36 mA = 360 μ A = gm = 0.48 mA/V \Rightarrow R = 3.3 k vgs vbs 1 20 × 0.2 × × 0.32 2 0.5 I = 0.36 mA = 360 μ A = gm = 0.48 mA/V \Rightarrow R = 3.3 k vgs vbs 1 20 × 0.2 × × 0.32 2 0.5 I = 0.36 mA = 360 μ A = gm = 0.48 mA/V \Rightarrow R = 3.3 k vgs vbs 1 20 × 0.2 × × 0.32 2 0.5 I = 0.36 mA = 360 μ A = 36 Now to obtain I = 0.2 mA, we write 1 mA 0.2 R = 0.7 - 0.025 ln 0.2 mA To obtain the required bias current, we use 1 W 2 VOV I = ID = μ n Cox 2 L v x gmbvbs = 27.8 27.8 1 0.48 = 1.81 k Thus, the open-circuit voltage gain is B v x Ro ix The figure shows the equivalent circuit of the source follower prepared for finding Ro . 6.52. P3.80. P7.87. Thus, where VA 100 = 100 k = ro = IC 1 IC = 0 11 - 1 = 0.1 mA 100 Thus, IC becomes 1.1 mA. vO 0.5 V 0 B vI vI 0.3 V vO RC 5 V A 5 V Chapter 6-6 This figure belongs to Problem 6.15(b). In the nonlimiting region 1000 vO = ≥ 0.94 vI 1000 + R R ≤ 63.8 During T1, v O = V1 = -t/RC At = T1 = T, v O = V1 = -T /RC Chapter 3-38 V1 0 From (1) + 0.1 + 0 and (2) we find that V'1 V2 T1 V1 = 2|V2| t V'2 Then using (1) and neglecting α V1 yields T2 3 |V2| = $20 \Rightarrow |V2|$ = 6.67 V V1 = 13.33 V where for T CR V1 V1 (1 - T/CR) = V1 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2, we have 6.67 V V1 = 13.33 V where for T CR V1 V1 (1 - T/CR) = V1 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2, we have 6.67 V V1 = 13.33 V where for T CR V1 V1 (1 - T/CR) = V1 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2, we have 6.67 V V1 = 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha)
The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V buring the interval T2 (1 - \alpha) The result is where α 1 13.33 V e-T/(CR/2) T |V2 | 1 - = |V2 | (1 - 2\alpha) RC/2 2 V Now V1 + |V2 | = 20 \Rightarrow V1 + |V2 | - α V1 = 20 (1) and V2 + V1 = 20 \Rightarrow V1 + |V2 | - α V1 = 20 (2) (h) Using a method similar to that employed for case (f) above, we obtain 13.33 V 6.67 V Exercise 4-1 IS 10-16 = 10-18 A β 100 IC 1 mA = VT ln = 25 ln IS 10-16 Ex: 4.1 iC = IS ev BE /VT iC2 v BE2 - v BE1 = VT ln iC1 0.1 v BE2 = 700 + 25 ln 1 = 25 × 29.9336 = 642 mV = 748 mV v BE3 10 = 700 + 25 ln 1 ISB = VBE Ex: 4.6 = 758 mV VCC 5 V Ex: 4.2 $\therefore \alpha = \beta \beta + 110 \text{ A} 150 50 \text{ VB}$, the transistor is operating in the active mode, as assumed. 4.15(a) with RC = 5.1 k and RE = 6.8 k. Since the amplifier is operating at IC IE = 100 µA = 0.1 mA and β = 100, 25 mV = 250 0.1 mA gm = 0.1 mA = 4 mA/V 0.025 V rm = β 100 = = 25 k gm 4 RL 1/gm CS To make CE responsible for 80% of fL, we use 1 = 0.8 ω L = 0.8 × 2mfL τ CE = Using the equivalent circuit in Fig. Since the right-hand side of Eq. (1) does not have any MOSFET parameters, these graphs apply for any n-channel MOSFET with the assumption that $\lambda = 0$. At node 2, we have a resistance R to ground and an equal resistance looking to the left. (a) Assume v id = 0 and the two sides of the differential amplifier are matched. 2.5 V The current I1 through the 10-k resistor is given by IE2 101 I1 = IC1 - IB2 = IC1 - 10 k 2 V Q1 IB VB Noting that the voltage drop across the 10 k resistor is equal to (IE2 × 8.2 + 0.7), we can write VE IE I1 × 10 = 8.2IE2 + 0.7 1 k Thus, IE2 = $0.56 \text{ V V3} = 0.56 \text$ to operate in saturation with the drain voltage as low as -0.8 V, and for it to have the minimum possible W/L, we operate Q5 at VGS1 = VGS2 so that ID2 = IREF ID2 (W/L)1 (ID3 = ID2 VGS3 = VGS4, thus IO = ID4 = IREF ID4 (W/L)3 (W/L)2 (W/L)4. Thus, R1 R4 R2 = R2nominal (1 -) 2.63 See solution to Problem 2.62 above. = 0.4 mA/V and \Rightarrow Dividing Eq. (2) by Eq. (1), we have 2= For k n = 50 μ A/V2 W = 20 L Vt = 0.5 V W 1 × $0.4 \times \times (1.8 - 0.5)$ 2 L For v GS = 2 V and v DS = v CS - Vt v DS - v 2DS 2 1 = 1 (2 - 0.5) × $0.1 - \times 0.12$ 2 = 0.145 mA = 145μ A For v GS = 2 V, pinch-off will occur for W = 5.92 L v DS = v GS - Vt v DS - v 2DS 2 1 = 1 (2 - 0.5) × $0.1 - \times 0.12$ 2 = 0.145 mA = 145μ A For v GS = 2 V, pinch-off will occur for W = 5.92 L v DS = v GS - Vt v DS - v 2DS 2 1 = 1 (2 - 0.5) × $0.1 - \times 0.12$ 2 = 0.145 mA = 145μ A For v GS = 2 V, pinch-off will occur for W = 5.92 L v DS = v GS - Vt v DS - v 2DS 2 1 = $1 (2 - 0.5) \times 0.1 - \times 0.12$ 2 = 0.145 mA = 145μ A For v GS = 2 V, pinch-off will occur for W = 5.92 L v DS = v GS - Vt v DS - v 2DS 2 1 = $1 (2 - 0.5) \times 0.1 - \times 0.12$ 2 = 0.145 mA = 145μ A For v GS = 2 V, pinch-off will occur for W = 5.92 L v DS = v GS - Vt v DS - v 2DS 2 1 = $1 (2 - 0.5) \times 0.1 - \times 0.12$ 2 = 0.145 mA = 145μ A For v GS = 2 V, pinch-off will occur for W = 5.92 L v DS = v GS - Vt v DS - v 2DS 2 1 = $1 (2 - 0.5) \times 0.1 - \times 0.12$ 2 = 0.145 mA = 145μ A For v GS = 2 V, pinch-off will occur for W = 5.92 L v DS = v CS - Vt v DS - v 2DS 2 1 = $1 (2 - 0.5) \times 0.1 - \times 0.12$ 2 = 0.145 mA = 145μ A For v GS = 2 V, pinch-off will occur for W = 5.92 L v DS = v CS - v and v DS = v CS - v A = v A = v A = v A = v A = v A = v A = v A = v A = v A = v A = v A = v A = v A = v A = v A = v A = v A = 2 - 0.5 = 1.5 V For L = 0.18 µm and the resulting drain current will be W = 1.07 µm iD = 5.18 For VGS = VDS = 1 V, the MOSFET is operating in saturation, = 1 k n (0.8 - Vt) 2 2 (2) Dividing Eq. (1) by Eq. (2) and taking square roots gives 1 - Vt 0.8 - Vt = 0.6 V Substituting in Eq. (1), we have $0.4 = 1 \text{ k} \text{ n} \times 0.422 \Rightarrow \text{ k} \text{ n} = 5 \text{ mA/V2 } 1 \text{ k} \text{ n}$ (v GS - Vt)2 2 1 × 1 × (2 - 0.5)2 2 = 1.125 mA ID = 2 = 1.5 - Vt 1 - Vt \Rightarrow k n = 1000 μ A/V2 For v GS = v DS = 1.8 V, the MOSFET is operating in saturation. 3. Using ID = IS eVD /VT, the required current I is found to be 3.9 mA. From the figure we Rin = ro1 1 rn1 rn2 gm1 Since ro1 rn1, g2 d2 g2, d2 Rin vgs2 1 gm2 gm2vgs2 S3 io = gm2 vn2 Since vn2 = vn1 = ii Rin, then the short-circuit current gain Ais is given by see that from a small-signal point of view it is equivalent to a resistance 1/gm2. For RL = 10 μ A × v oc = 10 μ A × v and Rs = 1 k. 7.20 (a) IC1 IREF = 0.1 mA g vgs d 1 mA VBE1 = $0.7 - 0.025 \ln 0.02 \text{ mA} = 2 \times \text{s} 0.1 = 0.002 \text{ mA} = 0.7 - 0.025 \ln 0.002 \text{ mA} = 2 \times \text{Figure 1 VBE3 Replacing the MOSFET with its hybrid-} model but neglecting ro results in the equivalent circuit in Fig. Rin = ro + RL 1 + gm$ $ro 20 + 20 = = 980 \ 1 + 2 \times 20 \ gm = 2ID \ 2 \times 0.2 = = 2 \ mA/V \ VOV \ 0.2 \ ro = VA \ 20 = = 100 \ k \ ID \ 0.2 \ Rout = ro + Rs + gm \ ro \ Rs \Rightarrow Rs = = 20 + 1 + 2 \times 20 \times 1 = 61 \ k \ VBIAS \ RL \ vo = vsig \ Rs + Rin = ID \ RS + Vt + VOV = 20 = 10.1 \ V/V \ 1 + 0.98 = 0.2 \times 2 + 0.5 + 0.2 \ Sin \ Si$ = 1.1 V Chapter 7-19 7.50 Refer to Fig. 9.10, we have τC1 = CC1 [(RB rπ) + Rsig] For CC1 to contribute 10% of fL, we use 1 = 0.1 × 2π × 50 \Rightarrow τC1 = 31.8 ms Thus, CC1 = 0.1 × 2π × 50 \Rightarrow 1) = 49.8 k Without Rf present (i.e., Rf = ∞), Rin = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0.1 1 + 1000 - 10 V/V Without Rf, -Av o = 10 V/V and Ro = 0.1 1000 0.1 k = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0.1 1 + 1000 - 10 V/V Without Rf, -Av o = 10 V/V and Ro = 0.1 1000 0.1 k = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0.1 1 + 1000 - 10 V/V Without Rf, -Av o = 10 V/V and Ro = 0.1 1000 0.1 k = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0.1 1 + 1000 - 10 V/V Without Rf, -Av o = 10 V/V and Ro = 0.1 1000 0.1 k = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0.1 1 + 1000 - 10 V/V Without Rf, -Av o = 10 V/V and Ro = 0.1 1000 0.1 k = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0.1 1 + 1000 - 10 V/V Without Rf, -Av o = 10 V/V and Ro = 0.1 1000 0.1 k = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0.1 1 + 1000 - 10 V/V Without Rf, -Av o = 10 V/V and Ro = 0.1 1000 0.1 k = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0.1 1 + 1000 - 10 V/V Without Rf, -Av o = 10 V/V and Ro = 0.1 1000 0.1 k = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0.1 1 + 1000 - 10 V/V Without Rf, -Av o = 10 V/V and Ro = 0.1 1000 0.1 k = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0.1 1 + 1000 - 10 V/V Without Rf, -Av o = 10 V/V and Ro = 0.1 1000 0.1 k = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0.1 1 + 1000 - 10 V/V Without Rf, -Av o = 10 V/V and Ro = 0.1 1000 0.1 k = 100 k and 1 - (1/100 × 1000) Av o = -100 × 0.1 0 + 1000 Av o
= -100 × 0.1 0 + 1000 Av o = -100 × 0.1 0 + 100 × RE = 0.025 ln 0.25 Ad = Gm Ro = 5 × 400 = 2000 V/V RE = 215 where |VA| 100 = 800 k ro2 = ro4 = I /2 0.125 thus Chapter 8-36 5 V Ro = 200 k 200 k = 100 k Ad = Gm Ro = 8 × 100 = 800 V/V Rid = 2r\pi = 2\beta/gm Q3 Q4 vO Q2 Q1 R 300 = 37.5 k 8 |VA| 40 = 100 k REE = I 0.4 The common-mode gain can be found = I IREF using Eq. (8.165): ro4 Acm = $-\beta3$ REE = -Q6 Q5 RE 5 V 200 = -0.013 V/V 150 × 100 The CMRR can be obtained from 800 | Ad | = = 60,000 CMRR = | Acm | 0.013 or 96 dB Gv = The output resistance of the Widlar current source is given by Eq. (7.102). vI (t) Ex: 2.17 Given v Icm = +5 V 10 V v Id = 10 sin ω t mV 2R1 = 1 k, R2 = 0.5 M 2 ms t 0 R3 = R4 = 10 $k 1 1 v I 1 = v I cm - v I d = 5 - x 0.01 sin \omega t 2 2 = 5 - 0.005 sin \omega t V 10 V 1 v I 2 = v I cm + v I d 2 = 5 + 0.005 sin \omega t V v - (op amp A2) = v I 2 = 5 + 0.005 sin \omega t V v I d = v I 2 - v I 1 = 0.01 sin \omega t v I d v O1 = v I 1 - R2 \times 2R1 = 5 - 0.005 sin \omega t V v O (t) t v - (op amp A2) = v I 2 = 5 + 0.005 sin \omega t V v I d = v I 2 - v I 1 = 0.01 sin \omega t v I d v O1 = v I 1 - R2 \times 2R1 = 5 - 0.005 sin \omega t V v I d = v I 2 - v I 1 = 0.01 sin \omega t V v I d = v I 2 - v I 1 = 0.01 sin \omega t v I d v O1 = v I 1 - R2 \times 2R1 = 5 - 0.005 sin \omega t V v I d = v I 2 - v I 1 = 0.01 sin \omega t V I d = v I 2 - v I I = 0.01 sin \omega t V I d = v I 2 - v I I = 0.01 sin \omega t V I d = v I 2 - v I I = 0.01 sin \omega t V I d = v I 2 - v I I = 0.01 sin \omega t V I d = v I 2 - v I I = 0.01 sin \omega t V I d = v I 2 - v I I = 0.01 sin \omega t V I d = v I 2 - v I I = 0.01 sin \omega t V I d = v I 2 - v I I = 0.01 sin \omega t V I d = v I I = 0.01 sin \omega t V I d = v I I = 0.01 sin \omega t V I d = v I I = 0.01 sin \omega t V I d = v I I = 0.01 sin \omega t V I d = v I I = 0.01 sin \omega t V I d = v I I = 0.01 sin \omega t V I d = v I I = 0.01 sin \omega t V I d =$ ω t) V v Id v O2 = v I 2 + R2 × 2R1 When v I = +10 V, the current through the capacitor will be in the direction indicated, i = 10 V/R, and the output voltage will decrease linearly from +10 V to -10 V. P5.52(e). P5.51(a): Assuming saturation-mode operation, we have 1 2 k n VOV 2 1 2 2 = × 4 VOV 2 \Rightarrow VOV = 1 V ID = VGS = |Vt| $V1 = 0 - VGS = -2 V V2 = 5 - 2 \times 2 = +1 V$ Since VDG = +1 V, the MOSFET is indeed in saturation. Since VD1 = VBE1, we have $IE2 = V1 = VE1 VC2 = 28 \times 0.1 = 2.8 V IC2 = IE = 28 mA$ This figure belongs to Problem 4.62, part (a). 4.6(b). 909 = 0.82 mV 1109 8.109 (a) With the two input terminals connected to a dc voltage of VDD / 2 = +0.6 Vand for Q1 - Q4 to conduct a current of 200 μ A, we have 1 W ID1,2 = k n V2 2 L 1,2 OV 1 W 200 = \times 540 × \times 0.152 2 L 1,2 (b) A1 is proportional to gm1,2, thus A1 increases by a factor of 2 and the overall voltage gain increases by a factor of 2. Thus, Rsig 10 k Q1 Q2 re = re1 v sig (a) Refer to Fig. (2) and (3) gives iC = iE = (\beta + 1) + (+ 1)ICBO |VBE | at 0° C = $0.7 + 0.002 \times 25 = 0.75$ V |VBE | at 100° C = $0.7 - 0.002 \times 75 = 0.55$ V The required value of RE can be found from 4.35 (a) If the junction temperature rises to 50° C, which is an increase of 30° C, the EB voltage decreases to VE - (-1.5) RE = IE v EB = 692 - 2 \times 30 = 632 mV - 0.76 + 1.5 = 3.66 k 0.202 To establish VC = 0.5 V, we select RC according to RE = RC = IS ev BE /VT = $\beta ICBO$ (b) First, we evaluate VT at $20 \circ C$ and at $50 \circ C$: VT = 1.5 - 0.5 = 5 k 0.2 kT q where $k = 8.62 \times 10 - 5 eV/K$. Thus the transistor must be in the saturation mode and IC = $\alpha IE = 0.99 \times 0.212 = 0.21 mAVC = VE - VECsat V12 = -3 + 0.21 \times 10 = -0.9 V = 3 - 0.2 = 2.8 V 4.58 4.57 5$ V 3 V RE IE 2.3 V IB 100 k VC IC RC RB VC IC IB = 2.3 V = 0.023 mA 100 k RC 5 V Chapter 4-22 We required IE to be nominally 1 mA (i.e., at $\beta = 100$) and to remain within ±10% as β varies from 50 to 150. Thus ID1 = ID2 1 W kn (1 - Vt) 2 2 L W 1 × 1.03 × (1 - Vt) 2 = k n 2 L Thus, ID2 = 1.03 ID1 That is, a 3% mismatch in the W/L ratios results in a 3% mismatch in the drain currents. The overall increase in ro is by a factor of $4 \times 4 = 16$. 1(b) (see figure below) is that in Fig. Thus Q1 will have a VBE 1 = 0.7×0.4 $100 \text{ IE} = \times 0.5 \text{ IC} = \alpha \text{IE} = \beta + 1100 + 1 = 0.495 \text{ mA VC} - (-2.5) \text{ RC} = \text{IC} - 0.5 + 2.5 = = 4.04 \text{ k} 4 \text{ k} 0.495 \text{ The transistor VEB can be found from}$ $0.5 \text{ mA VEB} = 0.64 + \text{VT} \ln 0.1 \text{ mA } 0.7 = 9 - 1 \times \text{RC} = 8.3 \text{ k} \text{ Since the meter reads full scale when the current flowing through it (in this case, IB is 50 \mu A), a full-scale reading corresponds to 1 mA 0.7 = 9 - 1 \times \text{RC} = 8.3 \text{ k} \text{ Since the meter reads full scale when the current flowing through it (in this case, IB is 50 \mu A), a full-scale reading corresponds to 1 mA 0.7 = 9 - 1 \times \text{RC} = 8.3 \text{ k} \text{ Since the meter reads full scale when the current flowing through it (in this case, IB is 50 \mu A), a full-scale reading corresponds to 1 mA 0.7 = 9 - 1 \times \text{RC} = 8.3 \text{ k} \text{ Since the meter reads full scale when the current flowing through it (in this case, IB is 50 \mu A), a full-scale reading corresponds to 1 mA 0.7 = 9 - 1 \times \text{RC} = 8.3 \text{ k} \text{ Since the meter reads full scale when the current flowing through it (in this case, IB is 50 \mu A), a full-scale reading corresponds to 1 mA 0.7 = 9 - 1 \times \text{RC} = 8.3 \text{ k} \text{ Since the meter reads full scale when the current flowing through it (in this case, IB is 50 \mu A), a full-scale reading corresponds to 1 mA 0.7 = 9 - 1 \times \text{RC} = 8.3 \text{ k} \text{ Since the meter reads full scale when the current flowing through it (in this case, IB is 50 \mu A), a full-scale reading corresponds to 1 mA 0.7 = 9 - 1 \times \text{RC} = 8.3 \text{ k} \text{ Since the meter reads full scale when the current flowing through it (in this case, IB is 50 \mu A), a full-scale reading corresponds to 1 mA 0.7 = 9 - 1 \times \text{RC} = 8.3 \text{ k} \text{ scale when the current flowing through it (in this case, IB is 50 \mu A), a full-scale reading corresponds to 1 mA 0.7 = 9 - 1 \times \text{RC} = 8.3 \text{ k} \text{ scale when through it (in this case, IB is 50 \mu A), a full-scale reading corresponds to 1 mA 0.7 = 9 - 1 \times \text{RC} = 8.3 \text{ k} \text{ scale when through it (in this case, IB is 50 \mu A), a full-scale reading corresponds to 1 mA 0.7 = 9 - 1 \times \text{RC}$ IC = 20 β = IB 50 μ A If the meter reads 1/5 of full scale, then IB = 10 μ A and 1 mA β = 100 10 μ A meter reading of 1/10 full scale indicates that 1 mA = 200 β = 5 μ A = 0.68 V 4.29 Refer to Fig. Thus, 111 + = -vi gm - vo ro RG2 RG2 1 vo = - gm - (ro RG2) RG2 vi gm = |v^o| = |v^o| = 0.5 + 2.375 - |v^o| |Av| Thus, RG2 3 M 0.95 + 2ID $2 \times 0.2 = 0.894 \text{ mA/V} = \text{VOV } 0.45 \text{ VA } 20 = 100 \text{ k} = \text{ID } 0.2$ 1 vo = $-0.89 - \times (100 \ 3000) \text{ vi } 3000 \text{ ro} = -86.5 \text{ V/V}$ To obtain the maximum allowable negative signal swing at the output, we first determine the dc voltage at the output, we first determine the dc voltage at the output, we first determine the dc voltage at the output by referring to Fig. IE1 = IE2 = 0.2 \text{ mA } \text{IC1} = \text{IC2} = \alpha \times 0.2 = 0.99 \times 0.2 = 0.198 \text{ mA} 0.198 VBE1 = VBE2 = $0.7 + 100 \times 100 \times 100 \text{ vi } 3000 \text{ ro}$ referring to Fig. IE1 = IE2 = 0.2 mA IC1 = IC2 = $\alpha \times 0.2 = 0.99 \times 0.2 = 0.198 \text{ mA}$ 0.198 VBE1 = VBE2 = $0.7 + 100 \times 100 \times 100 \text{ vi } 3000 \text{ ro}$ referring to Fig. IE1 = IE2 = 0.2 mA IC1 = IC2 = $\alpha \times 0.2 = 0.99 \times 0.2 = 0.198 \text{ mA}$ 0.198 VBE1 = VBE2 = $0.7 + 100 \times 100 \times 100 \text{ vi } 3000 \text{ ro}$ referring to Fig. IE1 = IE2 = 0.2 mA IC1 = IC2 = $\alpha \times 0.2 = 0.99 \times 0.2 = 0.198 \text{ mA}$ 0.198 VBE1 = VBE2 = $0.7 + 100 \times 100 \times 100 \text{ vi } 3000 \text{ ro}$ referring to Fig. IE1 = IE2 = 0.2 \text{ mA} IC1 = IC2 = $\alpha \times 0.2 = 0.99 \times 0.2 = 0.198 \text{
mA}$ 0.198 VBE1 = VBE2 = $0.7 + 100 \times 100 \times 100 \times 100 \text{ vi } 3000 \text{ ro}$ referring to Fig. IE1 = IE2 = 0.2 \text{ mA} IC1 = IC2 = $\alpha \times 0.2 = 0.99 \times 0.2 = 0.198 \text{ mA}$ 0.198 VBE1 = VBE2 = $0.7 + 100 \times 100 \times 100 \times 100 \times 100 \text{ vi } 3000 \text{ ro}$ referring to Fig. IE1 = IE2 = 0.2 \text{ mA} IC1 = IC2 = $\alpha \times 0.2 = 0.99 \times 0.2 = 0.198 \text{ mA}$ 1.100 × 100 × 100 \times 1 $0.025 \ln 1 \text{ VCC} 2.5 \text{ V RC} 5 \text{ k RC} 5 \text{ k VC1 VC2} = 0.660 \text{ V VE1} = \text{VE2} = -1 - 0.66 = -1.66 \text{ V } 0.5 \text{ V VC1} = \text{VC2} = \text{VCC} - \text{IC1.2 RC} 12 \text{ C1} \text{ Q1} \text{ Q2} = 2.5 - 0.198 \times 5 = +1.51 \text{ V VE} 8.24 0.4 \text{ mA VCC} 2.5 \text{ V IC1 IC2 RC} 5 \text{ k VC1 VC2} = 0.5 \text{ V Q1} \text{ Q2 VEE} 2.5 \text{ V (b)}$ (b) With v B1 = -0.5 V, Q1 turns off and Q2 conducts all the bias current (0.4 mA) and thus exhibits a VBE of 0.677 V, thus VE = -0.677 V VE 0.4 mA VEE 2.5 V (a) (a) For v B1 = +0.5 V, Q1 conducts all the current I (0.4 mA) while Q2 cuts off. Thus VCC 5 V VICM max = VC1 + 0.4 = 4.3 + 0.4 = 4.7 V Q3 Q4 Thus the input commonmode range is vO Q2 Q1 -4 V \leq VICM \leq +4.7 V The common-mode gain can be found using Eq. (8.165): Acm = -R I I Q6 Q5 ro4 β 3 REE Here, ro4 = |VA| 100 = 800 k I /2 0.125 β 3 = 100 REE = ro5 = 5 V Gm = gm1,2 I /2 VT I /2 5 = VT Thus Acm = -800 = -0.02 V/V 100 × 400 The CMRR can be found as CMRR = \Rightarrow I = 0.25 mA Utilizing two matched transistors, Q5 and Q6, the value of R can be found from 0 - (-5) - 0.7 = 0.25 mA I = R \Rightarrow R = 17.2 k β 100 = 40 k = 2×Rid = 2r π = 2 gm 5 Ro = ro2 ro4 |VA| 100 = = 400 k I 0.25 |Ad| 2000 = = 100,000 |Acm| 0.02 or 100 dB 8.101 See figure on next page. 20 log Av o = 40 dB \Rightarrow Av o = 100 V/V vo Av = vi 500 = 100 × 500 + 100 = 83.3 V/V 1.43 1V 1 M For a peak output sine-wave current of 20 mA, the peak output voltage will be 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output is possible is that for which this output voltage will be 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA, the peak output voltage will be 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which this output sine-wave current of 20 mA × 500 = 10 V. P8.47. The highest frequency at which the highest frequency at 5 V (0.1 + 0.2 + 0.4 + 0.8) mA 7.14 There are various ways this design could be achieved, but the most straightforward is the one shown: 4 2 Q1 1 8 + 5 V (0.1 + 0.5 + 1 + 2) mA PT = 7.5 mW + 18 mW = 25.5 mW 7.15 Refer to the circuit in Fig. For saturation-mode operation of an NMOS transistor, $v DG \ge -V \text{transistor}$, $v DG \ge -V \text{transistor}$, mode operation. Chapter 3-11 \therefore We need 8 diodes. (1) and (2) and selecting (arbitrarily) RP0 = 10 k results in RP1 = 10 k and RP2 = 3.33 k. Ex: 9.23 From Eq. (9.120), we obtain Rsig Rsig + RL RL + = gm RL + 1 gm R $\times 13.9 \times 10 - 12 \times 25 = 458$ MHz Rsig R + C + C Rsig 1 + RL Cn + Cµ 1 + L n L re rn Thus, Rgs = = $\beta + 10.99 = 0.97$ V/V 0.99 + 0.025 + (1/101) Cn + Cµ = ft = |AM| fH = 242 \times 470 = 113.8 MHz Rsig RL qm RL + 1 b1 = Rsig R 1 + L + re rn 0.99 13.9 + 21 + ×1 + (13.9 + 0)0.99 0.025 = 10.99 + 1 + 0.025 2.5 = 2.66 × 10 - 9 s b2 = Cn Cu RL Rsig $13.9 \times 2 \times 0.99 \times 1 = 0.991$ Rsig RL 1 + + 1 + + 0.025 2.5 rn re = $0.671 \times 10 - 18$ Exercise $9-7 \omega P 1$ and $\omega P 2$ are the roots of the equation Ex: 9.28 Ad = gm1,2 (ro 2 ro 4) 1 + b1 s + b 2 s = 0 where Solving we obtain, 0.5 = 20 mA/V 0.025 100 = 200 k ro 2 = ro 4 = 0.5 Ad = $20(200 \ 200) = 2000$ V/V 2 gm1,2 = fP 1 = 67 MHz fP 2 = 563MHz Since fP 1 fP 2, The dominant high-frequency pole is that introduced at the output node, fH fP 1 = 67 MHz Ex: 9.26 (a) ID 1.2 = 1 W un Cox V2 2 L 1.2 OV 1 2 × 0.4 = $4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 × 0.4 = 4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV } 0.2 \text{ (b) Ad} = qm = 2ID 2 \times 0.4 \text{ mA/V VOV }$ $2\pi(CL + Cgd 1 + Cdb)(RD ro) 1 2\pi(100 + 10 + 10) \times 10 - 15 \times 4.545 \times 103 = 292 \text{ MHz}(d) \tau gs = Cgs Rsig = 50 \times 10 = 500 \text{ ps } \tau gd = Cgd [Rsig (1 + gm RL) + RL] = 10[10(1 + 18.2) + 4.545] = 1965.5 \text{ ps } \tau CL = (CL + Cdb)(RL = 110 \times 4.545) = 500 \text{ ps } \tau H = \tau gs + \tau gd + \tau CL = 500 + 1965.5 + 500 = 2965.5 \text{ ps } 1 \text{ fH} = 2\pi \times 2965.5 \text{ sc}$ 10-12 = 53.7 MHz Ex: 9.27 fZ = = fH = = 12π CL (ro 2 ro 4) $12\pi \times 2 \times 10-12 \times 100 \times 103 = 0.8$ MHz Ex: 9.29 (a) AM = -gm RL where RL = RL ro = $20\ 20 = 10\ k$ AM = $-2\ 10 = -20\ V/V\ TH = Cgs$ Rgs + Cgd Rgd + CL RL = Cgs Rsig + Cgd [Rsig (1 + gm RL) + RL] + CL RL = $20\ \times 20 + 5[20(1 + 20) + 10] + 5\ \times 10 = 400 + 2150 + 50 = 10$ 2600 ps fH = 1 $2\pi \times 1600 \times 10 - 12 = 61.2 \text{ MHz}$ GB = | AM | fH = 20 × 61.2 = 1.22 GHz (b) Gm = qm 2 = 0.67 mA/V = 1 + qm Rs 1 + 2 Ro ro (1 + qm Rs) = 20 × 3 = 60 k 1 $2\pi \times 75 \times 103 \times 0.4 \times 10 - 12 = 5.3 \text{ MHz}$ Thus, the 3-dB frequency of the CMRR is 5.3 MHz. RL = RL Ro = 20 60 = 15 k AM = -Gm RL = -0.67 × 15 + 10 + 20 k AM = -Gm RL = -0.67 × 15 + 10 + 20 k AM = -Gm RL = -0.67 mA/V = 1 + qm Rs $= -10 V/V Rgd = Rsig (1 + Gm RL) + RL = 20(1 + 10) + 15 = 235 k Exercise 9 - 8 RCL = RL = 15 k fP 2 = Rsig + Rs + Rsig Rs / (ro + RL) ro 1 + gm Rs ro + RL Rgs = = 1 2 \pi C \mu RL 1 2 \pi \times 2 \times 10 - 12 \times 10 \times 103 where = 8 MHz 2 = 1 k Rs = gm T (s) = 20 \times 1 20 + 1 + 20 + 20 Rgs = 20 1 + 2 \times 20 + 20 = 10.75 k \tau H = Cgs Rgs + Cgd Rgd + CL RCL$ $= 20 \times 10.75 + 5 \times 235 + 5 \times 15 = 215 + 1175 + 75 = 1465$ ps fH = 1 = 109 MHz $2\pi \times 1465 \times 10 - 12$ GB = 10 × 109 = 1.1 GHz Ex: 9.30 Refer to Fig. 3.24. Thus = REE = [1 + gm5 (RE rn 5)]ro5 where gm5 I 0.25 mA = 10 mA/V = = VT 0.025 V rn 5 = β 100 = 10 k = gm5 10 100 VA = = 400 k I 0.25 = [1 + 10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid +
10(0.215 10)] × 400 Rid × Ad Rid + 10(0.215 10)] × 400 Rid × Ad Rid Rsig 37.5 × 800 = 444.4 V/V 37.5 + 30 8.103 Refer to Fig. We design for a minimum voltage of |VOV| across each of Q1 and Q2. VC = VCC = +10 V and IC = Ex: 4.21 Refer to the circuit in Fig. Assuming active-mode operation, we obtain 5 - 0.7 = 3.6 mA 10 1+ 51 VE = -3.6 VIE = IC + IB results in VE = 0.5 - 0.1(VE + 0.2) + 0.25 - 0.05(VE + 0.2 $28 11100 59 111011 (c) v = 0.1 sin(2000t), V (d) v = 0.1 sin(2\pi \times 103 t), V \sqrt{1.29} (a) Vpeak = 117 \times 2 = 165 V \sqrt{(c)} Vpeak = 220 \times 2 = 311 V \sqrt{(d)} Vpe$ 0 1 0 -2 1 0 1 1 -3 1 1 0 0 -4 Average value = 0.5 V 1 1 0 1 -5 Peak-to-peak value = 1 V 1 1 1 0 -6 1 1 1 1 -7 1.30 Comparing the given waveform has an amplitude of 0.5 V (1 V peak-to-peak) and its level is shifted up by 0.5 V (the first term in the equation). In addition, the four op amps can all share one terminal for positive power supply and one terminal for negative power supply. Vq = Vsiq RG + Rsiq + qm Vq YS YS + qm - 1 qm + sCS RS Is = 1 Vq qm + $gm + 1/RS 2\pi CS fP2 = fZ = Thus$, $fP1 = s + 1/CS RS gm + 1/RS + CS 1 2\pi CS RS$ where We required gm = 5 mA/V and $RS = 1.8 k fP1 \le 10 4 2\pi CS rS$ where We required gm = 5 mA/V and $RS = 1.8 k fP1 \le 10 4 2\pi CS rS$ where We required gm = 5 mA/V and $RS = 1.8 k fP1 \le 10 4 2\pi CS rS$ where $RS = 1.8 k fP1 \le 10 4 2\pi CS rS$ where $RS = 1.8 k fP1 \le 10 2\pi CS rS$ where RS = 1.8 k rSSelect CS = 10 µF. 2 2 Note: V, mA, k, and mW constitute a consistent set of units. (a) Each of the three transistors is operating at ID = IREF. = 10 10 1018 × × 16 20 5 10 Ip = 100 In Now I = Ip + In = 100 In + In = 1 mA In = 1.88 Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, ND = 1016 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1017 cm - 3, and ni = 1.5 × 1010, we have V0 = 754 mV Using Eq. (1.46) with NA = 1000 mV Using Eq. (1.46) with N (1.55) with VR = 5 V, we have W = 0.907 µm. 0.02 VA ~ = ID ro = 0.5 × 50 = 25 V λ = 1 = 0.04 V - 1 VA 5.29 VA = VA L, where VA is completely process VA dependent. factor = 0.5 (c) W and L are doubled \rightarrow rDS is unchanged. Transistor Q5 must carry a current of 400 µA, thus 1 W 400 = k n V2 2 L 5 OV W 1 = × 540 × × 0.152 2 L 5 W \Rightarrow = 65.8 L 5 (c) $0.15 V \le v O \le (1.2 - 0.15)$ that is, $0.15 V \le v O \le 1.05 V$ Similarly, Q7 is required to conduct a current of 400 µA, thus $W W = 65.8 L 7 L 5 Q4 Q5 Q6 Q7 |VA| = 4.5 k 0.4 mA 0.4 A2 = -gm6 (ro6 ro7) = -5.33(4.5 4.5) = 12 V/V A0 = A1 A2 = -12 \times -12 -1$ 144 V/V 8.110 Refer to Fig. CC Vo ale Rsig RC RL Vsig V b Ie re CE Zin Figure 1 9.11 Replacing the BJT with its T model results in the equivalent circuit shown in Fig. $\sqrt{}$ The rms value of the fundamental will be 441/2 = 312 mV. T (s) = R2 R2 + R1 + R2
R1 + R indicate that this amplifier has a low-pass STC frequency response with a low-frequency gain of 40 dB, and a 3-dB frequency of 104 Hz. From our knowledge of the Bode plots for low-pass STC networks [Fig. (b) Replacing the MOSFET with its hybrid-II model, we obtain the equivalent circuit shown in Fig. For this RD we have to recalculate ID := VD \Rightarrow RD = ID = 1 × 1 × (VGS - 1)2 2 1 (VDD - RD ID - 1)2 2 (VGS = VD = VDD - RD ID) = 1 (4 - 6.2 ID) 2 \Rightarrow ID ~ = 0.49 mA 2 VD = 5 - 6.2 × 0.49 = 1.96 V ID = Ex: 6.32 RD = VDD - VD 5-2 = 6 k = ID 0.5 \Rightarrow RD = 6.2 k ID = 1 W 2 1 2 k V \Rightarrow 0.5 = × 1 × VOV 2 n L OV 2 Ex: 6.34 Refer to Example 6.12. The voltage v id is required to produce v od in the direction shown which is opposite in direction to VO and of course |v od| = |VO|, thus 1 Ad v id = Gm Ro v id = Gm Ro v id 20 + Ro 2 Thus, Ro = 20 k Ad (with RL = ∞) = Gm Ro v id = Gm Ro v id 20 + Ro 2 Thus, Ro = 20 k Ad (with RL = ∞) = Gm Ro v id 20 + Ro 2 Thus, Ro = 20 k Ad (with RL = ∞) = Gm Ro v id = Gm Ro v id 20 + Ro 2 Thus, Ro = 20 k Ad (with RL = ∞) = Gm Ro v id = Gm Ro v id 20 + Ro 2 Thus, Ro = 20 k Ad (with RL = ∞) = Gm Ro v id = Gm Ro v id 20 + Ro 2 Thus, Ro = 20 k Ad (with RL = ∞) = Gm Ro v id = Gm Ro ro4 For Q3 ro2 = ro4 = $|VA| = I/2I/252 \times 5 \times 0.5 = II2.515$ Ro = $\times = 2II$ Thus, = Q1 Q2I2.5I × = 10 V/V Ad = Gm Ro = 0.25I8.80 Q4 $|VA|LQ8 Q7 Q5 Q6 1IW 2 = \mu n Cox VOV 2 2 L 1 2 \times 0.2 \times 50 \times VOV 2 \Rightarrow VOV = 0.14 V 0.1 = gm1, 2 = 2 \times (I/2) 2 \times 0.1 = 1.4 mA/V = VOV 0.14 VSS <math>|V| \times L|VA| 5 \times 0.5 = A = ro2 = ro4 = I/2I/2 0.1 = I/2I$ $25 \text{ k} \Rightarrow \text{VOV} = 0.2 \text{ VA} = \text{gm1}, 2 \text{ (ro2 ro4)} \text{ VGS} = \text{Vt} + |\text{VOV}| = 1.4 \times (25 25) = 0.5 + 0.2 = 0.7 \text{ V} = 17.5 \text{ V/V For Q5}, Q6, Q7, and Q8 : ID = 0.2 \text{ mA} 8.81 \text{ Ad} = \text{gm1}, 2 \text{ (ro2 ro4)} \text{ WID gm1}, 2 = 2 \text{ kn} \text{ L} \sqrt{\sqrt{4}} = 4 \text{ I} = 2 \text{ I ro2} |\text{VA}| 2 \text{ VA} | 2 \text{$ 0.28 V 0.2 = VGS = 0.5 + 0.28 = 0.78 V From the figure we see that for each transistor to operate at VDS at least equal to VGS, the total power supply is given by VDD + VSS = VDS4 + VDS2 + VDS7 + VDS6 = 0.7 + 0.78 + 0.78 + 0.78 = 2.96 3.0 \text{ V} 8.83 8.82 See figure. The required value of RE can now be determined as -1.7 - (-5) 3.3 RE = = 3.3 k IE 1 mA RB = Rin = RB $[(\beta + 1)[\text{re} + (\text{RE ro RL})]$ where ro = VA 100 V = 100 k = IC 1 mA Rin = 100 (100 + 1)[0.025 + (3.3 100 1)] = 44.3 k Rin 44.3 vi = = 0.469 V/V v sig Rin + Rsig 44.3 + 50 RE ro RL vo = 0.968 V/V vi re + (RE ro RL) vo = 0.469 × 0.968 = 0.454 V/V Gv = v sig RB + Rsig RB + Rout = ro RE re + β +1 100 50 = 100 3.3 0.025 + 101 = 320 Chapter 6-1 6.1 Coordinates of point A: v GS = Vt = 0.5 V and v DS = VDD = 5 V. 6.54.9 - 7.2 = 10.69 mA 0.167 IL = I - IZ = 10.69 I R and VO VZ 10 - VO 10 - 7.5 R = = 167 I 15 When the supply undergoes a change VS, the change in the output voltage, VO, can be determined from VO (RL rz) + R IZ IL RL Chapter 3-23 VZ = VZ0 + IZT rz and RL is at its lowest value, to maintain regulation, the zener current must be at least equal to IZK, thus 9.1 = VZ0 + $0.009 \times 40 \Rightarrow VZ0 = 8.74 V IZ = 0.5 mA$ For IZ = 10 mA, $VZ = VZK VZ0 8.74 VZ = 8.74 + 0.01 \times 40 = 9.14 v IL = I - IZ = 15.87 mA 0.3 15 - 9.14 = 306$ 19.4 RL = VZ 8.74 = 589 = IL 15.37 Select R = 300 The lowest value of output voltage = 8.74 V Denoting the resulting output voltage VO, we obtain Line regulation = I = IL = 15 - VO 0.3 (1) VO 1 (2) VO - VZ0 VO - 8.74 = IZ = rz 0.04 = 113 mV/V Load regulation = -(rz R) = -(40 300) = -35 mV/mA (3) Since I = IZ + IL, we can use (1)-(3) to obtain VO : VO - 8.74 15 - VO = + VO 0.3 0.04 Or using the results obtained in this problem: For a reduction in IL of 4.6 mA, VO = +0.16 V, thus Load regulation = $- \Rightarrow$ VO = 9.15 V VO = VS rz RL (rz RL) + R (0.04 1) = $\pm 1.5 \times (0.04 1) + 0.3 = \pm 0.17$ V If IL is reduced by 50%, then IL = I = IZ = $19.15 \times = 4.6$ mA 2 1 15 - VO 0.3 15 - VO VO - 8.74 = +4.6 0.3 0.04 \Rightarrow VO = 9.31 V which is an increase of 0.16 V. For the circuits in (a) and (b) to remain in saturation, VD must not fall below VG by more than Vt. 2.14 Gain is 46 dB vI 5 k 0V vO 2.17 R1 = R1nominal (1 ± x%) |G| = R2 R2nominal (1 ± x%) |G| = R2tolerance of the closed-loop gain is $\pm 2x\%$. For v I = 1 V, v O = G × v I = 9.99 V, therefore, v + - v - = 9.99 vO = = 0.0999 mV 1 mV A 104 (a) R1 = R3 = 2 k, R2 = R4 = 200 k If A = 105, then G = 9.999 and = -0.01\% Since R4 / R3 = R2 / R1 we have: For v I = 1 V, v O = G × v I = 9.999 thus, Ad = 9.999 vO = = 0.0999 mV v + - v - = A 105 0.1 mV occurs when the resistor tolerances are such that the quantity in parentheses is maximum. Since the cathode of D1 will be 12.5 + 13.2 = 25.7 V. The drop in gain is This in turn will happen if 11111 = +C1 R1 C1 + C2 R1 R2 1+ 1 20 log This transfer function will be independent of frequency (s) if the second factor reduces to unity. It furthers the University's objective of excellence in research, scholarship, and education by publishing worldwide. Each is a full-wave rectifier similar to that of the tapped-transformer circuit. Thus their currents must be related by the ratio of their scale currents IS, which are proportional to the

junction areas. V DS $2V \Rightarrow IO = = 0.025$ mA ro = I O 80 k Ex: 5.7 5 V 1 W 2 k V in saturation 2 n L OV Change in ID is: Ex: 5.3 ID = VG ID (a) double VDS, no change (ignoring length modulation) k p = 60 μ A/V2 (e) changes (a)-(d), 4 W = 10 \Rightarrow k p = 600 μ A/V2 L (a) Conduction occurs for VSG \geq |Vtp | = 1 V Case (c) would cause leaving saturation if VDS < 2VOV Ex: 5.4 For saturation v DS \geq VOV , so VDS must be changed to 2VOV ID = 1 W 2 k V, so ID increases by a factor of 4. (a) Ie = See Fig. 1 we see that ID1 0.1 mA/V But ID1 = 1 W 2 µn Cox VOV 2 L 1 2 0.1 = × 2 × VOV 2 \Rightarrow VOV = 0.316 V VGS = Vt + VOV = 1.316 V V Rin vo = × Av vsig Rin + Rsig vo $487 \times -19.5 = vsig 487 + 500 = -9.6$ V/V (e) The suggested configuration, shown partially in Fig. Equation (2.19) can be employed to evaluate the worst-case common-mode gain. 1.5 V R RL ≤ 2 k. v D1 = v D2 = VDD - iD1,2 RD v D2 = VDD - iD2 RD = 1 - 0.08 × 5 = 0.6 V = $1 - 0.8 \times 5 = 0.6$ V = $1 - 0.8 \times$ iD1 = 0.12 mA and iD2 = 0.04 mA, $1 W (v GS2 - Vtn) 2 iD2 = \mu Cox 2 L 0.04 = 1 \times 0.4 \times 10 \times (v GS2 - 0.4) 2 2 \Rightarrow v GS2 = 0.541 V Thus$, v S = -0.541 V Thus, Therefore: W ratio must stay L W is kept at 10) L VA = ro iD = 100 k × 0.2 mA = 20 V (for the standard device) W = 5 × 10 = 50 μ m (so VA = 5 × 20 = 100 V (for the new device) 5.30 L = 1.5 μ m = 3× minimum. To determine Rin , we have applied a test voltage vx . So v O = 0 and v D = v I - v O = v I . For VD Vs , conduction angle π , and v O, avg = vO vS vS $2 2 \text{ Vs} - \text{VD} = \text{Vs} - 0.7 \, \pi \, (a)$ For v O, avg = $10 \text{ V} \, \pi \times 10.7 = 16.8 \text{ V} 2 \sqrt{120} 2 = 10.1$ to 1 Turns ratio = 16.8 D4 R D2 Vs = (b) For v O, avg = $100 \text{ V} \, \pi \times 100.7 = 158.2 \text{ Vs} = 3.70$ Refer to Fig. Since the collector is connected to the base with a 10-k resistor and β is assumed to be very high, the voltage drop across the 10-k resistor will be close to zero and the base voltage will be equal to that of the collector: I5 = IE = VB = V7 This also implies active-mode operation. P5.22. This can be achieved by shunting the input of the v 1 transconductance Chapter 1-18 This figure belongs to Problem 1.53. Thus 0.1 0.1 IO1 = = = 0.0999 mA 2 2 1 + 2 vO 1 + Q.E.D. = -2 v Id R1 RG R2 RG The circuit on the left ideally has infinite input resistance (iii) <math>vO = +2 V/V vi R2 = 1. (1) and (2) and using $2 = VOVP + \mu Cox = 3\mu Cox gives 3VOVN \sqrt{ID2} = ID1 = -1 W 2 \mu Cox VOVP 2 L |VOVP| = 5 = 2.5 V 2 3 VOVN 1 W \mu Cox (VGS1 - Vt) 2 2 L 1 10 × 50 × (2.5 - 1) 2 1 = 562.5 \mu A Now, Q3 has the$ same VGS at Q1 and is matched to Q1. Thus ID = 1.2 k n VOV = 1.2 k n VOV = 0.2 V = 1.2 vov = 0.2 V = 0.2vO 100 kΩ 10 kΩ βv O1 = v - 2 βv O1 βv O1 = v - 2 βv O1 βv O1 = v O1 = R R β - 1 B v1 - 100 kΩ Calculate v O2 : v O2 v O2 = v + \Rightarrow vO2 = 1 - βv O2 = 2 2 v2 \Rightarrow v O2 = 1 - βv O2 = 2 2 v2 \Rightarrow v O2 = v + \Rightarrow vO2 = 1 - βv O2 = v + \Rightarrow vO2 = 1 - βv O2 = v + \Rightarrow vO2 = v obtain the following circuit: 100 k (1011) v (1011) v I2 (100 // 10) k = vO v1 v2 + β - 1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - β Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - \beta Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - \beta Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - \beta Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - \beta Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - \beta Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - \beta Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - \beta Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - \beta Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 = v2 - v1 1 - \beta Ad = (100 // 10) k I1 v O = v O1 + v O2 = vO 1 + v O2 = v $11 = 10(v I 2 - v I 1) 6.8 = 0.9 \Rightarrow R5 = 756 6.8 + R5$ For v I 1 = v I 2 = v Icm, v O = 0, thus 2.66 See partial analysis on circuit diagram on next page. Rin Gv = -gm (RD RL ro) $RG + Rsig 10 \times 3 \times (10\ 20\ 100) 10 + 1 = -17\ V/V = -6.108$ (a) Refer to Fig. Thus it is not a good method for biasing the BJT. Thus x 1 Rs $100 \le x - 1 = x \operatorname{Ri} 1 - 1 - 100 \operatorname{100} \operatorname{A0} x$ (Ro RL) $1 - 100 \operatorname{Gm} \ge$ which can be expressed as (5) Substituting Rs = 10 k and x = 10% in (3) results in Rs V s $11 + \ge 2\pi \operatorname{CL} \operatorname{f3dB} \operatorname{RL} \operatorname{Ro} \operatorname{Bandwidth} = 159 \operatorname{kHz}$. \therefore T (s) = Ti (s)To (s) = 100 - 1 x Vi Ri Ro Gm Vi RL Vo CL Ro \le 1 2 π × 2 × 10 × 20 × 10 - 12 - 6 = 6.61 k 1 104 Chapter 1-26 Substituting A0 = 100, x = 10%, RL = 10 k, and Ro = 6.61 k, Eq. (5) results in 100 = 27.9 mA/V 10 (10 6.61) × 103 1 - 100 which, using Eq. (1), can be expressed in the alternate form 1 R2 R1 + R2 Gm \ge Vo = Vi 1.72 Using the voltage divider rule, we obtain Thus when the attenuator is compensated (C1 R1 = C2 R2), its transmission can be determined either by its two resistors R1, R2 or by its two res the signal across Re must be 50 - 5 = 45 mV and thus Re = 9re We choose to operate at this value of I. It follows that for the circuit in Fig. The gain of the first stage is Av 1 = -gm1 (ro1 /2) is the equivalent resistance at the output of Q1 and includes ro1 in parallel with the output resistance of the current-source load, which is equal to ro1. However, Ro will be increased to I Ro = 5 × 200 k = 1 M vo If the amplifier is fed with a signal source having Rsig = 5 k and a 100-k load resistance is connected to the output, the equivalent circuit shown below results. The results of part (a), however, will not change. Thus, at no load VZ $5.1 V \therefore$ Total conduction angle = $180 - 2\theta = 175.2 \circ$ For line regulation: b. (1 1) 500 vo = = (re in) vb (1 1) + re 500 + re β = 50: vb 21.3 = 0.68 V/V = v sig 21.3 + 10 vo 500 = 0.94 V/V = vb 500 + 32.1 vo = 0.836 × 0.94 = 0.64 V/V v sig 50.9 + 10 vo 500 = 0.94 V/V v sig
50.9 + 10 vo 500 = 0.94 V/V v sig 50.9 + 10 vo 500 = 0. the circuit in Fig. P6.111(b): 1 Rin = 10 k = 10 0.1 = 99 gm vo 5 2 = 10(5 2) = 14.3 V/V vi 2 //gm Rin (c) vi 2 = (Av o vi) Rin + Ro 99 = $0.99 \times \text{ vi} \times 99 + 99 0.5 \text{ vi } 1V = 10 \text{ k} 0.1 \text{ mA VG} = 0$, thus VS = -VGS, where VGS can be obtained from 1 2 ID = k n VOV 2 1 2 $0.4 = \times 5 \times \text{VOV} 2 \Rightarrow \text{VOV} = 0.4 \text{ V/S} = -1.2 \text{$ -1.2 - (-5) = 9.5 k RS = 0.4 To remain in saturation, the minimum drain voltage must be limited to VG - Vt = 0 - 0.8 = -0.8 V. B vsig vp gmvp rp ro C vo RL very high 6.51 The largest possible voltage gain is obtained when RL $\rightarrow \infty$, in which case IC VA vo = -gm ro = -v sig VT IC To obtain maximum gain and the largest possible signal swing at the output for v eb of 10 mV, we select a value for RC that results in VA = - VT which is the highest allowable voltage at the collector while the transistors are acceptable. VA = $200 \text{ k} \text{ I} / 2 (W/L)6 (I/2) (W/L)6 \times 50100$ Thus, thus, $(W/L)6 = 2001 \text{ Ro5} = \times 100 \times 200 = 10 \text{ M} 2$ Using Eq. (8.171), we get Ro = Ro4 Ro5 = 10 10 = 5 M I7 = Ad = Gm Ro = 20 mA/V × 5000 k = 105 V/V or 100 dB (W/L)7 I (W/L)5 = 100 = (W/L)7 × 100 200 thus, (W/L)7 = 200 Ex: 8.20 From Exercise 8.17, we get ID = 0.4 mA VOV = 0.2 V gm1, 2 = 4 mA/V Gm = 4 mA/V Ad = 100 V/V Now, RSS = 25 k gm3 = 1 W I = µp Cox V2 2 2 L 1 OV1 $50 \Rightarrow VOV 1 = = 0.129 V 1 \times 30 \times 200 2$ Similarly for Q2, VOV 2 = 0.129 V 2µp Cox W L For Q6, ID p $\sqrt{2} \times 0.1 \times 200 \times 0.4 = 4$ mA/V 1 1 = 0.005 V/V = |Acm| = 2qm3 RSS 2 × 4 × 25 CMRR = (b) For Q1, 100 = $\Rightarrow VOV 6 = 0.105 V$ (c) qm = 100 |Ad| = |Acm| 0.005 = 20,000 or 20 log 20,000 = 86 dB Ex: 8.21 From Exercise 8.18, we get 1 2 × 0.1 × 200 × 0.4 = 4 mA/V 1 1 = 0.005 V/V = |Acm| = 2qm3 RSS 2 × 4 × 25 CMRR = (b) For Q1, 100 = $\Rightarrow VOV 6 = 0.105 V$ (c) qm = 100 |Ad| = |Acm| 0.005 = 20,000 or 20 log 20,000 = 86 dB Ex: 8.21 From Exercise 8.18, we get 1 2 × 0.1 × 200 × 0.4 = 4 mA/V 1 1 = 0.005 V/V = |Acm| = 2qm3 RSS 2 × 4 × 25 CMRR = (b) For Q1, 100 = $\Rightarrow VOV 6 = 0.105 V$ (c) qm = 100 |Ad| = |Acm| 0.005 = 20,000 or 20 log 20,000 = 86 dB Ex: 8.21 From Exercise 8.18, we get 1 2 × 0.1 × 200 × 0.4 = 4 mA/V 1 1 = 0.005 V/V = |Acm| 0.005 = 20,000 or 20 log 20,000 = 86 dB Ex: 8.21 From Exercise 8.18, we get 1 2 × 0.1 × 200 × 0.4 = 4 mA/V 1 1 = 0.005 V/V = |Acm| 0.005 = 20,000 or 20 log 20,000 = 86 dB Ex: 8.21 From Exercise 8.18, we get 1 2 × 0.1 × 200 × 0.4 = 4 mA/V 1 1 = 0.005 V/V = |Acm| 0.005 = 20,000 or 20 log 20,000 = 86 dB Ex: 8.21 From Exercise 8.18, we get 1 2 × 0.1 × 200 × 0.4 = 4 mA/V 1 1 = 0.005 V/V = |Acm| 0.005 = 20,000 or 20 log 20,000 = 86 dB Ex: 8.21 From Exercise 8.18, we get 1 2 × 0.1 × 200 × 0.4 = 4 mA/V 1 1 = 0.005 V/V = |Acm| 0.005 = 20,000 or 20 log 20,000 = 86 dB Ex: 8.21 From Exercise 8.18, we get 1 2 × 0.1 × 200 × 0.4 = 4 mA/V 1 1 = 0.005 V/V = |Acm| 0.005 = 20,000 or 20 log 20,000 = 86 dB Ex: 8.21 From Exercise 8.18, we get 1 2 × 0.1 × 200 × 0.4 = 4 mA/V 1 1 = 0.005 V/V = |Acm| 0.005 = 20,000 or 20 log 20,000 = 86 dB Ex: 8.21 From Exercise 8.18, we get 1 2 × 0.1 × 200 × 0.4 = 4 mA/V 1 1 = 0.005 V/V = |Acm| 0.005 = 20,000 or 20 log 20,000 = 86 dB Ex: 8.21 From Exercise 8.18, we get 1 2 × 0.1 × 0.0 From Exercise 8.18, we get 1 2 × 0.1 × 0.0 From Exercise 8.18, we get 1 2 × 0.1 × 0.0 From Exercise 8.18, we get 1 2 × 0.1 × 0.0 From Exercise 8.18, we get 1 2 × 0.0 From Exercise 8.18, we get 1 2 × 0.0 From $90 \times 200VOV 62 2ID VOV ID Q1 Q2 Q6 VOV 50 \mu A 0.129 V 0.775 mA/V 50 \mu A 0.129 V 0.775 mA/V 100 \mu A 0.105 V 1.90 mA/V I = 0.8 mA, IC 0.4 mA, VA = 100 V (d) ro2 = 10/0.05 = 200 k ro2 = ro4 = 250 k, Ad = 2000 V/V ro6 = 10/0.1 = 100 k REE = 100 V = 125 k$ 0.8 mA Using Eq. (8.165), | Acm | = ro4 250 = = 0.0125 V/V \Beta REE 160 × 125 CMRR = 2000 | Ad | = -160, 000 V/V | Acm | 0.0125 20 log CMRR = 104 dB gm (e) Eq. (8.169): A2 = -gm6 (ro6 ro7) = -95 V/V V V Exercise 8-6 Overall voltage gain is A1 × A2 = -77.5 × -95 = 7363 V/V Ex: 8.23 Rid = 20.2 k Av o = 8513 V/V Ro = 152 With RS = 10 k and RL = 1 k, 1 20.2 × 8513 × Gv = 20.2 + 10 (1 + 0.152) = 4943 V/V Ex: 8.24 ie8 = β 8 + 1 = 101 ib8 ib7 R3 3 = 0.0126 = = ic5 R3 + Ri3 3 + 234.8 ic5 = β 5 = 100 ib5 R1 + R2 40 ib5 = = 0.888 = ic2 R1 + R2 + Ri2 40 + 5.05 ic2 = β 2 = 100 i1 Thus the overall current gain is ie8 $= 101 \times 0.0492 \times 100 \times 0.0126 \times 100$ ii $\times 0.888 \times 100 = 55,599$ A/A and the overall voltage gain is R5 15.7 ib8 = 0.0492 = ic7 R5 + Ri4 15.7 + 303.5 R6 ie8 vo = \cdot v id Ri1 i1 ic7 = β 7 = 100 ib7 = 3 × 55599 = 8257 V/V 20.2 Chapter 8-1 8.1 Refer to Fig. 121.5 vb1 = vsig 121.5 + 500 7.90 = 0.2 V/V (considerably reduced) 5 V 200 A Rsig 500 k Q1 vo vsig Q2 200 A Rin Rin2 r2 (1.25 25) ve1 = vb1 (1.25 25) + 0.0125 = 0.99 V/V (unchanged) vo = -gm2 ro = -80×25 vb1 = -2000 V/V (unchanged) vo = -396 V/V Gv = vsig which has been reduced by a factor of 3.5! All this reduction in Rin . If iD = 5 - 1 = 4 mA. 6.26(b), we show the reduction in Rin . If iD = 5 - 1 = 4 mA. (2.26(b) + 2.26(b) + 2 obtain the equivalent circuit shown below. 10.7 - 0.7 = 2 mA 5 k Assuming operation in the active mode, $I1 = IC = \alpha I1$ I1 = 2 mA (2) V7 + 9.3 V7 = -4.5 V and I6 = -4.5 + 9.3 V7 = -4.5 V and I6 = -4.5 + 9.3 V7 + 9.3 V7 = -4.5 V and I6 = -4.5 + 9.3 V7 + 9.3 V7 = -4.5 V and I6 = -4.5 + 9.3 V7 + 9.3 V7 = -4.5 V and I6 = -4.5 + 9.3 V7 + 9.3 V7 = -4.5 V and I6 = -4.5 V and $I6 = -4.5 \text{$ active mode, as assumed. 2.20(b): 1 v I 1 = v Icm - v Id 2 1 v I 2 = v Icm + v Id 2 1 v - (A1) = v Icm - v Id 2 1 v - (A2) = v Icm + v Id 2 1 v - (A2) = v Icm + v Id 2 2.70 (a) Refer to the circuit in Fig. IE = (b) For design 2, RE = 3.3 k, R1 = 8 k, and R2 = 4 k. With this value of R3, the new value of R3, amplifier is capacitively coupled in the manner of Fig. Thus at VSB = 4 V, $\sqrt{\sqrt{Vt}} = 1 + 2[0.6 + 4 - 0.6] = 3.74 V$ But, ID1 + ID2 = $200 \mu A = 1.24 V$ ID2 = $80 \mu A$ Thus, $V1 = 2.5 - 0.12 \times 20 = 0.1 V$ Vt = -1.24 V V2 = $2.5 - 0.08 \times 20 = 0.9$ V To find V3, we find VGS from the can write and Vt = Vt0 + γ [$2\phi f$ + VSB - $2\phi f$] ∂iD /iD = $-0.002/\circ$ C, VGS = 5 V ∂T where and Vt0 = 1.0 V + $2 \text{ v} = 0.5 \text{ V}/2 - 0.002 = <math>\partial V f = -2 \text{ mV}/\circ$ C = $-0.002 \text{ V}/\circ$ C $\partial T \text{ or } -0.3\%/\circ$ C 125.61 iD = k n (v GS - Vtn)v DS - v DS , 2 for v DS \leq v GS - Vtn 1 k n (v GS - Vtn) v DS - v DS , 2 for v DS \leq v GS - Vtn 1 k n (v GS - Vtn) v DS - v DS / \circ C $\partial T \partial r - 0.3\%/\circ$ C 125.61 iD = k n (v GS - Vtn)v DS - v DS , 2 for v DS \leq v GS - Vtn 1 k n (v GS - Vtn) v DS - v DS / \circ C $\partial T \partial r - 0.3\%/\circ$ $(1 + \lambda v DS)$, 2 for v DS \geq v GS - Vtn iD = For v DS = 2 V, iD = 0.4(1 + 0.02 × 2) = 0.416 mA For v DS = 3 V, iD = 0.4(1 + 0.02 × 3) = 0.424 mA For v DS = 3 V, iD = 0.4(1 + 0.02 × 3) = 0.424 mA For v DS = 3 V, iD = 0.4(1 + 0.02 × 3) = 0.424 mA For v DS = 10 V, For our case, Vtn = -2 V, k n = 0.2 mA/V2, $\lambda = 0.02 V - 1$ and v GS = 0.3.28 For a diode conducting a constant current, the diode voltage decreases by approximately 2 mV per increase of $1 \circ C$.
11 = 0.033 V - 1 VA 30 $1 W 2 ID = k n (1 + \lambda VDS) VOV 2 L$ $151 \times 0.52 (1 + 0.033 \times 2) = \times 0.2 \times 21.5 |v GS| = 3 V, |v DS| = 4 V = 0.267 mA |v DS| > |VOV| \Rightarrow saturation mode <math>\lambda = ro = 1 k 2 n 5.35 Vtp = 0.8 V, |VA| = 40 V iD = 3 mA |VOV| = |v GS| - |Vtp| = 2.2 V v GS = -3 V VA 30$ = $115 W 2 \times 0.2 \times 21.5 |v GS| = 3 V, |v DS| = 4 V = 0.267 mA |v DS| > |VOV| \Rightarrow saturation mode <math>\lambda = ro = 1 k 2 n 5.35 Vtp = 0.8 V, |VA| = 40 V iD = 3 mA |VOV| = |v GS| - |Vtp| = 2.2 V v GS = -3 V VA 30$ = $115 W 2 \times 0.2 \times 21.5 |v GS| = 4 V = 0.267 mA |v DS| > |VOV| \Rightarrow saturation mode <math>\lambda = ro = 1 k 2 n 5.35 Vtp = 0.8 V, |VA| = 40 V iD = 3 mA |VOV| = |v GS| - |Vtp| = 2.2 V v GS = -3 V VA 30$ = $115 W 2 \times 0.2 \times 21.5 |v GS| = 4 V = 0.267 mA |v DS| > |VOV| \Rightarrow saturation mode \lambda = ro = 1 k 2 n 5.35 Vtp = 0.8 V, |VA| = 40 V iD = 3 mA |VOV| = |v GS| - |Vtp| = 2.2 V v GS = -3 V VA 30$ = $115 W 2 \times 0.2 \times 20.2 \times 20.2 \times 20.52 VOV 2$ 1.5 L v SG = +3 V v DS = -4 V = 120 k v SD = 4 V VDS $1V = = 0.008 mA ID = ro 120 k V tp = -0.8 V VA = -40 V \lambda = -0.025 V - 11 iD = k p (v GS - Vtp) 2 (1 + <math>\lambda v DS$) $2 1 3 = k p [-3 - (-0.8)] 2 (1 - 0.025 V - 11 iD = k p (v GS - Vtp) 2 (1 + <math>\lambda v DS$) $2 1 3 = k p [-3 - (-0.8)] 2 (1 - 0.025 V - 11 iD = k p (v GS - Vtp) 2 (1 + <math>\lambda v DS$) $2 1 3 = k p [-3 - (-0.8)] 2 (1 - 0.025 V - 11 iD = k p (v GS - Vtp) 2 (1 + <math>\lambda v DS$) $2 1 3 = k p [-3 - (-0.8)] 2 (1 - 0.025 V - 11 iD = k p (v GS - Vtp) 2 (1 + <math>\lambda v DS$) $2 1 3 = k p [-3 - (-0.8)] 2 (1 - 0.025 V - 11 iD = k p (v GS - Vtp) 2 (1 + \lambda v DS) 2 (1 + \lambda v DS) 2 (1 + \lambda v DS) = -0.025 V - 11 iD = k p (v GS - Vtp) 2 (1 + \lambda v DS) 2$ nearly constant for v id ≤ 10 mV. i3 ix i3 i2 vx Q.E.D. 7.83 Refer to circuit in Fig. Therefore, i2 = 1 mA v O = v 1 - i2 R2 = 0 - 1 mA × 10 k = -10 mA - 1 mA = -11 mA Voltage gain = 20 dB - 10 V vO = = -10 V/V or 1V 1V - 10 mA iL = -10 A/A or = i1 1 = -10 A/A or = i1 1 = -10 mA - 1 mA = -11 mA Voltage gain = 20 dB - 10 V vO = = -10 V/V or 1V 1V - 10 mA iL = -10 A/A or = i1 1 = -10 mA - 1 mA = -11 mA Voltage gain = 20 dB - 10 V vO = = -10 V/V or 1V 1V - 10 mA iL = -10 A/A or = i1 1 = -10 mA - 1 mA = -11 mA Voltage gain = 20 dB - 10 V vO = = -10 V/V or 1V 1V - 10 mA iL = -10 A/A or = i1 1 = -10 mA - 1 mA = -11 mA Voltage gain = 20 dB - 10 V vO = = -10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V vO = = -10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V vO = -10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 mA Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 A Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A or = i1 1 A Voltage gain = 20 dB - 10 V/V or 1V - 10 mA iL = -10 A/A o mA Power gain -10(-10 mA) PL = 100 W/W or 20 dB = Pi 1 V × 1 mA PL Note that power gain in dB is 10 log10 . Thus Av = -gm1 (ro /2) 1 - 40 =the feedback network and the Early effect, we see from Fig. Output dc offset voltage = $3 \text{ mV} \times 1000 = 3 \text{ mV} \times 10$ (c) In this case, Since R is very large, we may ignore VOS compared to the voltage drop across R. Thus, VICM min = $-VSS + VOV = 0.212 \times 0.5 = 0.353 \times 0.32$ the current ID and Since ID is proportional to VOV hence the bias current I must be increased by the ratio (0.353/0.212)2, then I must be 0.353/0.212)2, then I must be increased by the ratio (0.353/0.212)2, then I must be 0.353/0.212)2, then I must be increased by the ratio (0.353/0.212)2, then I must be 0.353/0.212)2, then I must be 0.353/0.212)2, then I must be 0.353/0.212)2, then I must be 0.353/0.212)2. + 5v 2), It is also desired that for a maximum output voltage of 10 V, the current in the feedback resistor not exceed 1 mA. To obtain IE = 0.5 mA we select RE according to RE = Assuming active-mode operation, we obtain $3 - 0.7 = 4.6 \text{ k} 0.5 \text{ IC} = \alpha IE = 0.99 \times 2.16 = 2.14 \text{ mA}$ To obtain VC = -1 V, we select RC according to RC = -1 - (-3) = 4 k 0.5and $VC = 5 - 2.14 \times 1 = +2.86$ V Since VC > VB - 0.4, the transistor is operating in the active region, as assumed. 1.23(a)], we can complete the table entries and sketch the amplifier frequency response. VS = 3.5 and ID = 0.5 mA; thus RS = VS 3.5 = 7 k = ID 0.5 VDD = 15 V and VD = 6 V; thus RD = VDD - VD 15 - 6 = = 18 k ID 0.5 mA \Rightarrow RE = 10.5 mA; thus RS = VS 3.5 = 7 k = ID 0.5 VDD = 15 V and VD = 6 V; thus RD = VDD - VD 15 - 6 = = 18 k ID 0.5 mA \Rightarrow RE = 10.5 mA; thus RS = VS 3.5 = 7 k = ID 0.5 VDD = 15 V and VD = 6 V; thus RD = VDD - VD 15 - 6 = = 18 k ID 0.5 mA \Rightarrow RE = 10.5 mA; thus RS = VS 3.5 = 7 k = ID 0.5 VDD = 15 V and VD = 6 V; thus RD = VDD - VD 15 - 6 = = 18 k ID 0.5 mA \Rightarrow RE = 10.5 mA; thus RS = VS 3.5 = 7 k = ID 0.5 VDD = 15 V and VD = 6 V; thus RD = VDD - VD 15 - 6 = = 18 k ID 0.5 mA \Rightarrow RE = 10.5 mA; thus RS = VS 3.5 = 7 k = ID 0.5 VDD = 15 V and VD = 6 V; thus RD = VDD - VD 15 - 6 = = 18 k ID 0.5 mA \Rightarrow RE 4.3 k To obtain VOV, we use IC vo = gm RC, where gm = = vi VT 40 mA/V. 8.15(d). Therefore ID = 0.49 mA and IE = 4 - 0.7 = 0.94 mA 4080 3+ 51 For $\beta = 150$, IE = 4 - 0.7 = 0.94 mA 4080 3+ 51 because VAn = |VAp | = |VA | and both Q1 and Q2 are operating at equal currents I, we have ro1 = ro2 = ro The overall voltage gain Av will be Av = Av 1 Av 2 1 gm1 gm2 ro2 4 If the two transistors are operated at equal overdrive voltages, |VOV |, both will have equal gm, Av = Av = _ = |VAp | and 7.38 Refer to Fig. d2, g1, g2 iosc ro1 ii vgs1 vgs2 gm1vgs1 gm2vgs2 ro2 Ri Ro This table belongs to Problem 8.116. 1.1b: For circuit a. Chapter 9-3 This figure belongs to Problem 9.6. CC2 Vo Id Is Rsig Vsig 1 = 0 CC1 = 63.7 nF Select CC1 = 100 nF = 0.1 µF. Thus, (2) Slope at VBE of 700 mV = 10 mA = 400 mA/V 25 mV Chapter 4-10 Slope at VBE of 500 mV $= 0.134 \text{ mA/V} 3.35 \mu \text{A} 25 \text{ mV} 4.38 \text{ R2} 68 \text{ k} \text{ I2} 400 3000 \text{ Ratio of slopes} = 0.134 \text{ I1} \text{ R1} 6.8 \text{ k} \text{ IB} \text{ VBE } 4.37 \text{ Use Eq.}$ (4.18): v CE iC = IS ev BE /VT 1 + VA At 25° C, assume IE = 1 mA. (c) If iI is in the direction shown in the figure above, the maximum allowable value of iI will be determined by v O reaching -12 V, at which point v x = -iI max × 10 and $v O = -12 = v x - iLmax \times 1 = -10$ iI max = 12 = 0.57 mA 21 If iI is in a direction opposite to that shown in the figure, then v x = 10iI + 11iI = 21iI The maximum value of iI will result in v O = +12 V. For IE = 1 mA and VC = 2.3 V, VCC - VC RC IE = 1 = 10 - 2.3 RC \Rightarrow RC = 7.7 k Now, using Eq. (6.147), we obtain Ex: 6.35 Refer to Fig. \therefore Hole concentration in P-doped Si is pn = Substituting the values given in the problem, $3/2 - 1.42/(2 \times 8.62 \times 10 - 5 \times 300)$ ni = 3.56×10 (300) e = 2.2×10 carriers/cm 3 6 ni = BT 3/2 e $-Eg/2kT = 1.5 \times 1010$ holes/cm3 ni = 4.72×1012 cm-3; 14×1.78 Hole concentration in intrinsic
Si = ni 1.76 Since NA ni we can write pp \approx NA = 5 × 1018 cm - 3 1.5 × 1010 = 1.5 × 102 cm - 3 108 Now, nn ND and pn nn = n2i /pn = (1.5 × 1010) 1.5 × 102 2 = 1.5 × 1018 atoms/cm3 Using Eq. (1.4); n2 np = i = 45 cm - 3 pp For intrinsic silicon, 1.77 T = 27° C = 273 + 1018 atoms/cm3 Using Eq. (1.3), we have 1.79 (a) The resistivity of silicon is given by Eq. (1.41); n2 np = i = 45 cm - 3 pp For intrinsic silicon, 1.77 T = 27° C = 273 + 1018 atoms/cm3 Using Eq. (1.41); n2 np = i = 45 cm - 3 pp For intrinsic silicon, 1.77 T = 27° C = 273 + 1018 atoms/cm3 Using Eq. (1.3), we have 1.79 (a) The resistivity of silicon is given by Eq. (1.41); n2 np = i = 45 cm - 3 pp For intrinsic silicon, 1.77 T = 27° C = 273 + 1018 atoms/cm3 Using Eq. (1.41); n2 np = i = 45 cm - 3 pp For intrinsic silicon, 1.77 T = 27° C = 273 + 1018 atoms/cm3 Using Eq. (1.41); n2 np = i = 45 cm - 3 pp For intrinsic silicon, 1.77 T = 27° C = 273 + 1018 atoms/cm3 Using Eq. (1.41); n2 np = i = 45 cm - 3 pp For intrinsic silicon, 1.77 T = 27° C = 273 + 1018 atoms/cm3 Using Eq. (1.41); n2 np = i = 45 cm - 3 pp For intrinsic silicon, 1.77 T = 27° C = 273 + 1018 atoms/cm3 Using Eq. (1.41); n2 np = i = 45 cm - 3 pp For intrinsic silicon, 1.77 T = 27° C = 273 + 1018 cm - 3 np = 100 cm - 3 np = 10 $27 = 300 \text{ K} \text{ At } 300 \text{ K}, \text{ ni} = 1.5 \times 1010 \text{ /cm3 } \text{p} = n = \text{ni} = 1.5 \times 1010 \text{ cm} - 3 \text{ Using } \text{µn} = 1350 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{s}, \text{ and } \text{µp} = 480 \text{ cm} 2 \text{ /V} \cdot \text{cm} 2$ 100 (d) v 2 = v 1 + v d = 5.10 - 0.051 = 5.049 V All the results seem to be reasonable. On the other hand, in circuit (b), the first stage amplifies the differential signal by R2 1+ and the common-mode signa pF Cje0 VCB m 1+ V0c C μ = C μ = |hfe| 40 = 20 = 10.4 fF 2 0.5 1 + 0.75 gm fT = 2 π (C π + C μ) = 9.21 For f f β , fT f 2000 MHz = 10 MHz = β 0 200 9.22 rx = 5.1 GHz rp 9.20 For f f β , |hfe| = B' B Cp fT f Cm C, E At f = 50 MHz and IC = 0.2 mA, Zin fT 50 \Rightarrow fT = 500 MHz |hfe| = 10 = With the emitter and the collector grounded, the equivalent circuit takes the form shown in the figure, and the input impedance becomes At f = 50 MHz and IC = 1.0 mA, fT 50 \Rightarrow fT = 600 MHz 1 1 + j ω (C π + C μ) r π r π = rx + 1 + j\omega(C π + C μ) r π r π = rx + 1 + j\omega(C π + C μ) r π r π = rx + 1 + j\omega(C π + C μ) r π r π = rx + 1 + j\omega(C π + C μ) r π r π = rx + 1 + j\omega(C π + C μ) r π r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx + 1 + j\omega(C π + C μ) r π = rx $rx + r\pi 2 \omega 1 + \omega\beta C\pi = Cde + Cje Zin = rx + = \tau F gm + Cje C\mu = 0.1 pF At IC = 0.2 mA, gm = 500 \times 106 = 0.2 = 8 mA/V, thus 0.025 8 \times 10 - 3 2\pi(C\pi + 0.1) \times 10 - 12 \tau F \times 10 - 3 2\pi(C\pi + 0.1) \times 10 - 12 \tau F \times 10 - 3 2\pi(C\pi + 0.1) \times 10 - 12 \tau F \times 10 - 3 2\pi(C\pi + 0.1) \times 10 - 12 \tau F \times 10 - 3 2\pi(C\pi + 0.1) \times 10 - 12 \tau F \times 10 - 3 2\pi(C\pi + 0.1) \times 10 - 12 \tau F \times 10 - 3 2\pi(C\pi + 0.1) \times 10 - 12 \tau F \times 10 - 3 2\pi(C\pi + 0.1) \times 10 - 12 \tau F \times 10 - 3 2\pi(C\pi +
0.1) \times 10 - 12 \tau F \times 10 - 3 2\pi(C\pi + 0.1) \times 10 - 12 \tau F \times 10 - 3 2\pi(C\pi + 0.1) \times 10 - 12 \tau F \times 10 - 3 2\pi(C\pi + 0.1) \times 10 - 3 2\pi(C\pi + 0.1$ IC = 1 mA, gm = 0.025 τF × 40 × 10-3 + Cje = 10.51 × 10-12 rπ Re (Zin) = rx + ⇒ Cπ = 2.45 pF 600 × 106 = 1, then (Cπ + Cµ)rπ (2) ω ωβ 2 For the real part to be an estimate of rx accurate to within 10%, we require rπ $2 \le 0.1$ rπ $\omega 1 + \omega\beta$ But rx $\le rx$ rπ, thus ≤ 0.1 , 10 rπ Chapter 9-10 1 $\omega \omega\beta$ 1 + 9.25 (a) Vo = -AVi 2 $\leq 0.1 \times 0.1$ If the current flowing through Rsig is denoted Ii, we obtain Ii sC(Vi - Vo) = Yin = Vi Vi Vo = sC(1 + A) or, equivalently, $2 \omega 1 + \geq 100 \omega\beta = \omega \geq 10\omega\beta$ Thus, Cin = C(1 + A) 1/sCin Vi (s) = (b) 1 Vsig (s) Rsig + sCin 1 = 1 + sCin Rsig 9.23 To complete the table below we use the following relationships: re = VT 25 mV = IE IE $(mA) gm = IC \alpha IE IE IE (mA) = = VT VT VT 0.025 VA Vo (s) = -Vsig (s) 1 + sCin Rsig \beta 0$, k gm (mA/V) gm fT = $2\pi(C\pi + C\mu) r\pi = f\beta = (c) DC gain = 40 dB = 100 V/V$, $\Rightarrow A = 10$ VD = 0.700 V, $ID = 1 A \Rightarrow IS = 6.91 \times 10 - 13 A$; 10% of ID gives $VD = 0.64 V D2 VD \Rightarrow VD = 0.025 \ln 10 = 57.6 mV 3.20 IS$ can be found by using $IS = ID \cdot e$ ID2. The resistances Ro1 and Ro2 altogether. If the two devices Ro1 and Ro2 altogether. If the two devices Ro1 and Ro2 will be much larger than the input resistances Ro1 and Ro2 altogether. If the two devices Ro1 and Ro2 altogether Ro1 and Ro2 altogether. If the two devices Ro1 and Ro2 altogether Ro1 and Ro2 altogether. If the two devices Ro1 and Ro2 altogether Ro1 and Ro2 altogether Ro1 and Ro2 altogether Ro1 and Ro2 altogether. If the two devices Ro1 and Ro2 altogether Ro1 are matched, 12 ID1 = k n (1 - Vt) 21 + 2 VA 12.5 ID2 = k n (1 - Vt) 21 + 2 VA $12 0.5 \text{ ID} = \text{ID2} - \text{ID1} = k n (1 - \text{Vt}) 2 \text{ VA} 100 1.01 \text{ ID} = and 100 + \text{ID} = 1.05 \times 100 = 104 \mu\text{A} \text{ or } 4\%$ To reduce ID by a factor of 2, we need to reduce λ by a factor of 2, which can be obtained by doubling the channel length to 3 μ m. The largest values of v O on positive and negative side are +10 V and -10 V, respectively. 9.10(b), we get RB Rsig τ CE = CE re + β +1 1 2 ms 0.8 × 2 π × 100 Thus, (200 20) × 103 = 2 × 10-3 CE 250 + 101 = CE = 4.65 μ F Select, CE = 5 μ F. 7.16(a). It is the value of the resolution of the ADC. C 10 F 100 k 1V 0.01 mA 0.01 mA 0.01 mA The capacitor voltage v O will rise linearly from its initial value of -10 V. P7.95(e). Using the voltage divider rule at the input side, we find v o by multiplying the current gm v π (v o = $-\text{gm v}\pi$ (ro RL) (2) Finally, v o /v s can be obtained by combining Eqs. 2ID 2 × 0.5 (b) gm = = = 2 mA/V VOV 0.5 VA 100 ro = = 200 k ID 0.5 (c) See Fig. Thus 1 iD = 0.2 2 v DS - v 2DS, 2 iD = 0.4(1 + 0.02 v DS), For v DS ≤ 2 V for v DS \leq 0.2 = 4.8 V To operate at the edge of saturation, VEC = 0.3 V and IE 1 mA 3 IC 1 k IC /IB = $\beta = 50$ VC 3 0 3 V 4 0V VE 0 V 1 k 0 2 (c) 1 Chapter 4-14 The analysis and the results are given on the circuit diagrams of Figs. vO (V) 3.7 3.5 4.2 3.5 3.5 0 4.2 vI (V) slope 1 (Not to scale) 3.5 3.7 D1 and D2 OFF D1 OFF D2 ON D1 ON D2 OFF (b) Figure (b) shows a sketch of the transfer characteristic of this double limiter. Ex: 5.8 1 1 60 W 2 \Rightarrow 0.3 = \times ID = μ n Cox VOV 2 L 2 1000 120 2 V \Rightarrow \times 3 OV VOV = 0.5 V \Rightarrow RS = Q1 Since Q2 is identical to Q1 and their VGS values are the same, ID2 = ID1 = 0.032 mA For Q2 to operate at the triode-saturation boundary, we must have VS - VSS ID VD2 = VOV = 0.2 V - 1.5 - (-2.5) 0.3 RS = 3.33 k = RD = Q2. R2 = VDD - VD 2.5 - 0.4 = 7 k = ID 0.3 1.8 V - 0.2 V = 50 k 0.032 mA Ex: $5.11 \text{ RD} = 12.4 \times 2 = 24.8 \text{ k} \text{ VGS} = 5 \text{ V}$, assume triode region: $12 \text{ W ID} = \text{ k} \text{ n} (\text{VGS} - \text{Vt}) \text{VDS} - \text{VDS} \text{ k} = 12.4 \times 2 = 24.8 \text{ k} \text{ VGS} = 5 \text{ V}$, assume triode region: $12 \text{ W ID} = \text{ k} \text{ n} (\text{VGS} - \text{Vt}) \text{VDS} - \text{VDS} \text{ k} = 12.4 \times 2 = 24.8 \text{ k} \text{ VGS} = 5 \text{ V}$, assume triode region: $12 \text{ W ID} = \text{ k} \text{ n} (\text{VGS} - \text{Vt}) \text{VDS} - \text{VDS} \text{ k} = 12.4 \times 2 = 24.8 \text{ k} \text{ VGS} = 5 \text{ V}$, assume triode region: $12 \text{ W ID} = \text{ k} \text{ n} (\text{VGS} - \text{Vt}) \text{VDS} - \text{VDS} \text{ k} = 12.4 \times 2 = 24.8 \text{ k} \text{ VGS} = 5 \text{ V}$, assume triode region: $12 \text{ W ID} = \text{ k} \text{ n} (\text{VGS} - \text{Vt}) \text{VDS} - \text{VDS} \text{ k} = 12.4 \times 2 = 24.8 \text{ k} \text{ VGS} = 5 \text{ V}$, assume triode region: $12 \text{ W ID} = \text{ k} \text{ n} (\text{VGS} - \text{Vt}) \text{VDS} - \text{VDS} \text{ k} = 12.4 \times 2 = 24.8 \text{ k} \text{ VGS} = 5 \text{ V}$, assume triode region: $12 \text{ W ID} = \text{ k} \text{ n} (\text{VGS} - \text{Vt}) \text{VDS} - \text{VDS} \text{ k} = 12.4 \times 2 = 24.8 \text{ k} \text{ VGS} = 5 \text{ V}$, assume triode region: $12 \text{ W ID} = \text{ k} \text{ n} (\text{VGS} - \text{Vt}) \text{VDS} - \text{VDS} \text{ k} = 12.4 \times 2 = 24.8 \text{ k} \text{ VGS} = 5 \text{ V}$, assume triode region: $12 \text{ W ID} = \text{ k} \text{ n} (\text{VGS} - \text{Vt}) \text{ VDS} - \text{VDS} \text{ k} = 12.4 \times 2 = 24.8 \text{ k} \text{ VGS} = 5 \text{ V}$, assume triode region: $12 \text{ W ID} = \text{ k} \text{ n} (\text{VGS} - \text{Vt}) \text{ VDS} - \text{VDS} \text{ k} = 12.4 \times 2 = 24.8 \text{ k} \text{ VGS} = 5 \text{ V}$. 1)VDS - DS 24.8 2 Ex: 5.9 1.8 V R VD 2 - 8.08VDS + 0.4 = 0 \Rightarrow VDS \Rightarrow VDS = 0.05 V < VOV \Rightarrow triode region ID = 5 - 0.05 = 0.2 mA 24.8 Ex: 5.12 As indicated in Example 5.6, Vtn = 0.5 V μ n Cox = 0.4 mA/V2 VD \geq VG - Vt for the transistor to be in the saturation region. Also all have the same channel length and |VA|; thus all ro values are equal. 3 Req = 10R R + 10 = 1.6 W Thus, for a 1% reduction, Thus, the resistor should have a 2-W rating. W gm1 = 2µn Cox ID L $\sqrt{22 \times 0.4 \times 25 \times 0.1} = 1.41$ mA/V VA 1.8 ro1 = = 18 k ID 0.1 I 0.1 = 4 mA/V gm2 = = VT 0.025 1.8 VA = = 18 k ro2 = I 0.1 \beta 125 rm 2 = 31.25 k = gm2 4 = 1.7 - 0.6 = 1.1 V 2ID2, 3 2 × 0.2 gm2 = gm3 = = 1.6 mA/V VOV 2,3 0.25 VA 10 = = 50 k ID 0.2 Ro = gm3 ro3 ro2 ro2 = ro3 = = $1.6 \times 50 \times 50 = 4 \text{ M} 7.77$ (gm3ro3) (gm2ro2)ro1 IREF Gm = gm1 = 1.41 mA/V IO Ro = gm2 ro2 (ro1 rn 2) = $4 \times 18 \times (18 \ 31.25) = 822.3 \text{ k Av } o = -Gm \text{ Ro} = -1.41 \times 822.3 = -1159 \text{ V/V}$ (b) Refer to circuit in Fig. d +1.0 +1.5 Sat.* e 0 0 0 -1.0 +1.0 +0.5 -0.5 -1.0 +2.5 1.0 +2. +1.5 +1.0 f +1.0 f +1.0 +1.0 g -1.0 0 h -1.5 0 i -1.0 0 j +0.5 +2.0 +0.5 +2.0 +0.5 +2.0 +0.5 +2.0 +0.5 +1.5 +0.5 Cutoff Triode 0 -1.0 0 Cutoff 0 +1.0 cutoff 0 Republic France Greece Guatemala Hungary Italy Japan Poland Portugal Singapore South Korea Switzerland Thailand Turkey Ukraine Vietnam Copyright 2017 by Oxford University Press For titles covered by Section 112 of the US Higher Education Opportunity Act, please visit www.oup.com/us/he for the latest information about pricing and alternate formats. As shown in the diagram, the output is zero between $(\pi - \theta)$ to $(\pi + \theta) = 2\theta$ t Exercise 3-6 Here θ is the angle at which the input signal reaches VD. In this 2.99 ft = A0 fb A0 fb (Hz) 105 102 107 106 1 106 105 102 107 106 1 106 105 102 107 106 1 106 105 102 4 105 102 4 106 2 × 105 102 × 106 2 ×
106 2 × 106 A0 80,000 V/V Chapter 2-34 At f = 100 kHz, the gain is 40 dB or 100 V/V. (1.51) and (1.52) to find xn and xp : we have V0 = 778 mV. Thus IE increases by = RE 0.2 V = 0.035 mA to become 0.435 mA. P3.6 we see that when v I < VB ; that is, v I < 3 V, D1 will be conducting the current I and iB will be zero. v O = 0 V ~ The output is always shorted to ground as D1 conducts when v I > 0 and D2 conducts when v I < 0. 4.19. IE = (a) For v I = 0, both transistors are cut off and all currents are zero. Thus VBE for each will be $0.5 \text{ VBE} = 0.7 + 0.025 \text{ ln} 1 = 0.683 \text{ V} \Rightarrow v \text{ E} = 5 - 0.683 \text{ = } +4.317 \text{ V}$ (b) gm = IC 0.5 mA = = 20 VT 0.025 V (c) iC1 = $0.5 + \text{gm1} \text{ v} \text{ BE1} = 0.5 + 20 \times 0.005 \text{ sin}$ ($2\pi \times 1000t$) = $0.5 \text{ VBE} = 0.7 + 0.025 \text{ ln} 1 = 0.683 \text{ V} \Rightarrow v \text{ E} = 5 - 0.683 \text{ = } +4.317 \text{ V}$ (b) gm = IC 0.5 mA = = 20 VT 0.025 V (c) iC1 = $0.5 + \text{gm1} \text{ v} \text{ BE1} = 0.5 + 20 \times 0.005 \text{ sin}$ ($2\pi \times 1000t$) = $0.5 \text{ VBE} = 0.7 + 0.025 \text{ ln} 1 = 0.683 \text{ V} \Rightarrow v \text{ E} = 5 - 0.683 \text{ m} 1 = 0.683 \text{ V} \Rightarrow v \text{ E} = 5 - 0.683 \text{ m} 1 = 0.5 \text{ m} 1 = 0.683 \text{ m} 1 = 0.68$ + 0.1 sin(2 π × 1000t), mA Exercise 8-3 iC2 = 0.5 - 0.1 sin(2 π × 1000t), mA (d) v C1 = (VCC - IC RC) - 0.1 × RC sin(2 π × 1000t) = 10 - 1 sin(2 π × 1000t) , V (e) v C2 - v C1 = 2 · sin(2 π × 1000t) , V (f) Voltage gain = v C2 - v C1 v B1 - v B2 2 V peak = 200 V/V = 0.01 V peak Ex: 8.13 If the output of a MOS differential amplifier is taken single-endedly, then 1 gm RD 2 (that is, half the gain obtained with the MOSFET source. P5.51(b): The transistor is operating in saturation, thus 1 2 k n VOV 2 1 2 2 = \times 4 \times VOV \Rightarrow VOV = 1 V 2 VGS = 2 V ID = \Rightarrow V3 = 2 V Chapter 5-14 Refer to Fig. Thus gm1,2 = 2ID / VOV 1,2 | increase by a factor of 2. For the nominal case, β = 100 and Exercise 6-9 4 - 0.7 = 0.99 1 mA 48 3.3 + 101 For β = 50, To maintain active-mode operation at all times, the collector voltage should not be allowed to fall below the value that causes the CBJ to become forward biased, namely, -0.4 V. Thus, v id = -0.104 V v GS1 = 0.541 V v GS2 = 0.645 V v D1 = VDD - iD1 RD = $1 - 0.04 \times 5 = 0.4$ V v D2 - v D1 = -0.4 V \Rightarrow v id = 0.104 V (e) iD1 = 0 (Q1 just cuts off) and iD2 = 0.16 mA. The voltage at the gate is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β of v o with R1 β = R1 + R2 Now, the current is a fraction β = R1 + R2 Now, the current is a fraction β = R1 + R2 Now, the current is a fraction β = R1 + R2 Now, the current is a fraction β = R1 + R2 Now, the current is a fraction β = R1 + R2 Now, the current is a fraction β = R1 + R2 Now, the current is a fraction β = R1 + R2 Now, the current is a fraction β = R1 + R2 Now, the current is a fractine (R1 + R2 + R2 + R2 $-\beta v$ o i = gmv sig $-\beta gmv$ o (2) 1/gm Substituting for i from Eq. (2) into Eq. (1) yields v o = (gm v sig $-\beta gm v o$) RD VGS Thus gm RD vo = v sig 1 + $\beta gm RD$ 7 i from Eq. (2) into Eq. (1) yields v o = (gm v sig $-\beta gm v o$) RD VGS Thus gm RD vo = v sig 1 + $\beta gm RD$ 7 i from Eq. (2) into Eq. (3) yields v o = (gm v sig $-\beta gm v o$) RD VGS Thus gm RD vo = v sig 1 + $\beta gm RD$ 7 i from Eq. (3) Q.E.D The input resistance Rin can be obtained as follows: v sig 1 Substituting for i from Eq. (1) yields v sig R Rin = vo D v sig and replacing by the inverse of the gain vo expression in Eq. (3) gives 1 1 Rin = 1 + gm RD + (0.5/0.5) v sig $1 + 1 \times (82.4 \ 1000) 2 = 1.95$ V/V = 2 + 76.13 R2 Note that the gain 1 + 2, similar to that R1 of an op amp connected in the noninverting configuration! 0.5 1 1 + 1 × (82.4 1000) Rin = 1 0.5 + 0.5 = 39.1 k 6.114 (a) DC bias: VDD 10 V VD VGS R1 0.5 M Figure 1 VGS = Vt + VOV = 0.6 + 0.2 = 0.8 V The current in the voltage divider is VD 4 = = 1.6 \mu A = 0.0016 mA R1 + R2 2.5 Thus the current through RD will be (0.107 + 0.0016) 0.109 mA and 10 - 4 VDD - VD RD = = 55 k 0.109 0.109 2ID 2 × 0.107 (b) gm = = 1.07 mA/V VOV 0.2 VA 60 ro = = 561 k = ID 0.107 (c) Upon replacing the MOSFET with its hybrid- π model, we obtain the small-signal equivalent circuit of the amplifier, shown in Fig. Rs 1.39 vs +3 V 1 mA t Ri Av ovi RL vi 20 mA (average) vo vi 2.2 V ii Ro 0.2 V 20 mA (average) 3 V RL 100 Thus, Ri RL vo = Av o vs Ri + Rs RL + Ro (a) Av o = 100, Ri = 10Rs , RL = 10Ro : 10Rs + Rs 10Ro + Ro = 82.6 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 11 V/V (b) Av o = 100, Ri = Rs , RL = Ro : vo 1 1 = 100 × × = 25 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 11 V/V (b) Av o = 100, Ri = Rs , RL = Ro : vo 1 1 = 100 × × = 25 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 11 V/V (b) Av o = 100, Ri = Rs , RL = Ro : vo 1 1 = 100 × × = 25 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 11 V/V (b) Av o = 100, Ri = Rs , RL = Ro : vo 1 1 = 100 × × = 25 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 11 V/V (b) Av o = 100, Ri = Rs , RL = Ro : vo 1 1 = 100 × × = 25 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 11 V/V (b) Av o = 100, Ri = Rs , RL = Ro : vo 1 1 = 100 × × = 25 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 11 V/V (b) Av o = 100, Ri = Rs , RL = Ro : vo 1 1 = 100 × × = 25 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 11 V/V (b) Av o = 100, Ri = Rs , RL = Ro : vo 1 1 = 100 × × = 25 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 11 V/V (b) Av o = 100, Ri = Rs , RL = Ro : vo 1 1 = 100 × × = 25 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 11 V/V (b) Av o = 100, Ri = Rs , RL = Ro : vo 1 1 = 100 × × = 25 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 100 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 100 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 100 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 100 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 100 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 100 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 100 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 100 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 100 V/V or $20 \log 82.6 = 38.3$ dB vo 2.2 Av = = vi 0.2 = 100 V/V or 20Chapter 1-13 vo RL = vs RL + Rs (c) Av o = 100 V/V, Ri = Rs /10, RL = Ro /10: Rs /10 Ro /10 vo = 100 vs (Rs /10) + Rs (Ro /10) larger than the source resistance. Sedra University of Waterloo New York Oxford OXFORD UNIVERSITY PRESS Oxford University Press is a department of the third stage now becomes Ri2 = $(\beta + 1)$ $(2re4,5 + 2Re4,5) - 130.5 V/V = 101 (2 \times 0.025 + 2 \times 0.025)$ and the overall voltage gain increases to = 10.1 k vo 130.5 = 1.73 × 105 V/V = v1 10 µV = v or 20 log 1 × 105 = 100 dB Ai = 2N ≥ 2501 \Rightarrow N = 12, = iO v O /RL 1 V/10 k = = iI iI 100 nA 0.1 × 10-3 0.1 mA = 1000 A/A 100 nA 100 × 10-9 or 20 log Ai =
60 dB Ap = v O iO vO iO = × v I iI vI iI = 1 × 105 × 1000 = 1 × 108 W/W or 10 log AP = 80 dB (c) Av = vO 5V = 5 V/V = vi 1V or 20 log 5 = 14 dB Chapter 1-12 Ai = iO v O /RL 5 V/10 = = iO v O /RL 5 V/10 = 1 × 105 × 1000 = 1 × 108 W/W or 10 log AP = 80 dB (c) Av = vO 5V = 5 V/V = vi 1V or 20 log 5 = 14 dB Chapter 1-12 Ai = iO v O /RL 5 V/10 = = iO v O /RL 5 V/10 = iO v iI iI 1 mA or 20 log 11 = 20.8 dB Ai = 0.5 A = 500 A/A = 1 mA 22 mA = 22 A/A 1 mA or 20 log Ai = 26.8 dB \sqrt{po} (2.2/2)2 /100 Ap = = pi 0.2 10-3 $\sqrt{\times \sqrt{2}}$ 2 = or 20 log 500 = 54 dB v O iO vO iO = × v I iI vI iI Ap = io 2.2 V/100 = ii 1 mA = 5 × 500 = 2500 W/W or 10 log Ap = 34 dB = 242 W/W 1.38 For ±5 V supplies: The largest undistorted $\sqrt{sine-20}$ sinewave output is of 4-V peak amplitude or 4/2 = 2.8 Vrms. (d) Voltage gain = 8.37 2V = 20 V/V 0.1 V VCC RC RC $r\pi$ = 10 k yod β = 10 k gm 100 = 10 k = gm 2 10 mA/V Ad = 100 = m RC RC = 100 100 = 10 k = gm = 10 mA/V Ad = 100 = m RC RC = 100 100 = 10 k = gm = 10 mA/V Ad = 100 = m RC RC = 100 100 = 10 k = gm = 10 mA/V Ad = 100 = m RC RC = 100 100 = 10 k = gm = 10 mA/V Ad = 100 = m RC RC = 100 100 = 10 k = gm = 10 mA/V Ad = 100 = m RC RC = 100 100 = 10 k = gm = 10 mA/V Ad = 100 mV Ad 1)[re1 + (rn 2 ro1)] Rsig 100 k = 101[0.125 + (12.5 250)] Q1 = 1.215 M Rin 1.215 vb1 = 0.71 V/V = vsig Rin + Rsig 1.215 + 0.5 rn 2 ro1 ve1 = 0.99 V/V vb1 (rn 2 ro1) + re1 vo = -gm2 ro2 = -8 × 250 = -2000 V/V vb1 vo = 0.71 × 0.99 × -2000 = -1405 V/V Gv = vsig Q2 vsig Rout RL 1 k Rin Chapter 7-34 Rin = (\beta + 1)[re1 + (\beta 2 + 1)(re2 + 1)(RL)] (b) gm1 = = 101[0.25 + (101)(0.0025 + 1)] = 10.25 M Rout = re2 + re1 + Rsig /($\beta1 + 1$) $\beta2 + 1.100 \times 103\ 101 = 2.5 + = 14.8\ 101$ With RL removed, vo Gv o = =1 vsig 250 + vo RL = Gv o vsig RL + Rout = 1 × 1 = 0.985\ 1 + 0.0148\ gm2 = IC2\ 1\ mA = = 40\ mA/V\ VT\ 0.025\ rm\ 2 = \beta\ 200 = 5\ k = gm2\ 40\ (c) Neglecting RG , we can write rm2 6.8 k $vb2 = vi (rn2 \ 6.8 \ k) + 1 \ gm1 = 0.65 \ V/V \ vo = -gm2 \ (3 \ 1) \ vb2$ With RL connected, $Gv = 2ID1 \ 2 \times 0.1 = 0.632 \ mA/V = VOV \ 0.316 = -40 \times 3 = -30 \ V/V \ vi \ (d) \ 7.92 \ RG \ 5 \ V \ Avvi \ ii \ vi \ RG \ 10 \ M \ 3 \ k \ Figure \ 2 \ 0.7 \ VGS \ From \ Fig. \ 10 \ M \ 16 \ k \ 7 \ V \ 1.5 \ V \ 5 \ M \ VGS = VDS = 1.207 \ V \ gm = 2.83 \ mA/V, ro = 50 \ k \ and \ vo = -23.6 \ V/V \ vi \ (d) \ 7.92 \ RG \ 5 \ V \ Avvi \ ii \ vi \ RG \ 10 \ M \ 3 \ k \ Figure \ 2 \ 0.7 \ VGS \ From \ Fig. \ 10 \ M \ 16 \ k \ 7 \ V \ 1.5 \ V \ 5 \ M \ VGS = VDS = 1.207 \ V \ gm = 2.83 \ mA/V, ro = 50 \ k \ and \ vo = -23.6 \ V/V \ vi \ (d) \ 7.92 \ RG \ 5 \ V \ Avvi \ ii \ vi \ RG \ 10 \ M \ 3 \ k \ Figure \ 2 \ 0.7 \ VGS \ From \ Fig. \ 10 \ M \ 16 \ k \ 7 \ V \ 1.5 \ V \ 1.5 \ V \ 5 \ M \ VGS \ = 1.207 \ V \ gm = 2.83 \ mA/V, ro = 50 \ k \ and \ vo = -23.6 \ V/V \ vi \ (d) \ 7.92 \ RG \ 5 \ V \ Avvi \ ii \ vi \ RG \ 10 \ M \ 3 \ k \ Figure \ 2 \ 0.7 \ VGS \ From \ Fig. \ VOS \ From \ Fig. \ From \ Fig. \ VOS \ From \ Fig. \ From \ Fi$ 0.5 mA 7 k Figure 1 6.29 For the NMOS device: 1 W 2 ID = 100 = µp Cox VOV 2 L 10 1 2 × VOV = × 400 × 2 0.5 = VOV = 0.16 V 2ID 2 × 0.1 mA = 1.25 mA/V = gm = VOV 0.16 VA = 5L = 5 × 0.5 = 2.5 V VA 2.5 = 25 k = ro = ID 0.1 For the PMOS device: 1 W 2 ID = 100 = µp Cox VOV 2 L 10 1 2 × VOV = × 400 × 2 0.5 = VOV = 0.316 V 2ID 2 × 0.1 mA = 1.25 mA/V = gm = VOV 0.16 VA = 5L = 5 × 0.5 = 2.5 V VA 2.5 = 25 k = ro = ID 0.1 For the PMOS device: 1 W 2 ID = 100 = µp Cox VOV 2 L 10 1 2 = × 100 × × VOV 2 0.5 = VOV = 0.316 V 2ID 2 × 0.1 mA = 1.25 mA/V = gm = VOV 0.16 VA = 5L = 5 × 0.5 = 2.5 V VA 2.5 = 25 k = ro = ID 0.1 For the PMOS device: 1 W 2 ID = 100 = µp Cox VOV 2 L 10 1 2 = × 100 × × VOV = 0.316 V 2ID 2 × 0.1 mA = 1.25 mA/V = gm = VOV 0.16 VA = 5L = 5 × 0.5 = 2.5 V VA 2.5 = 25 k = ro = ID 0.1 For the PMOS device: 1 W 2 ID = 100 = µp Cox VOV 2 L 10 1 2 = × 100 × × VOV = 0.316 V 2ID 2 × 0.1 mA = 1.25 mA/V = gm = VOV 0.16 VA = 5L = 5 × 0.5 = 2.5 V VA 2.5 = 25 k = ro = ID 0.1 For the PMOS device: 1 W 2 ID = 100 = µp Cox VOV 2 L 10 1 2 = × 100 × × VOV = 0.316 V 2ID 2 × 0.1 mA = 1.25 mA/V = gm = VOV 0.16 VA = 5L = 5 × 0.5 = 2.5 V VA 2.5 = 25 k = ro = ID 0.1 For the PMOS device: 1 W 2 ID = 100 = µp Cox VOV 2 L 10 1 2 = × 100 × × VOV = 0.316 V 2ID 2 × 0.1 mA = 1.25 mA/V = gm = VOV 0.16 VA = 5L = 5 × 0.5 = 2.5 V VA 2.5 = 25 k = ro = ID 0.1 For the PMOS device: 1 W 2 ID = 100 = µp Cox VOV 2 L 10 1 2 = × 100 × × VOV = 0.316 V 2ID 2 × 0.1 mA = 1.25 mA/V = gm = VOV 0.16 VA = 5L = 5 × 0.5 = 2.5 V VA 2.5 = 25 k = ro = ID 0.1 For the PMOS device: 1 W 2 ID = 100 = µp Cox VOV 2 L 10 1 2 = × 100 × 1 bias voltage would be 0.1 Vpp 1 = 1.8 - 0.2 - (0.1) 22 = 1.55 V (c) V SG2 = |VOV| + Vtp = 0.2 + 0.5 = 0.7 V RL 1 400 k 1 + = + gm2 ro2 gm2 20 1 mA/V = <math>21 k Av 1 = -1 mA/V (20 k 21 k) = -10.2 V/V Av = -1 mA/V (20 k 21 k) = -10.2Figure 2 shows the circuit with the value of VB that results in the transistor operating in saturation, with IE = $VB - 0.7 = VB - 0.7 = VB - 0.7 = VB - 0.7 = VB - 0.7 = 0.3 \times 1 = -0.3 \times$ operating in saturation, and our original assumption is incorrect. P5.22 have the i-v relationship 1 W i = k (v - |Vt|)2 (1) 2 L where k represents in the PMOS case. Transistor Q3 is operating at an emitter bias current IE3 = IB1 + IB2 = 2IB = 2IC / β = 2(1 - α) IC α Now, using ix = α ie from Eq. (1), we have Thus, vx 2VT = ix IREF Rin = 2(1 - α) IREF α Replacing each of the three transistors with its T model and applying an input test voltage vx to determine Rin, we obtain the equivalent circuit shown. (a) we see that for $-3.5 \text{ V} \le \text{v I} \le +3.5 \text{ V}$, diodes D1 and D2 will be cut off and i = 0. Thus (c) We shall assume that both Q3 and Q4 are operating in saturation. Thus, I = 0.5 mW = 0.28 mA (0.98 mA + 0.9 V = +0.52 V VC2 = VCC - IC2 × RC = $2.5 - 0 \times 5 = 2.5$ V 8.23 Refer to Fig. The added series resistance must be 10% of R (i.e., 0.1R). = -12 dB PL Pi where PL = 6.25 mW and Pi = v i i1, v i = 0.5 V and ii = 1 V = 0.5 V A 1 M + 1 M Exercise 1-3 This figure belongs to Exercise 1.15. 0 + 1.5 + 0.5 + 1.5 Sat. 100 k v1 and 100 k For the second summer, to obtain 100 k v2 100 k v0 then Rc = 3 R3 and 100 k v3 v0 = -3 v3 v0 = -5 v4 100 k requires Rc = 5 R4 We can select Rc = Rb = 60 k, resulting in R3 = 20 k and R4 = 12 k. As v I further increases, the diode current increases but its voltage remains constant at 0.7 V. These two resistances must carry equal currents \Rightarrow I1 = I. P4.55(a). 7.43, from Eq. (7.102), we have Rout $[1 + gm (RE \ rn)]$ ro From Example 7.6, RE = R3 = 11.5 k; therefore, mA Rout 1 + 0.4 (11.5 k 250 k) 10 M V \therefore Rout = 54 M Gv = vo = -145.5 V/V vsig These results apply for both Rsig = 4 k and Rsig = 400 k. Thus, 10 μ A VEB = VT ln ISB VEB = 0.616 V Thus, VB = -VEB = -0.616 V The collector current can be found as 1 IC = β IB VCEsat (V) 0.231 0.178 0.161 0.133 = 50 × 10 = 500 \muA = 0.5 mA This table belongs to Problem 4.19. Finally, if v I is a symmetrical square wave of 1-kHz frequency, 5-V amplitude, and zero average, the output will be zero during the negative half cycles of the input and will equal twice the input during the positive half cycles. RC RL Chapter 6-47 vo vo = = -gm (RC RL) v b2 vn2 = -40(6.8 2) = -61.8 V/V vo v b2 v b1 vo = × × = -61.8 (f) v sig v b2 v b1 v sig (e) × $-69.2 \times 0.32 = 1368.5$ V/V From Fig. Thus 1 - ID RDmax = -0.4 RDmax = 1.4 = 17.5 k 0.08 Chapter 5-11 5.43 5.42 1.3 V VDD 1.8 V RD ID2 ID1 ID R2 R VD2 Q2 VGS Q1 VD1 1 W k (VGS - Vt) 2 2 VGS Q1 VD1 1 W k (VGS - Vt) 2 2 VGS Q1 VD1 1 W k (VGS - Vt) 2 Q2 VGS Q1 VD1 1 W k (VGS - Vt) 2 Q2 VGS Q1 VD1 1 W k (VGS -
Vt) 2 Q2 VGS Q1 VD1 1 W k (VGS - Vt) 2 Q2 VGS Q1 VD1 1 W k (VGS nL W 1 = $\times 0.4 \times (1.3 - 0.4)22$ L W = 0.162 L ID = (a) ID1 = 50 µA 0.05 = 1 1.44 2 $\times 0.4 \times V2$ 0.36 OV \Rightarrow VOV = 0.25 V W RD L VGS1 = Vt + VOV VD = 1.3 - 10 RD = 1.3 - 0.162 = 0.5 + 0.25 = 0.75 V For the MOSFET to be at the edge of saturation, we must have VD1 = VGS1 = 0.75 V VDD - VD1 1.8 - 0.75 = 21 k R = = ID1 0.05 (b) Note that both transistors operate at the same VGS and VOV, and ID2 = 0.5 mA But ID2 = 1 W2 2 kn VOV 2 L2 0.5 = 1 W2 × $0.4 \times \times 0.252$ 2 0.36 VD = VOV = 1.3 - 0.4 = 0.9 Thus 0.9 = 0.9 $1111fL = + + 2\pi \tau CE \tau C1 \tau C2$ (200 20) × 103 $\tau CE = 5 \times 10 - 6 \times 250 + 101 = 2.15 \text{ ms } \tau C1 = 0.5 \times 10 - 6 (20 + 10) \times 103 = 15 \text{ ms } 3$ 10 103 103 1 $fL = + + 2\pi 2.15 21.1 15 = 92.2 \text{ Hz}$ which is lower (hence more conservative) than the required value of 100 Hz. Ctotal = 5 + 0.5 + 0.5 = 0.5 \times 10 - 6 (20 + 10) \times 103 = 15 \text{ ms } 3 10 103 103 1 $fL = + + 2\pi 2.15 21.1 15 = 92.2 \text{ Hz}$ which is lower (hence more conservative) than the required value of 100 Hz. Ctotal = 5 + 0.5 + 0.5 = 0.5 \times 10 - 6 (20 + 10) \times 103 = 15 \text{ ms } 3 10 103 103 1 $fL = + 2\pi 2.15 21.1 15 = 92.2 \text{ Hz}$ which is lower (hence more conservative) than the required value of 100 Hz. Ctotal = 5 + 0.5 + 0.5 = 0.5 \times 10 - 6 (20 + 10) \times 103 = 15 \text{ ms} 3 10 103 103 1 $fL = + 2\pi 2.15 21.1 15 = 92.2 \text{ Hz}$ which is lower (hence more conservative) than the required value of 100 Hz. Ctotal = 5 + 0.5 + 0.5 = 0.5 \times 10 - 6 (20 + 10) \times 103 = 15 \text{ ms} 3 10 103 103 1 $fL = + 2\pi 2.15 21.1 15 = 92.2 \text{ Hz}$ which is lower (hence more conservative) than the required value of 100 Hz. Ctotal = 5 + 0.5 + 0.5 = 0.5 \times 10 - 6 (20 + 10) \times 103 = 15 \text{ ms} 3 10 103 103 1 $fL = + 2\pi 2.15 21.1 15 = 92.2 \text{ Hz}$ which is lower (hence more conservative) than the required value of 100 Hz. Ctotal = 5 + 0.5 + 0.5 = 0.5 \times 10 - 6 (20 + 10) \times 103 = 15 \text{ ms} 3 10 103 103 1 $fL = + 2\pi 2.15 21.1 15 = 92.2 \text{ Hz}$ which is lower (hence more conservative) that her required value of 100 Hz. Ctotal = 5 + 0.5 \times 10 - 6 (20 + 10) \times 103 = 15 \text{ ms} 3 10 103 103 1 $fL = + 2\pi 2.15 21.1 15 = 92.2 \text{ Hz}$ $6.0 \ \mu F$ Using the method of short-circuit time constants and the information in Fig. Thus, the minimum voltage allowed at the emitters of Q1 and Q2 is $-2.5 \ V + 0.3 \ V = -2.2 \ V$. Thus, the cascoding of the bias current source must raise its output resistance RSS by a factor of 100. The transistor is biased at IE = $0.33 \ mA$. $\Rightarrow VZ0 = 7.2 \ V \therefore R = At IZ = 0.33 \ mA$. $2IZT = 0.4 \text{ A}, VZ = 7.2 + 0.4 \times 1.5 = 7.8 \text{ V}9 - 6.8 = 110 20 \text{ Line regulation} = P = 7.8 \times 0.4 = 3.12 \text{ W} = 3.57 \text{ VZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VS \text{ rZ} + R 5 5 + 110 = 43.5 \Rightarrow VZ0 = 8.9 \text{ V mV V} \text{ SECOND DESIGN: limited current from 9-V supply At IZ = 10 mA, VZ = 8.9 + 0.01 \times 10 = 9.4 \text{ VZ} = 8.9 + 0.05 \times 10 = 9.4 \text{ VZ} = 8.9 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + IZT \text{ rZ} 9.1 = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VO } \text{ rZ} = VZ0 + 0.02 \times 10 \text{ VZ} = VZ0 + 0.02 \times 10 \text{ VZ} = VZ0 + 0.02 \times 10 \text{$ V IZ = 0.25 mA VZ = VZK VZO - calculate VZO + rZ IZT 3.58 (a) Three 6.8-V zeners provide 3 × 6.8 = 20.4 V with 3 × 10 = 30- resistance. Pi = Ra Ra Rc Rc v1 + v2 R1 Rb R2 Rb Rc - v3 R3 We want to design the circuit such that v O = 2v 1 + v 2 - 4v 3 Thus we need to have Ra R1 Rc Rb = 2, Ra R2 Rc Rb = 1, and Rc = 4 R3 From the above three equations, we have to find six unknown resistors; therefore, we can arbitrarily choose three of these resistors. Then, gm of each transistor can be determined as 2ID //VOV | and ro as |VA |/ID . 5.57 Refer to the circuit in Fig. P5.22 is biased to operate at v = |Vt | + |VOV |, then its incremental resistance r at the bias point can be obtained by differentiating Eq. (1) relative to v and then substituting v = |Vt| + |VOV| as follows: W $\partial i = k (v - |Vt|) \partial v L = 0$ W r=1 Q.E.D = 1 k VOV $\partial v v = |Vt| + VOV L = 0$ W r=1 Q.E.D = 1 k VOV $\partial v v = |Vt| + VOV L = 0$ W r=1 Q.E.D = 1 k VOV $\partial v v = |Vt| + VOV L = 0$ W r=1 Q.E.D = 1 k VOV $\partial v v = |Vt| + VOV L = 0$ W r=1 Q.E.D = 1 k VOV $\partial v v = |Vt| + VOV L = 0$ W r=1 Q.E.D = 1 k VOV $\partial v v = |Vt| + VOV L = 0$ W r=1 Q.E.D = 1 k VOV $\partial v v = |Vt| + VOV L = 0$ $\omega \omega 1$ = 2 k \Rightarrow R1 = 2 k Thus, R1 = 2 k, R2 = 200 k, C1 0.4 μ F, and C2 4 pF. P6.116. Now, VD = 0 = VDD - ID RD 0 = 5 - 0.5 × RD \Rightarrow RD = 10 k 6.88 ID = 1.78 mA or 1 mA VDD The first answer is physically meaningless, as it would result in VS = 5.33 V, which is greater than VG , implying that the transistor is cut off. (1) and (2) as rn vo = - gm (ro RL) vs rn + Rs Chapter 1-8 This figure belongs to Problem 1.18. Thus, I /2 Ro6 = gm ro2 Ad = gm (gm ro2) 1 (gm ro) 2 I 2 |VA | gm ro = $\times = |VOV|$ I |VOV | 8.84 The currents i1 to i13 are shown on the circuit diagram. VSGP = 1.768 V If Q3 and Q4 have W = 100 µm, nothing changes for Q1 and Q2 This situation pertains for v Id ≥ -4 mV. If we neglect this internal feedback, that is, assume g12 = 0, we can compare the two models and thus obtain: Dividing the numerator by ($\beta + 1$) gives ve RE = vb RE + [r $\pi/(\beta + 1)$] Q.E.D 1.59 Ri = 1/g11 gm gmv1 v1 100 mA/V R 5 k Ro = g22 vo R Av o = g21 1.61 Circuits of Fig. The output the numerator by ($\beta + 1$) gives ve RE = vb RE + [r $\pi/(\beta + 1)$] Q.E.D 1.59 Ri = 1/g11 gm gmv1 v1 100 mA/V R 5 k Ro = g22 vo R Av o = g21 1.61 Circuits of Fig. The output the numerator by ($\beta + 1$) gives ve RE = vb RE + [r $\pi/(\beta + 1)$] Q.E.D 1.59 Ri = 1/g11 gm gmv1 v1 100 mA/V R 5 k Ro = g22 vo R Av o = g21 1.61 Circuits of Fig. The output the numerator by ($\beta + 1$) gives ve RE = vb RE + [r $\pi/(\beta + 1)$] Q.E.D 1.59 Ri = 1/g11 gm gmv1 v1 100 mA/V R 5 k Ro = g21 1.61 Circuits of Fig. The output the numerator by ($\beta + 1$) gives ve RE = vb RE + [r $\pi/(\beta + 1)$] Q.E.D 1.59 Ri = 1/g11 gm gmv1 v1 100 mA/V R 5 k Ro = g21 1.61 Circuits of Fig.
The output the numerator by ($\beta + 1$) gives ve RE = vb RE + [r $\pi/(\beta + 1)$] Q.E.D 1.59 Ri = 1/g11 gm gmv1 v1 100 mA/V R 5 k Ro = g21 1.61 Circuits of Fig. The output the numerator by ($\beta + 1$) gives ve RE = vb RE + [r $\pi/(\beta + 1)$] Q.E.D 1.59 Ri = 1/g11 gm gmv1 v1 100 mA/V R 5 k Ro = g21 1.61 Circuits of Fig. The output the numerator by ($\beta + 1$) gives ve RE = vb RE + [r $\pi/(\beta + 1)$] Q.E.D 1.59 Ri = 1/g11 gm gmv1 v1 100 mA/V R 5 k Ro = g21 1.61 Circuits of Fig. The output the numerator by ($\beta + 1$) gives ve RE = vb RE + [r $\pi/(\beta + 1)$] Q.E.D 1.59 Ri = 1/g11 gm gmv1 v1 100 mA/V R 5 k Ro = g21 1.61 Circuits of Fig. The output the numerator by ($\beta + 1$) gives ve RE = vb RE + [r $\pi/(\beta + 1)$] Q.E.D 1.59 Ri = 1/g11 gm gmv1 v1 100 mA/V R 5 k Ro = g21 1.61 Circuits of Fig. The output the numerator by ($\beta + 1$) gives ve RE = vb RE + [r $\pi/(\beta + 1)$] Q.E.D 1.59 Ri = 1/g11 gm gmv1 v1 100 mA/V R 5 k Ro = g21 1.61 Circuits of Fig. The output the numerator by (\beta + 1) Ro = g21 1.61 Circuits of Fig. The output the numerator by (\beta + 1) Ro = g21 1.61 Circuits of Fig. The output the nu becomes 1 V. Thus, replacing the 15.7-k resistance with a constant-current source is an excellent modification to make! 8.114 (a) vo = A1 A2 A3 A4 v id = $20 \times -29.6 \times -6.42 \times 1 = 3800.6$ V/V which is less than half the gain obtained without the emitter resistances. It is symmetrical. α I 2 8.78 Gm = 2 mA/V α 2I RC VC1 = VCC - 3 α I VC2 = VCC - RC 3 and the dc offset voltage at the output will be With RL = ∞ , Ad = Gm Ro and vo = Gm Ro vid VO = VC2 - VC1 With RL = 20 k, 1 VO = α IRC 3 To reduce this output voltage to zero, we apply a dc input voltage to zero, we apply a dc input voltage to zero, we apply a dc input voltage to zero. = IS1 × e0.75/0.025 = IS1 = 4.7 × 10-17 A 4.8 β 10 20 50 100 200 500 1000 IS2 = 4IS1 = 1.87 × 10-16 A β α = 0.5 0.67 0.91 0.95 0.98 0.999 β + 1 4.3 IC1 = 10-13 e700/25 = 0.145A = 145 mA 4.9 β = -18 700/25 = 0.145A = 145 mA 4.9 β = $0.025 \ln 10 - 13 = 0.412 \text{ V} 4.4 \text{ AE1 } 200 \times 200 \text{ IS1} = = 250,000 \text{ IS2 } AE2 0.4 \times 0.4 \text{ IC1} = \text{IS1 } eVBE1 / VT \text{ IC2} = \text{IS2 } e \text{ VBE2} - VBE1 = 0.025 \ln (250,000) = 0.31 \text{ V} 10 - 3 = 2 \times 10 - 15 \text{ eVBE1} / VT \text{ IC2} = \text{IS2 } e \text{ VBE2} / VT \text{ For IC1} = \text{IS2 } e \text{ VBE2} / VT \text{ For IC1} = \text{IS2 } e \text{ VBE2} / VT \text{ For IC1} = 1.52 \text{ eVBE2} / VT \text{ eVBE2} / VT \text{ For IC1} = 1.52 \text{ eVBE2} / VT \text{ eVB$ $0.7 \text{ VVC } 4 \text{ V1 mA Ex: } 4.24 10 \text{ V10 V IC } 5IB 4.7 \text{ k VB } 0.5 \text{ RC For a } 4-\text{V reverse-biased voltage across the CBJ, VC = } -4 \text{ V VB Refer to the figure. } 5 \text{ mA b. Ad = gm RD VDD } -2.1 \ge 0.505 - 0.5 \text{ Chapter } 8-7 \text{ where } W \text{ I } 2 \text{ mA Ex: } 4.24 10 \text{ V I O V IC } 5IB 4.7 \text{ k VB } 0.5 \text{ RC For a } 4-\text{V reverse-biased voltage across the CBJ, VC = } -4 \text{ V VB Refer to the figure. } 5 \text{ mA b. Ad = gm RD VDD } -2.1 \ge 0.505 - 0.5 \text{ Chapter } 8-7 \text{ where } W \text{ I } 2 \text{ m Cox } W \sqrt{\text{ I } / 2 \text{ RD } L } (2) \text{ Equating the gains from Eqs. Ex: } 1.8 \text{ P = 1 T T Ex: } 1.9 (a) \text{ D can}$ represent 15 distinct values between 0 and +15 V. (a) |Vo /Vi | = 1 at ω = CR 104 = 1.59 kHz. Correspondingly, f = 2π (b) At f = 1.59 kHz, the output sine wave leads the input sine wave by 90°. This table belongs to Problem 4.13. Thus, 4.32 ICBO approximately doubles for every 10° C rise in temperature. P6.58. Now, since the op-amp saturation levels are ± 10 V, the room left for output signal swing is approximately ± 7 V. If an ideal Miller integrator is fed with a -1-V pulse will cause a current I = 1 V/R to be drawn through R and C. VGS = 0.97 V. P5.39. (ii) However, if the circuit is to operate in the temperature range of $0 \circ C$ to $75 \circ C$ (i.e., at a temperature that deviates from room temperature by a maximum of $50 \circ C$), the input offset voltage will drift from by a maximum of $50 \circ C = 500 \ \mu V$ or $0.5 \ mV$. Case VS VG VD VGS VOV VDS Region of operation a +1.0 + 1.0 + 2.5 + 2.0 + 1.5 + 0.5 + 1.0 Sat. (b) (b) See analysis on Fig. re = 25 Rin = $(\beta 1 + 1)(2 \text{ re}) = 101 \times 0.05 = 5.05 \text{ k}$ Exercise 7-8 $\alpha 2$ RL 5 vo = = 100 V/V vi 2 re 0.05 vi vo vo = × rsig vsig vi Thus, Rin vo = × Rin + Rsig vi 1 vo = gm RL vi 2 = and vo = iRL where 5.05 × 100 = 50 V/V 5.05 + 5 gm = 21D 2I = VOV VOV Thus, Ex: 7.32 2I 1 IRL vo = × RL = vi 2 VOV VOV (b) I = 0.1 mA and RL = 20 k, to obtain a gain of 10 V/V, RL i vo vi Q1 1 gm1 (a) From the figure we see that i = 1 vi = gm v i 2/gm 2 10 = 0.1×20 VOV \Rightarrow VOV = 0.2×20 VOV = 0.0.5 V or 2VOV. P2.55. The value of R is found as follows: But R = \Rightarrow VC = VOV 1,2 (2) 1,2 \Rightarrow VOV 3 = VC + VOV 1,2 (1) and since \Rightarrow VC = 0 (ii) Rs = 1 W VOV L 3,4 substituting from (2) into (1) gives But VOV 3 = VC + VOV 1,2 (2) 1,2 \Rightarrow VOV 3 \times VOV 3 VOV 1,2 rDS3,4 = \Rightarrow VC = 0 (ii) Rs = 1 W VOV L 3,4 substituting from (2) into (1) gives But VOV 3 = VC + VOV 1,2 (2) 1,2 \Rightarrow VOV 3 \times VOV 3 \times VG7 IREF 0.8 - (-0.8) = 8 k 0.2 Chapter 8-9 Since I = IREF, Q3 and Q6 are matched and are operating at A summary of the result is the transfer characteristic sketched in Fig. 1 we see that VDG = IR Since for the PMOS transistor to operate in saturation, VDG \leq |Vtp | It follows the (b) Refer to the circuit in Fig. = -74(3.92) = -97.83 vo = $-0.371 \times 97.83 = -36.3$ V/V v sig 6.115 Refer to the circuit of Fig. The same current is flowing in Q2 and Q1; thus I V1 = -2.7 + R 2 With this scheme, But 5 - 0.7 - 0.7 - (-5) = 86 k 0.1 mA and each transistor has EBJ areas proportional to the current required. Assume VD = 0.7 V ID = 5 - 0.7 = 0.43 mA = IS e0.7/VT (1) At a current I (mA), I = IS eVD /VT Use Eq. (3.5) and note that Using (1) and (2), we obtain V1 = 0.7 V, II = 1 mA I = e(VD - 0.7)/VT (2) Exercise 3-3 For an output voltage of 2.4 V, the voltage drop 2.4 = 0.8 V across each diode = 3 Now I, the current through each diode, is (d) V 0.7 V I = e(0.8-0.7)/0.025 = 54.6 mA 10 - 2.4 R = 54.6 × 10 - 3 0.7 5 2.5 1.72 mA 1 2.5 k 5 0.7 I 1.72 mA 1 2 k 1.7
V 0 1 V 1 V 5 V (c) Ex: 3.13 rd = VT ID ID = 0.1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3$ ID = 1 mA rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3 \text{ mA}$ rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3 \text{ mA}$ rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3 \text{ mA}$ rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3 \text{ mA}$ rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3 \text{ mA}$ rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3 \text{ mA}$ rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3 \text{ mA}$ rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3 \text{ mA}$ rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3 \text{ mA}$ rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3 \text{ mA}$ rd = $25 \times 10 - 3 = 25$ $1 \times 10 - 3 = 2$ /V T iD1 iD = iD2 - iD1 = iD1 ev D /V T - iD1 = iD1 ev D /V T - 1 c. The corresponding maximum input signal permitted v² be is v² be = 0.7 V 0.7 = 4.4 mV | Av | 160 IC RC VCC - VCE = - VT VT On the verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be VBE (5 v be verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be VBE (5 v be verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be VBE (5 v be verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be VBE (5 v be verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be VBE (5 v be verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be VBE (5 v be verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be VBE (5 v be verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be VBE (5 v be verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be VBE (5 v be verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be VBE (5 v be verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be verge of saturation Av = -6.11 VCE - v² ce = 0.3 V For linear operation, v ce = Av v be 5 V IC VCE - | Av v² be | = 0.3 RC 1 k vO v be verge of saturation Av v² be | = 0.3 RC 1 k vO v be - IC RC) - |Av | × 5 × 10-3 = 0.3 But |Av | = IC RC VT Thus, IC RC = |Av |VT - |Av | × 5 × 10-3 = 0.3 For IC = 0.5 mA, we have IC RC 0.5 Av = - = -20 V/V = -VT 0.025 VCE = VCC - IC RC |Av | (0.025 + 0.005) = 5 - 0.3 |Av | = 156.67. (c) The circuit with the largest area (58n) as compared to the circuit with the smallest area (0.065n): Av is 364.5/40.5 = 9 times larger, but Ro is 11.1 times lower. | Av |VT \geq P This figure belongs to Problem 6.15(a). Thus the dc voltage at the emitter will be VB = 5 VE = VB - 0.7 = 1.8 V 5 V VT IE \Rightarrow IE = 0.5 mA re = 50 = Thus, 5 - VE = 0.5 mA RE where VE = 0.5 mA = RE 3.6 and IC IE = 0.5 mA = RE 3.6 and IC IE = 0.5 mA = RE 3.6 and IC IE = 0.5 mAro) Rin + Rsig Gv = $-4.64 \times 20 \times (18\ 20\ 200)\ 4.64 + 10 = -57.3\ V/V\ Ex: 6.42\ Refer$ to the solutions of Exercises 6.40 and 6.41 above. 1 Rsig CE re + β + 1 and the pole due to CC will have a frequency ω PC ω PC = 1 CC (RC + RL) (c) The overall voltage transfer function can be expressed as Vo s s = AM Vsig s + ω PC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + ω PC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + ω PC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + ω PC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + ω PC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + ω PC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + ω PC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + ω PC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + ω PC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + ω PC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + \omegaPC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + \omegaPC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + \omegaPC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + \omegaPC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + \omegaPC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + \omegaPC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + \omegaPC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s s = AM Vsig s + \omegaPC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s = AM Vsig s + \omegaPC VT 25 mV = 25 (d) reference to the solution can be expressed as Vo s = AM Vsig s + \omegaPC VT $= IE 1 mA 100(10 k 10 k) AM = -101 \times 25 \times 10 - 3 k + 10 k = -40 V/V Figure 2 The gain at fP2 (10 Hz) is 12 dB. Rsig 10 k vsig vp1 rp1 vp2 gm1vp1 rp2 vo gm2vp2 RC1 RC2 RL Chapter 6-25 which requires a bias current IE of VT 25 mV = = 1.25 mA Re = 1.80 Rin Gv = Rin + Rsig - \alpha \times Total resistance in the second s$ collector × Total resistance in emitter $-0.99 \times 6.15 \times = 15 + 30.0.2 - 10 \text{ V/V} \text{ v}^{0} = 0.15 \times |\text{Gv}| = 1.5 \text{ V} 6.70 \text{ Using Eq. (6.113), we have RC RL } + (\beta + 1)(\text{re + Re}) 10 |\text{Gv}| = (10/\beta) + 0.025 \text{ For the nominal case, } \beta = 100, 10 \text{ Gv} = 80 \text{ V/V nominal } 0.1 \text{ + Re}$ = 50, 10 Gv = = 44.4 V/V low 0.2 + 0.025 For β = 150, 10 Gv = 109.1 V/V = high (1/15) + 0.025 Thus, |Gv| ranges from 44.4 V/V to 109.1 V/V with a nominal value of 80 V/V. The - two supplies v + O and v O are identical. iD, peak = rd vs R rd VT /I VT = vs = vs VT rd + RS VT + IRS + RS I 25 mV Now, vo = 10 mV × 25 mV + 103 $vo = vs \times I$ vo The design is essentially the same since the supply voltage 0.7 V 1 mA 0.24 mV 0.1 mA 2.0 mV 1 μ A 9.6 mV 3.44 Use the exponential diode model to find the percentage change in the current. Thus, the output short-circuit transconductance Gm will be Gm = gm1 Q.E.D. vo = -gm11 + ro rπ |VA | |VA | 1 VT 1 + gm ro β |VA | 1 1 1 VT 1 + |VA | β VT |VA | (VT / |VA |) + (1/β) IRo = = For |VA | = 5 V and β = 50 we obtain 5 IRo = = 200 V (0.025/5) + (1/50) 7.70 VCC I (mA) VB4 Q4 VB3 Q3 Q.E.D. 0.1 0.5 1 Ro (k) 2000 400 200 7.72 The output resistance of the cascode amplifier (excluding the load) is Ro = gm ro (ro rπ) Thus, Ro Av = 200 V (0.025/5) + (1/50) 7.70 VCC I (mA) VB4 Q4 VB3 Q3 Q.E.D. 0.1 0.5 1 Ro (k) 2000 400 200 7.72 The output resistance of the cascode amplifier (excluding the load) is Ro = gm ro (ro rπ) Thus, Ro Av = 200 V (0.025/5) + (1/50) 7.70 VCC I (mA) VB4 Q4 VB3 Q3 Q.E.D. 0.1 0.5 1 Ro (k) 2000 400 200 7.72 The output resistance of the cascode amplifier (excluding the load) is Ro = gm ro (ro rπ) Thus, Ro Av = 200 V (0.025/5) + (1/50) 7.70 VCC I (mA) VB4 Q4 VB3 Q3 Q.E.D. 0.1 0.5 1 Ro (k) 2000 400 200 7.72 The output resistance of the cascode amplifier (excluding the load) is Ro = gm ro (ro rπ) Thus, Ro Av = 200 V (0.025/5) + (1/50) 7.70 VCC I (mA) VB4 Q4 VB3 Q3 Q.E.D. 0.1 0.5 1 Ro (k) 2000 400 200 7.72 The output resistance of the cascode amplifier (excluding the load) is Ro = gm ro (ro rπ) Thus, Ro Av = 200 V (0.025/5) + (1/50) 7.70 VCC I (mA) VB4 Q4 VB3 Q3 Q.E.D. 0.1 0.5 1 Ro (k) 2000 400 200 7.72 The output resistance of the cascode amplifier (excluding the load) is Ro = gm ro (ro rπ) Thus, Ro Av = 200 V (0.025/5) + (1/50) 7.70 VCC I (mA) VB4 Q4 VB3 Q3 Q.E.D. 0.1 0.5 1 Ro (k) 2000 400 200 7.72 The output resistance of the cascode amplifier (excluding the load) is Ro = gm ro (ro rπ) Thus, Ro Av = 200 V (0.025/5) + (1/50) 7.70 VCC I (mA) VB4 Q4 VB3 Q3 Q.E.D. 0.1 0.5 1 Ro (k) 2000 400 200 7.72 The output resistance of the cascode amplifier (excluding the load) is Ro = gm ro (ro rπ) Thus, Ro Av = 200 V (0.025/5) + (1/50) VCC I (mA) VB4 Q4 VB3 Q3 Q.E.D. 0.1 0.5 1 Ro (k) 2000 7.72 The output resistance of the cascode amplifier (excluding the
load) is Ro = gm ro (ro rπ) Thus, Ro Av = 200 V (0.025/5) + (1/50) VCC I (mA) VB4 Q4 VB3 Q3 Q.E.D. 0.1 0.5 1 Ro (k) 200 VCC I (mA) VB4 Q4 V $-gm(Ro RL) = -gm(Ro \beta ro) Chapter 7-27 For |VA| = 100 V, \beta = 50, and I = 0.2 mA we obtain I 0.2 gm = = 8 mA/V VT 0.025 \beta 50 = 6.25 k rn = = gm 8 100 |VA| = = 500 k I 0.2 Ro = 8 \times 500 \times (500 6.25) ro = = 24, 691 k Av = -8(24.7 25) \times 103 = -99.4 \times 103 - 105 V/V$ (b) Refer to the circuit in Fig. For VO = 3 V, voltage drop across each diode 3 = 0.75 V 4 and $R = iD = IS eV/VT IS = iD eV/VT = 5 \times 10 - 3 = 4.7 \times 10 - 16$ A e0.75/0.025 0 to 15 mA the minimum zener current should be $5 \times IZk = 5 \times 1 = 5$ mA Since the load current can be as large as 15 mA, we should select R so that with IL = 15 mA, a zener current of 5 mA is available. This will be obtained by selecting VGS as follows: VG3 = VD4 - VSG3 4 |VA| |VA| = 20 k = ro = ID I 0.2 Since Ron = (qm ro)ro = (2 × 20) × 20 = 800 k VG3 = 3.1 - 1 = 2.1 V VSG3 = VSG4 = 1 V Chapter 7-23 the highest allowable voltage at the output will be vD3max = VG3 + |Vtp| = 2.1 + 0.8 = 2.9 V Since both Q3 and Q4 carry the same current I = 100 µA and are operated at the same overdrive voltage, |VOV| = 0.2 V, their W/L ratios will be the same and can be found from 1 W |VOV|2 ID = $\mu p \cos 2 L 3,4$ W = 83.3 L 3,4 = W L = 10 1,2 For each of the PMOS transistors, 1 W |VOV|2 ID = $\mu p \cos 2 L 3,4$ W = 40 L 3,4 7.64 ix Ro To obtain Ro we first find gm and ro of both devices, gm3,4 = 2 × 0.1 2ID = 1 mA/V |VOV | 0.2 ro3,4 = |VA | 5 = 50 k = ID 0.1 Q2 ix vx vy ro1 Ro = (gm3 ro3) ro4 Q1 = 1 × 50 × 50 = 2.5 M 7.63 Refer to Fig. W L (μ A/V2) (V) 800 0.5 400 - 1.5 400 - 1.100 + 0.8 μ Cox Vt Sat. R = 0.99 \Rightarrow R = 990 k R + 10 (c) P = I 2 R = (1 × 10 - 3) 2 × 100 × 103 = 0.1 W 1 Thus, the resistor should have a -W rating. This figure belongs to 1.44, part (b). (0.47 IC3 + 2.7 β Substituting $\alpha = 0.99$ and $\beta = 100$ and solving for IC3 results in Ex: 4.28 Refer to the solution of Example 4.10. To determine the systematic input offset voltage resulting from the error in the current-transfer ratio of the mirror, Chapter 8-32 we ground the two input terminals and determine the output current i as follows: $i = \alpha \alpha I I I - \alpha 2 2 I + (2/\beta p2) I 2 \alpha I = 2 2 \beta p2 \beta p$ input offset voltage should be VO = v Omax - 1.5 = 4 - 1.5 = +2.5 V 2VT \beta p2 For $\beta p = 50$, VOS = - (a) VB7 = +5 - VEB6 - VEB7 = 5 - 0.7 - 0.7 v Omax = -1.5 = +2.5 V 2VT \beta p2 VB7 + 0.4 = +4 V Dividing i by Gm = gm1,2 VOS = -8.92 Refer to Fig. vO = 0 V (d) See figure (d) on next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 6.109 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 7.100 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 7.100 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 8.100 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 8.100 Refer to Fig. To find Is we use Thévenin's theorem as shown in the figures on the next page. 8.100 Refer to Fig. To fig the same for A=B X and Y are opposite if A = B π - 2 θ = 112.5 \circ 3.6 Thus the average value of iB becomes 60 × 112.5 \circ = 18.75 mA iB |av = 360 \circ 3.7 The case for the highest current in a single diode is when only one input is low and the other two are high. 0.2707 Choose N = 4. The current I in O5 will be drawn from O2, which forms a mirror with O1. (b) The maximum error in conversion occurs when the analog signal value is at the middle of a step. (b) We need to select a value of the coupling capacitor C that will place the 3-dB frequency of the resulting high-pass STC circuit at 100 Hz, thus $100 = 12\pi CR1 \Rightarrow C = Ex: 2.22$ (a) The inverting amplifier of -1000 V/V gain will exhibit an output dc offset voltage of $\pm VOS$ (1 + R2 /R1) = $\pm 3 \text{ mV} \times (1 + 1000) = \pm 3.03 \text{ V}$. Also, from the circuit, observe as s $\rightarrow \infty$, (1/sC) $\rightarrow 0$ and Vo /Vi = R2 /(R1 + R2). Chapter 3-34 These figures belong to Problem 3.82. $\pm 1 \pm 2.13 \text{ N} \times (1 \pm 1000) = \pm 3.03 \text{ V}$. 20 V 50 V 10 V 100 V d + 20 ID 0.5 mA 2 mA 0.1 mA 0.2 mA e + 20 ro 40 k 25 k 100 k 500 k f + 20 0.02 V 0.1 V 0.01 V VSG |VOV | VSD Region of operation + 2 + 21 0.5 Triode 0 Triode 0 Triode 0 Triode 0 Triode 0 A v 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 72 sat 2 = 1 Vt | = 1.0, 800 (3 - |Vt|) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 VGD ≥ - 1.0 V 1 V : sat : sat Case d 1 k n (2 - Vt) 2 VGD ≥ - 12 triode 270 k n (4 - Vt) VDS - VDS 2 Vtp = -0.5 V (after failing assumption that both cases are sat.) v G = +3 V $\rightarrow 0$ V As v G reaches +2.5 V, the transistor begins to conduct and enters the saturation region, since v DG will be negative. 6.58. Assuming $\alpha = 1$, RE = 10 - 0.7 = 9.3 k 1 Exercise 4-6 Ex: 4.27 Refer to the circuit in Fig. For CC2 we use the information in Fig. To maximize the voltage gain, we select RC as large as possible, consistent with obtaining a ±2-V signal swing at the collector. 6.26(b) results in the following amplifier equivalent circuit: v be rπ C aie where β 100 = 2 k = gm 50 rπ = B ie Thus, ib = ib vi 0.01 V = 0.005 mA peak to peak 2 k re E Re vo Rin 6.47 Replacing the BJT with the T model of Fig. Correspondingly, VCE will range from $(3 - 0.5 \times 2) = 1$ V to $(3 - 1.5 \times 2) = 0$ V. The $(-j\omega)$ factor in the transfer function means inversion and $+90^{\circ}$ phase shift, thus vO (V) 8V 0 1 2 t (ms) 8 V v O = $-5 \sin(106 t + 90^{\circ})$, V The output wave has the same frequency as the input signal. P7.95(d). That is, the voltage at each collector will range between 0.7 V and +1.3 V. 7.13 The solution is given in the circuit diagram. 1.87 V0 = VT ln NA ND n2i I = Agn2i Dp Dn + Lp ND Ln NA Here Ip = Agn2i PV /VT - 1 Dp V /VT e -1 Lp ND Dn V /VT - 1 e Ln NA Dp Ln NA Ip = · · In Dn Lp ND If NA or ND is increased by a factor of 10, then new value of V0 will be 1 NAND V0 = VT In n2i The change in the value of V0 is VT ln10 = 59.6 mV. RL = Rsig Q1 vs Gv = 1 gm1 Q2 1 gm2 vo $\alpha \times$ Total resistance in collector = vsig Total resistance in emitters 0.99 × 10 0.99 × 10 = 10 10 + 2 re + 2 × 0.05 β + 1 101 = 49.7 V/V (d) Refer to Fig. AM = - CS = - RG × gm (RD RL) RG + Rsig 2 × 3(20 10) 2 + 0.5 = -16 V/V Figure 1 Replacing the MOSFET with its T model results in the circuit shown in Fig. Thus 50 (2 - 1Vt 1)2 \Rightarrow |Vt | = 1.5, = 450 (3 - 1Vt 1)2 \Rightarrow |Vt | = 1.5, = 450 (3 - 1Vt 1)2 This table belongs to 5.38. Note that the conduction angle has the same expression as for the half-wave rectifier and is given by Eq. (3.30), 2Vr ~ $\omega t = (b)$ Vp Substituting for ωt , we get \Rightarrow iD, av = $\pi V p$ 2Vr · R Vp $= IL 1 + \pi dvS + iL dt t = -\omega t assuming iL is const. (8.45) yields I 1 + e(v B2 - v B1)/VT Rop = (gm5 ro5) ro7 = (1 \times 36) \times 36 iE1 = = 1.296 M Ad = gm1 Ron Rop 0.99
I = = (1 mA/V) (1.296 M 1.296 M) = 648 V/V IC1 I 1 + e(v B2 - v B1)/VT 1 v B1 - v B2 = -VT ln - 1 0.99 = -25ln (1/99) Ex: 8.7 = 25ln (99) = 115 mV Ex: 8.10 (a) The DC current$ in each transistor is 0.5 mA. Av = -gm 1 Ro = $-10 \times 60 = -600 \text{ V/V}$ ID = 0.2 mA VOV = 0.2 V 7.47 Refer to Fig. From the figure corresponding to Fig. The highest value of A0 is obtained with the second design when operated at ID = $10 \mu \text{A}$. $100 = 1.2 \times 500 \times \text{VOV} \Rightarrow \text{VOV} \Rightarrow \text{VOV} \Rightarrow 0.63 \text{ V}$ 2 VGS = 0.8 + 0.63 = 1.43 V V2 = -1.43 V (c) Refer to Fig. ii Rs = is Ri + Rs Ex: 1.18 ii v o = Rm ii × io RL RL + Ro vo RL = Rm ii RL + Ro is Rs Ri Ro RL Ais ii ii = is Rs Rs + Ri io = Ais ii Now vo vo ii Rs RL = × = Rm × ii is RL + Ro Ex: 1.21 Ro Rs Ro = Ais is Ro + RL Rs + Ri Ro + RL Rs + Ri Ro + RL Rs + Ri Ro + RL Rs × Rs + Ri Ro + RL Rs × Rs + Ri Ro + RL Rs + Ri Ro i (Ro RL) = Gm v s Ri + Rs Thus, Ri vo = Gm (Ro RL) vs Ri + Rs Ro Gmvi RL vo v b = ib $r\pi + (\beta + 1)$ ib Re = ib $[r\pi + (\beta + 1)$ Re] But v b = v x and ib = ix, thus vx vb = = $r\pi + (\beta + 1)$ Re Rin = ix ib Ex: 1.22 f 10 Hz 10 kHz 100 kHz 1 MHz Gain 60 dB 40 dB 20 dB 0 dB vo Exercise 1-5 Gain (dB) Ex: 1.24 Refer to Fig. 8.6 Refer to the circuit in Fig. P6.115. Ad 1 = 1 + R2 R1 R2 R1 cm1 = 0 dB (b) Refer to the circuit in Fig. Also 2 = -VS = 5 - RS ID ID = VGS 2 ID = $(4 - 6.2 \text{ ID})2 \Rightarrow 38.44 \text{ ID}2 - 51.6 \text{ ID}2 + 16 = 0 \Rightarrow ID = 0.49 \text{ mA}, 0.86 \text{ mA ID} = 0.49 \text{ mA}, 0.86 \text{ mA ID} = 0.86 \text{ results in VS} > 0 \text{ or VS} > VG$, which is not acceptable. A node equation at node 1 results in the current through (R/2) as 2I. Thus the maximum error is + 1 1 1 1 + 6 + 7 + 8 25 2 2 = 0.99609375 mA Corresponding from 0 to 1 the output changes by (10/10) × 1/28 = 3.91μ A. 6.13 See figure above Av = -0.3 mA vI 10 k IC RC 0.3 × 5 = -60 V/V = - VT 0.025 Case Av (V/V) P (V) | Av |VT VCCmin VCC 6.14 To obtain an output signal of peak amplitude P volts and maximum gain, we bias the transistor at VCE = VCEsat + P The resulting gain will be VCC - VCE Av = - VT which results in VCC of a -20 0.2 0.5 1.0 1.0 b -50 0.5 1.25 2.05 2.5 c -100 0.5 2.5 3.3 3.5 d -100 1.0 2.5 3.8 4.0 e -200 1.0 5.0 6.3 6.5 f -500 1.0 12.5 13.8 14.0 g -500 2.0 12.5 14.8 15.0 VCC = VCE + | Av | VT Thus the minimum required VCC will be VCCmin = VCEsat + P + | Av |VT 6.15 (a) See figure below but we have to make sure that the amplifier can support a positive peak amplitude of P, that is, (b) See figure on next page Note that in part (b) the graph is shifted right by +5 V. 2.31(b)] and the cc offset voltage at the output will be equal to VOS, that is, 3 mV. 1 v sg = isig × Rsig RS gm 1 (k) = 50 × 10-3 (mA) 100 9.5 2 = 0.024 V R2 i 0 bvo i 1/gm R1 v y = (gm RD) v sg vsig = (2 × 12.5) × 0.024 = 0.6 V 6.113 (a) DC bias: Figure 2 VDD 10 V RD RD R2 0.5 M VD R1 0.5 M RD where = RD (R1 + R2). Most of the solutions are new; however, I have used and/or adapted some of the solutions from the ISM of the International Sixth Edition. vO 5 V 5V vI B 4.7 V vO RC A 0 0 v CE 6.16 iC = IS e 1 + VA VCE IC = IS eVBE /VT 1 + VA 6.17 (a) Using Eq. (6.23) yields | Av max | = -60 = - VCE 1 eVBE /VT VA VT dv CE 1 - RC IS eVBE /VT dv BE VA 1 1 IC - RC A = -RC IC VCE VA v VT 1 + VA Thus, = -RC IS 1 + Av = -IC RC /VT IC RC 1 + VA + VCE IC = IS eVBE /VT VA VT dv CE 1 - RC IS eVBE /VT dv BE VA 1 1 IC - RC A = -RC IC VCE VA v VT 1 + VA Thus, = -RC IS 1 + Av = -IC RC /VT IC RC 1 + VA + VCE IC = IS eVBE /VT VA VT dv CE 1 - RC IS eVBE /VT dv BE VA 1 1 IC - RC A = -RC IC VCE VA v VT 1 + VA Thus, = -RC IS 1 + Av = -IC RC /VT IC RC 1 + VA + VCE IC = IS eVBE /VT VA VT dv CE 1 - RC IS eVBE /VT dv BE VA 1 1 IC - RC A = -RC IC VCE VA v VT 1 + VA Thus, = -RC IS 1 + Av = -IC RC /VT IC RC 1 + VA + VCE IC = IS eVBE /VT VA VT dv CE 1 - RC IS eVBE /VT dv BE VA 1 1 IC - RC A = -RC IC VCE VA v VT 1 + VA Thus, = -RC IS 1 + Av = -IC RC /VT IC RC 1 + VA + VCE IC = IS eVBE /VT VA VT dv CE 1 - RC IS eVBE /VT dv BE VA 1 1 IC - RC A = -RC IC VCE VA v VT 1 + VA Thus, = -RC IS 1 + Av = -IC RC /VT IC RC 1 + VA + VCE IC = IS eVBE /VT VA VT dv BE VA 1 1 IC - RC A = -RC IC VCE VA v VT 1 + VA Thus, = -RC IS 1 + Av = -IC RC /VT IC RC 1 + VA + VCE IC = IS eVBE /VT VA VT dv BE VA 1 1 IC - RC A = -RC IC VCE VA v VT 1 + VA Thus, = -RC IS 1 + Av = -IC RC /VT IC RC 1 + VA + VCE IC = IS eVBE /VT VA VT dv BE VA 1 1 IC - RC A = -RC IC VCE VA v VT 1 + VA Thus, = -RC IC VCE VA v VT 1 + VA + VCE IC = IS eVBE /VT VA VT dv BE VA 1 1 IC - RC A = -RC IC VCE VA v VT 1 + VA + VCE IC = IS eVBE /VT IC RC 1 + VA + VCE IC = IS eVBE /VT VA VT dv BE VA 1 1 IC - RC A = -RC IC VCE VA v VT 1 + VA + VCE IC = IS eVBE /VT IC RC 1 + VA + VCE IC = IS eVBE /VT IC RC 1 + VA + VCE IC = IS eVBE /VT IC RC 1 + VA + VCE IC = IS eVBE /VT IC RC 1 + VA + VCE IC = IS eVBE /VT IC RC 1 + VA + VCE IC = IS eVBE /VT IC RC 1 + VA + VCE IC = IS eVBE /VT IC RC 1 + VA + VCE IC = IS eVBE /VT IC RC 1 + VA + VCE IC = IS eVBE /VT IC RC 1 + VA + VCE IC = IS eVBE /VT IC RC 1 + VA + VCE IC = IS eVBE /VT IC VCE 3 - VCE VCC - VCE = - VT 0.025 \Rightarrow VCE = 1.5 V (c) IC = 0.5 mA IC RC = VCC - VCE = 3 - 1.5 = 1.5 V RC = 1.5 = 3 k 0.5 (d) IC = IS eVBE / 0.025 \Rightarrow VBE = 0.673 V Q.E.D (e) Assuming linear operation around the bias point, we obtain Substituting IC RC = VCC - VCE , we obtain (VCC - VCE)/VT Av = - VCC - VCE = 0.673 V Q.E.D (e) Assuming linear operation around the bias point, we obtain Substituting IC RC = VCC - VCE = 3 - 1.5 = 1.5 V RC = 1.5 = 3 k 0.5 (d) IC = IS eVBE / 0.025 \Rightarrow VBE = 0.673 V Q.E.D (e) Assuming linear operation around the bias point, we obtain Substituting IC RC = VCC - VCE = 3 - 1.5 = 1.5 V RC = 1.5 = 3 k 0.5 (d) IC = IS eVBE / 0.025 \Rightarrow VBE = 0.673 V Q.E.D (e) Assuming linear operation around the bias point, we obtain Substituting IC RC = VCC - VCE = 3 - 1.5 = 1.5 V RC = 1.5 = 3 k 0.5 (d) IC = IS eVBE / 0.025 \Rightarrow VBE = 0.673 V Q.E.D (e) Assuming linear operation around the bias point, we obtain Substituting IC RC = VCC - VCE = 3 - 1.5 = 1.5 V RC = 1.5 = 3 k 0.5 (d) IC = IS eVBE / 0.025 \Rightarrow VCE 1 + VA + VCE 0.E.D 5 - 3 Av (without the Early effect) = -0.025 = -80 V/V Av (with the Early effect) = $vce = Av \times vbe = -60 \times 5 \sin \omega t$, $mV = -0.3 \sin \omega t$, BE v = V, v = V BE BE CE CE vI v BE /VT VCE = VCC - RC IC dv CE Av = dv 4.5 V 5 V - 80 2 1 + 100 + 3 - v ce = 0.1 sin ωt , mA β 100 ic 0.1 ib = = sin ωt = 0.005 mA β 100 ic 0.1 ib = = sin ωt = 0.005 mA β 100 ic 0.1 ib = = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = = sin ωt = 0.005 mA β 100 ic 0.1 ib = = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = = sin ωt = 0.005 mA β 100 ic 0.1 ib = = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ωt , mA β 100 ic 0.1 ib = sin ωt = 0.001 sin ω point Q at VCC /2 = 2.5 V, we obtain vbe VBE 5 mV VCE = 2.5 V, 0.673 V IC = 2.5 mA IB = 0 t vCE VCE \Rightarrow VBB = IB RB + 0.7 = 2.5 + 0.7 = 3.2 V 1.8 V vce VBB - 0.7 = 2.5 mA IB 10 2.5 V 5 20 k I 2.5 0.1 mA 5 20 V 0.1 20 2 V (a) IO 2.5 V V 1.5 V V 1.5 V V 1.5 2.5 1 V (b) Chapter 3-4 I = 0.25 mA 3.10 3 V V = 0V 0.33 mA 12 k 1 V D1 OFF IO $\sqrt{1202} \ge 4.2 k 40$ The largest reverse voltage appearing across the diode is equal to the peak input voltage: $\sqrt{1202} = 169.7 V 3.11 R \ge D2$ ON V 1 V 0.33 mA 3.12 For v I > 0 V: D is on, v O = v I, iD = v I/R For v I < 0 V: D is off, v O = 0, iD = 0.6 k 3 V (a) (a) If we assume that both D1 and D2 are conducting, then V = 0 V and the current in D2 will be [0 - (-3)]/6 = 0.5 mA. 5 V 2.5 V 10 k 5 k Thévenin vO 0.3 mA vI vO In the results obtained, tabulated below, VCEsat = 0.3 V and VCC is the nearest 0.5 V to VCCmin . P9.7 will have the equivalent circuit in Fig. Each op amp has 2 input terminals (4 pins) and one output terminal (2 pins). VD = VT ln IS 10-12 || 3.37 Available diodes to split the 1 mA current evenly, as shown in the figure next. This 4 4 imbalance results from the fact that the current mirror is not a balanced load. The new value of VD is 5.50 VDD iD R VD = VDD - RD ID = $10 - 6 \times 0.45 = +7.3$ V vO as compared to +7 V found in Example 5.6. We conclude that this circuit is quite tolerant to variations in device parameters. Thus $2 = 1 \times 4 \times |VOV| = 1$ V $2 \times SG = |Vt| + |VOV| = 2$ V V6 = 5 - VSG = 5 - 2 = 3 $VV7 = +5 - 2VSG = 5 - 2 \times 2 = 1V$
 (b) Circuit (a): The 2-mA current source can be replaced with a resistance R connected between the MOSFET source and the -5-V supply with R= V1 - (-5) - 2 + 5 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): The 2-mA current source can be replaced with a resistance R, R= 5 - V3 5 - 2 = = 1.5 k 2 mA 2 Circuit (c): $0.05 \times 3.45 = 1.72$ f F Cgs = 2 WLCox + Cov 3 2 × 10 × 1 × 3.45 + 1.72 3 = 24.72 fF = = 15.9 Hz Cgd = Cov = 1.72 f F Since the highest-frequency singularity is fZ at 15.9 Hz, the lower 3-dB frequency fL will be Csb 0 10 Csb = = = 6.1 f F VSB 1 1 + 1 + V0 0.6 fL fP 2 = 334.2 Hz Cdb 0 10 = = 4.1 f F Cdb = VDB 2+1 1+ 1+ V0 0.6 Ex: 9.2 Refer to Fig. 7.11 and observe that IC1 IREF and IC2 = IC1; thus each of Q1 and Q2 is operating at a collector bias current approximately equal to IREF. In practice, the diode voltage increases slowly and the line will have a small nonzero slope. Thus = Ron = Rop = 2Ro = 2 × 280 = 560 k While vx appears across Ro, vy appears across ro1, Thus, vy ro1 = vx Ro ro1 = ro1 + ro2 + gm2 ro2 ro1 For gm2 ro2 1 and gm2 ro1 1, vy 1 vx gm2 ro2 560 = (gm ro) ro = 2|VA| |VA| |VOV | I 2|VA | 2 = 0.25 × 0.125 = VA = 2.96 V 2.96 VA = 0.6 μ m L = = VA 5 For each of the NMOS devices, 1 W V2 ID = μ n Cox 2 L 1,2 OV 1 W 125 = × 400 × × 0.252 2 L 1, 2, 7.65 Refer to Fig. This is an indication that the transfer characteristic is not a straight line. Thus, the area of Q3 For an output of 1.6 V, VSD2min = |VOV 2| = 1.8 - 1.6 = 0.2 V, Initial total area = Area of Q1 + Area of Q3 For an output of 0.2 V, = $6.46 \times 0.542 + 29.1 \times 0.542 + 29.1 \times 0.542 + 29.1 \times 0.542$ VDS1min = 0.2 V, = 18.85 µm2 Chapter 7-16 New total area = 6.46 \times 0.92 + 29.1 \times 0.92 + 29.1 \times 0.92 + 29.1 \times 0.92 + 29.1 \times 0.92 Therefore the extreme values of vO for which Q1 and Q2 are in saturation 0.33 V \leq vO \leq 2.98 V = 52.37 µm2 (c) From (b) we can find VIA and VIB : Thus, the increase is by a factor of 2.78. 2 we can find ii as 0 VGS Q1 0.1 mA 0.7 V ii = Q2 0 0.7 0.1 6.8 mA 6.8 k = vi - Av vi RG vi + 19.4 vi RG Thus, Rin = Figure 1 vi 10 M RG = = 487 k = ii 20.5 20.5 Thus the overall voltage gain becomes (a) From Fig. 7.10 Nominally, IO = IREF = 1 mA ro2 = VA2 90 = = 90 k IO 1 ro2 = VO 10 - 1 \Rightarrow = 90 \Rightarrow IO = 0.1 mA IO 10 0.1 IO = = 10\% change IO 1 7.12 Equation (7.21) gives the current transfer ratio of an npn mirror with a nominal ratio of m: $VO - VBE m IO = IREF 1 + m + 1 VA2 1 + \beta$ This equation can be adapted for the pnp mirror of Fig. 9.10. For v I \geq +3.5 V, diode D1 begins to conduct and its voltage reaches 0.7 V (and thus v O = +3.7 V) at i = 1 mA. E1.5, 17 1 1 as compared to , NA ND We can neglect the term = $0.25 \times 10-8 \times 1.08 \times 104$ NA ND W NA + ND NA ND W NA + ND NA ND W NA = AqND W NA ND W OE Equation (1.54), QJ = A 2s q ND VO Exercise 1-7 Ex: 1.33 In Example 1.10, NA = 1018 / cm3 and = 6.08 × 10-5 cm = 0.608 µm ND = 1016 / cm3 Using Eq. (1.53), NA ND W QJ = Aq NA + ND 18 10 × 1016 = $10-4 \times 1.6 \times 10-19 \times 6.08 \times 1018$ + 1016 In the n-region of this pn junction nn = ND = 1016 /cm3 pn = $n2i(1.5 \times 1010)2$ = 2.25×104 /cm3 nn 1016 As one can see from above equation, to increase minority-carrier concentration (pn) by a factor of 2, one must lower ND (= nn) by a factor of 2. With Re , 10 Gv = 2.25×104 /cm3 nn 1016 As one can see from above equation, to increase minority-carrier concentration (pn) by a factor of 2, one must lower ND (= nn) by a factor of 2. With Re , 10 Gv = 2.25×104 /cm3 nn 1016 As one can see from above equation, to increase minority-carrier concentration (pn) by a factor of 2. With Re , 10 Gv = 2.25×104 /cm3 nn 1016 As one can see from above equation. nominal $(10/100) + 0.025 + \text{Re} = 0.275 + \text$ $0.025 + 0.275 = 27.3 \text{ V/V} (+9.1\% \text{ of nominal}) \text{ low} = 6.71 \text{ Rin} = 1.1 = 0.5 \text{ k} = \text{gm 2 mA/V Rin} \times \text{gm} (\text{RD RL}) \text{ Rin} + \text{Rsig } 0.5 \times 2(5.5) = 0.5 + 0.75 = 2 \text{ V/V Gv} = \text{For Rin} = \text{Rsig} = 0.75 \text{ k} 1 = 0.75 \text{ m} = 1.33 \text{ mA/V gm}$ Since gm = 2 k n ID, then to change gm by a factor 1.33 = 0.67, ID must be changed by a factor of 2(0.67)2 = 0.45. Here QN and QP have the same ID = I3 . 3.3a and 3.3b. 2, we have IC 0.495 = 20 mA/V VT 0.025 VT re = 50 IE vi vi = i = re + Re 50 + 200 vi vi = = 4 v i, mA 250 0.25 k Node equation at the output: vo vo - vi + αi + =0 20 200 vo vi vo + 0.99 × 4v i + - =0 20 200 vo vi $100 1 + \beta + 1\beta = 50$: 2.3 = 0.78 mA 100 1 + 51 VE = IE RE = 0.78 VIE = 0.005 mA 20 k VB = VE + 0.7 = 1.48 V\beta = 200: 2.3 IE = = 1.54 V The dc emitter current is equal to 0.5 mA, and IC = α IE 0.5 mA; also, VT 25 mV = = 50 re = IE 0.5 mA Rin = re = 50 - v sig - v sig = ie = re + Rsig 50 + 50 - v sig -v sig $= 100 \ 0.1 \ k$ At the output node, VB = VE + 0.7 = 2.24 V (b) Rin = 100 (β + 1)[re + (1 1)] = 100 (β + 1)(re + 0.5) β = 50: VT 25 mV re $= 32.1 \ = 120.3 \ k \ v \ o = -\alpha ie(5100) \ v \ sig(5100) = \alpha \ 0.1 \ sig(5100) = \alpha \ 0.1 \ v \ sig(5100) = \alpha \ 0.1 \ sig(5100) = \alpha \ sig(5100) = \alpha \ sig(5100) = \alpha \ sig(5100) = \alpha \ sig(5100) = \alpha$ (0.0162 + 0.5)] = 50.9 k vb Rin (c) = v sig Rin + Rsig 6.124 Refer to the circuit in Fig. See figure. 7.4 we have I2 = IREF (W/L)2 (W/L)3, I3 = IREF (W/L)2 (W/L)3, I3 = IREF (W/L)1 (W/L)1 and I5 = I4 (W/L)2 (W/L)3, I3 = IREF (W/L)2 (W/L)3, I3 $120 = 15 \Rightarrow W2\ 200 \times (0.2)2 = 15 \times L2\ W2 = 15\ \mu\text{m}, W2\ W2 = 6 \Rightarrow W1 = 2.5\ \mu\text{m}\ W1\ 6\ W3 = 2 \Rightarrow W3 = 2 \times W1 = 5\ \mu\text{m}\ W1\ To\ allow\ the\ voltage\ at\ the\ drain\ of\ Q5\ to\ go\ up\ to\ within\ 0.2\ V\ of\ positive\ supply,\ we\ need\ VOV\ 5 = 0.2\ V:\ 1\ W\ V2\ I5 = k\ p\ 2\ L\ 5\ OV\ 5\ \mu\text{A}\ W\ 1\ 80\ \mu\text{A} = 80\ 2\ (0.2)2 \Rightarrow 2\ V\ L\ 5\ 2\ \times\ 80\ W = = 50 \Rightarrow W5 = 50\ L5\ L\ 5\ 80\ \times\ (0.2)2$ W5 = 50 μ m 50 μ m W5 = 4 \Rightarrow W4 = = 12.5 μ m W4 4 Thus: W1 = 2.5 μ m, W2 = 15 μ m, W3 = 5 μ m W4 = 12.5 μ m, W3 = 5 μ m W4 = 12.5 μ m, and W5 = 50 μ m Ex: 7.3 From Eq. (7.21) we have $\int (1 + 10) = 1 \text{ mA} + 1 \int 100 + 100 = 1.02 \text{ mA}$ IO = 1.02 mA Ro = ro2 = VA 100 V = 98 k 100 k IO 1.02 mA we have I2 = IREF I2 W2 W2 60 = = 6 \Rightarrow =
W1 IREF W1 10 I3 = IREF W3 I3 20 W3 \Rightarrow = = = 2 W1 W1 IREF 10 I5 = I4 W5 I5 80 W5 \Rightarrow = = = 4 W4 W4 I4 20 To allow the voltage at the drain of Q2 to go down to within 0.2 V of the negative supply voltage, we need VOV 2 = 0.2 V: 1 1 W W 2 VOV = V2 k I2 = µn Cox 2 2 L 2 2 n L 2 OV 2 1 µA W 60 µA = = = 4 W4 W4 I4 20 To allow the voltage at the drain of Q2 to go down to within 0.2 V of the negative supply voltage. $200\ 2\ (0.2)\ 2\ V\ L\ 2\ Ex:\ 7.4\ VCC\ R\ IREF\ IO\ VO\ Q1\ Q2\ From\ Eq.\ (7.23),\ we\ have\ IREF\ VO\ -\ VBE\ 1+\ IO\ =\ 1+\ (2/\beta)\ VA\ Exercise\ 7-2\ IO\ where\ VBE\ =\ VT\ ln\ IS\ 0.5\ \times\ 10\ -\ 15\ 2\ -\ 0.673\ IREF\ 1+\ \Rightarrow\ 0.5\ mA\ =\ 1\ +\ (2/100)\ 50\ IREF\ =\ W\ L\ =\ 12.5\ 1\ To\ obtain\ Ais\ =\ 5\ (W/L)\ 2\ (W/L)\ 1\ 5\ =\ Ais\ =\ 1.02\ =\ 0.497\ mA\ 1.026\ mA\ -\ VBE\ 1+\ VB\ VA\ Exercise\ 7-2\ IO\ where\ VB\ E\ =\ VT\ ln\ IS\ 0.5\ \times\ 10\ -\ 15\ 2\ -\ 0.673\ IREF\ 1+\ \Rightarrow\ 0.5\ mA\ =\ 1\ +\ (2/100)\ 50\ IREF\ =\ W\ L\ =\ 12.5\ 1\ To\ obtain\ Ais\ =\ 5\ (W/L)\ 2\ (W/L)\ 1\ 5\ =\ Ais\ =\ 1.02\ =\ 0.497\ mA\ 1.026\ mA\ -\ VB\ IREF\ 1+\ \Rightarrow\ 0.5\ mA\ =\ 1\ +\ (2/100)\ 50\ IREF\ =\ W\ L\ =\ 12.5\ 1\ To\ obtain\ Ais\ =\ 5\ (W/L)\ 2\ (W/L)\ 1\ 5\ =\ Ais\ =\ 1.02\ =\ 0.497\ mA\ 1.026\ mA\ -\ VB\ IREF\ 1+\ \Rightarrow\ 0.5\ MA\ =\ 1\ +\ (2/100)\ 50\ IREF\ =\ W\ L\ =\ 12.5\ 1\ To\ obtain\ Ais\ =\ 5\ (W/L)\ 2\ (W/L)\ 1\ 5\ =\ Ais\ =\ 1.02\ =\ 0.497\ mA\ 1.026\ mA\ -\ VB\ IREF\ 1+\ \Rightarrow\ 0.5\ MA\ =\ 1\ +\ (2/100)\ 50\ IREF\ 1+\ +\ 0.5\ MA\ =\ 1\ +\ 0.5\ MA\ =\ 1\ +\ 0.5\ MA\ =\ 1\ +\ 0.5\ MA\ =\ 0.5\ MA\$ $VCC - VBE \Rightarrow R = R IREF IREF = 0.5 \text{ mA VCC} \Rightarrow WL = 5 \times 12.5 = 62.5 2 \text{ Ro} = ro2 = 5 - 0.673 = 8.71 \text{ k} 0.497 \text{ mA VOmin} = VCEsat = 0.3 V R = VA2 VA2 = ID2 5ID1 \text{ Thus, For VO} = 5 V, From Eq. (7.23) we have VO - VBE IREF 1 + IO = 1 + (2/B) VA = 0.497 5 - 0.673 V 1 + = 0.53 \text{ mA IO} = 1 + (2/100) 50 40 \text{ k} = VA2 5 \times 0.1 \Rightarrow VA2 = 20 V \text{ But } L2$ $VA2 = VA2 = 20 \times L2 = 1 \ \mu m \ Ex; 7.5 \ I1 = I2 = \cdots = IN = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + \cdots + IBN \ L1 = L2 = 1 \ \mu m = IC \ |QREF + IB| \ + IB|$ IREF N +1 1+ β For β = 100, to limit the error to 10%, N +1 N +1 = β 100 0.1 = 1 gm1 Now, Rin = 1 k, thus 1 = 2(μ n Cox) 2 × 0.4 × · ID For ID = 10 μ A, we have gm = 2(387 μ A/V2)(10)(10 μ A) Since gm varies with W L A0 = 50 V/V gm1 = 1 mA/V gm1 = 2 μ n Cox Using Eq. (7.46): 2 μ n Cox (W/L) A0 = VA $\sqrt{$ ID 5 V/ μ m 2(387 μ A/V2)(10)(0.36)2 = $\sqrt{$ $10 \ \mu A = x$; 7.6 But gm = $0.28 \ m A/V \Rightarrow N = 9 \ Rin \ Q.E.D \ Using Eq. (7.42)$; W L W L ID1 1 × 0.1 1 1 D and A0 with $\sqrt{100 \ 101/2} = 1 = 100 \ \mu A \Rightarrow gm = 0.28 \ m A/V = 0.88 \ m A/V = 0.88 \ m A/V = 0.100 \ IC1 = I = 100 \ \mu A \Rightarrow gm = 0.28 \ IC1 = 0.100 \ IC1 = I = 100 \ IC1 = I = 0.100$ Ex: 7.8 VDD Q3 IC1 0.1 mA = 4 mA/V = VT 25 mV Rin = $r\pi 1 = \beta 1 100 = 25 \text{ k gm} 1 4 \text{ mA/V}$ VA 50 V = = 500 k I 0.1 mA |VA | 50 V = = 500 k I 0.1 mA A0 = gm1 ro1 = (4 mA/V) × Q2 vO IREF gm1 = (500 k 500 k) = -1000 V/V Q1 vI Ex: 7.10 Refer to Fig. 1 ≤ 100 Hz f3dB = -1000 Hz f3dB = $2\pi C(Rs + Ri) C \ge 1 = 0.16 \mu F 2\pi (1 + 9)103 \times 100 Ex: 1.23 Rs 1 k$ Vi Ri GmVi Ro RL Vo CL Vs Ri 9 k Vo = Gm Vi [Ro RL Vo CL Vs Ri 9 k Vo = Gm Vi [Ro RL Vo CL Vs Ri 9 k Vo = Gm Vi [1 + + sCL Ro RL Vo Gm 1 Thus, = × 1 1 sCL Vi + 1 + 1 1 Ro RL + Ro RL Ex: 1.25 T = 50 K ni = BT 3/2 e - Eg/(2kT) - 5 × 50) = 7.3 × 1015 (50)3/2 e - 1.12/(2 × 8.62 × 10 9.6 × 10 - 39 / cm 3 T = 350 K ni = BT 3/2 e - Eg/(2kT) - 5 × 50) = 7.3 × 1015 (50)3/2 e - 1.12/(2 × 8.62 × 10 9.6 × 10 - 39 / cm 3 T = 350 K ni = BT 3/2 e - Eg/(2kT) - 5 × 50) = 7.3 × 1015 (50)3/2 e - 1.12/(2 × 8.62 × 10 9.6 × 10 - 39 / cm 3 T = 350 K ni = BT 3/2 e - Eg/(2kT) - 5 × 50) = 7.3 × 1015 (50)3/2 e - 1.12/(2 × 8.62 × 10 9.6 × 10 - 39 / cm 3 T = 350 K ni = BT 3/2 e - Eg/(2kT) - 5 × 50) = 7.3 × 1015 (50)3/2 e - 1.12/(2 × 8.62 × 10 9.6 × 10 - 39 / cm 3 T = 350 K ni = BT $3/2 e - Eg/(2kT) - 5 \times 350 = 7.3 \times 1015$ (350) $3/2 e - 1.12/(2 \times 8.62 \times 10 = 4.15 \times 1011 / cm3 Gm (RL Ro) Vo = Vi 1 + sCL (RL Ro) Ex: 1.26 ND = 1017 / cm3 which is of the STC LP type. VOV = <math>\sqrt{8.64}$ (a) gm = 2k n IV = 1017 / cm3 which is of the STC LP type. VOV = $\sqrt{8.64}$ (a) gm = 2k n IV = 1017 / cm3 which is of the STC LP type. VOV = $\sqrt{8.64}$ (a) gm = 2k n IV = 1017 / cm3 which is of the STC LP type. VOV = $\sqrt{8.64}$ (a) gm = 2k n IV = 1017 / cm3 which is of the STC LP type. VOV = $\sqrt{8.64}$ (b) $\sqrt{8.63}$ gm = 2 k n (W/L)IV = k n IV = 1017 / cm3 which is of the STC LP type. VOV = $\sqrt{8.64}$ (c) $\sqrt{8.64}$ (c VOS 1 (1) If the three components are independent, $\sqrt{VOS} = 4.52 + 4.52 + 52 = 8.1 \text{ mV} 8.66 \text{ The offset voltage due to RD is}$ RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 (W/L) 2 Chapter 8-24 VCC The worst-case offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage
due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0.3 × 0.02 = 3 mV = VOS = 2 RD 2 The offset voltage due to RD is RD VOV 0. will be when all three components add up, VOS = 5 + 3 + 3 = 11 mV RC RC The major contribution to the total is the variability of Vt. Therefore v O cannot go as high as 10 V. 2, v c = $-\text{ie} \times 10 \text{ k}$ where ie = -vi vi = -re 0.125 k Thus, vc 10 k = vi 0.125 k = 80 V/V Chapter 6-16 This figure belongs to Problem 6.45. Instead: For the same closed-loop gain, the noninverting configuration realizes a higher GBP, and it is independent of the closed-loop gain and equal to ft of the op amp. Please send all corrections and comments by email to: Adel Sedra Waterloo, Ontario, Canada October 2015 Accuracy Checkers • Professor Tony Chan Carusone, University of Toronto - Assisted by

graduate students Jeffrey Wang and Luke Wang • Professor Vincent Gaudet, University of British Columbia • Professor Shahriar Mirabbasi and Mandana Amiri, University of Toronto • Professor Vincent Gaudet, University of Toronto • Professor Vincent 1.1 When output terminals are open-circuited, as in Fig. IDN = 0 Because of the symmetry, IDP = 0.104, VO = $-IDP \times 10 \text{ k} = -1.04 \text{ V} \sqrt{0.7 + 3} - 0.7 \text{ Ex}$; 5.16 Vt = 0.36 µm, VDS = 0 V W = 3.6 µm, VDS = 0 W = 3. μ m Q = Cox .W .L.VOV = 2.33 fC 5.2 k n = μ n Cox C/V C 1 m2 F F = = = V · s m2 V · s V · s v2 = VOV (V) gDS rDS (mA/V) () 0.5 0 0 ∞ 1.0 0.5 2.5 400 1.5 1.0 5.0 200 2.0 1.5 7.5 133 2.5 2.0 10 100 A V2 Since k n = k n W/L and W/L is dimensionless, k n has the same dimensionless, k n has the same dimensionless, k n + k n W/L and W/L is dimensionless. with ID = 90 μ A. v oc = v s (t) vs (t) For circuit b. See figures on next column. Thus, i= 10 V 10 V = 10 μ A = R1 + R2 = R1 + R2 = 0.5 M 2 v 2 = 0.4v 2 2 + 3 Ex: 2.12 Hence 9 k vO = 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O, we have v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O, we have v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O, we have v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O, we have v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O, we have v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O, we have v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O, we have v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O, we have v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O, we have v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O, we have v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O = 6v 1 + v + = 10 × 0.4v 2 = 4v 2 1 k (a) R2 Combining the contributions of v 1 and v 2 R1 v VI to v O = 6v 1 + v + = 10 × 0.4v + = 10 × 0.4v + $4v 2 \text{ vO Ex: } 2.10 9 \text{ k v I} - v - = v O / A \Rightarrow v - = v$ the closed-loop gain is 1 + , that is, 10. The dc circuit can be obtained by opening all coupling and bypass capacitors, resulting in the circuit shown in Fig. Thus, these are the 7th and 9th harmonics. This in turn can be achieved by ensuring that VD does not fall below VG (which is zero) by more than Vt (0.4 V). This is a range of -44.5% to +36.4% of nominal. The results are as follows: CMRRd = 2gm REE / RC RC VOS = $1\sqrt{I/k}$ n 2 RD RD (2) Thus, VOS (mV) 2 CMRRd = CMRRs RC /RC I (mA) 2 20 log = 34 dB RC /RC = 0.04 = 4% RC 3 4 5 4 8 12 16 20 We observe that by accepting a larger offset we are able to obtain a higher gain. c. Thus ICBO becomes ICBO = 10 nA × 1024 = 10.24 μ A At 20° C, T = 293 K and VT = 8.62 × 10-5 × 293 = 25.3 mV At 50° C, T = 323 K and VT = 8.62 × 10-5 × 323 = 27.8 mV If the transistor is operated at v BE = 700 mV, then (i) At 20° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes 4.33 iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0.69 mA (ii) At 50° C, iE becomes iE = 0.5e(700-692)/25.3 = 0. 0.5 V, From the figure we can write IS v BE /VT e - ICBO IB = β IC = IS ev BE /VT + ICBO iC = $10e(0.5-0.7)/0.025 = 3.35 \mu\text{A}(1)$ At a current IC and a BE voltage VBE, the slope of the iC -v BE curve is IC /VT. Now, VDS B is given by Eq. (6.8) [together with Eq. (6.7)], $\sqrt{2} \text{ kn} \text{ RD VDD} + 1 - 1 \text{ VDS } \text{ B} = (2) \text{ kn} \text{ RD RD} = \text{VDD} - \text{VDS } \text{ O ID } 5 - 0.712 = 0.712 \text{ m}$ $42.88 \text{ k} = 0.1 \ 213.7 \text{ (d) } \text{ k} \text{ n} = 4.98 \text{ mA/V2} \ 42.88 \ 4.98 \text{ W} = 24.9 \text{ L} \ 0.2 \ 6.9 \text{ VDD From the figure we see that } \text{VDS B} = \text{VOV} + v^{2}\text{gs} \ 22 \text{ where } \text{VOV} \text{ k} \text{ n} \ \text{RD} \times 0.2 \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ VDS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vLS B} = 0.2 + \text{ k} \text{ n} \ \text{RD} \text{ vI} \ 2.5 \text{ vI} \ 1.5 \text{$ VDD + 1 - 1 = 0.2 + k n RD k n RD substituting VDD = 5 V, rearranging the equation to obtain a quadratic equation in k n RD, and given Vt1 = Vt = Vt 1 W [VDD - v O - Vt]2 For Q2, iD = k n 2 L 2 1 W [vI - Vt]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq vO + Vt$]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq vO + Vt$]2 For Q1, iD = k n 2 L 2 1 W [vI - Vt]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq vO + Vt$]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq vO + Vt$]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq vO + Vt$]2 For Q1, iD = k n 2 L 2 1 W [vI - Vt]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq vO + Vt$]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq vO + Vt$]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq vO + Vt$]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq vO + Vt$]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq vO + Vt$]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq
vO + Vt$]2 For Q1, iD = k n 2 L 1 For Vt $\leq vI \leq vO + Vt$]2 For Q1, iD = k n 2 L 1 For Vt = Vt [V = Vt 2 V + Vt 2 V + Vt = Vt 2 Vt 2 Vt = Vt 2 Vt]2 For Q1, iD = k n 2 L 1 For Vt = Vt 2 Vt 2 Vt 2 I - Vt] 2 1 [VDD - vO - Vt] = vO = VDD - Vt + Vt - vIIC VCE (mA) (V) POS Neg vO (V) vO (V) (W/L) 1 (W/L) 2 0.5 4.5 - 20 0.5 4.2 1.0 4.0 -40 1.0 3.7 (W/L) 1 (W/L) 2 0.5 4.5 - 20 0.5 4.2 1.0 4.0 -40 1.0 3.7 (W/L) 1 (W/L) 2 0.5 4.5 - 20 0.5 4.2 1.0 4.0 -40 1.0 3.7 (W/L) 1 (W/L) 2 0.5 4.5 - 20 0.5 4.2 1.0 4.0 -40 1.0 3.7 (W/L) 1 (W/L) 2 0.5 4.5 - 20 0.5 4.2 1.0 4.0 -40 1.0 3.7 (W/L) 1 (W/L) 2 0.5 4.5 - 20 0.5 4.2 1.0 4.0 -40 1.0 3.7 (W/L) 1 (W/L) 2 0.5 4.5 - 20 0.5 4.5 - 20 0.5 4.2 1.0 4.0 -40 1.0 3.7 (W/L) 1 (W/L) 2 0.5 4.5 - 20 0.5 4.5 - 20 0.5 4.5 - 20 0.5 4.5 - 20 0.5 4.5 - 20 0.5 - 20 0.5 - 20 0.5 - 20 0.5 - 20 0.5 - 20 0.5 - 20 0.5 - 20 0.5 - 20 0.5 - 20 0.5 - 20 06.10 Refer to Fig. 2 Here also observe that this relationship (and graph) is universal and represents any MOSFET. Thus, including RF results in the nonideal integrator response shown in Fig. Thus, the current through the 80-k resistor is 0.05IE1 + 0.01IE1 = 0.06IE1 and VE2 = 6.3 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 7 V IC2 = $\alpha IE2 = 0.99 \times 20.13 = 20$ mA VB1 = VE1 + 0.7 = 10 mA VB1 $2IE1 + 0.7 0.06IE1 IC1 1.21 = 20.13 mA 0.06 0.06 VC2 = 20 \times 0.1 = 2 V 9 - (2IE1 + 0.7) 9 - VB1 = 80 80 Finally, with the resistance R connected between E1 and C2, it will conduct a current that we can initially estimate as <math>\Rightarrow$ IE1 = 1.22 mA 9 V VE 2 D2 Q2 IC1 VB1 ID1 0.05 IE1 100 V2 0.06 IE1 D1 IE 2 2 k ID2 80 k 0.01IE 2 Q1 0.01IE 1E1 = 20.13 mA 0.06 VC2 = 20 \times 0.1 = 2 V 9 - (2IE1 + 0.7) 9 - VB1 = 80 80 Finally, with the resistance R connected between E1 and C2, it will conduct a current that we can initially estimate as \Rightarrow IE1 = 1.22 mA 9 V VE 2 D2 Q2 IC1 VB1 ID1 0.05 IE1 100 V2 0.06 IE1 D1 IE 2 2 k ID2 80 k 0.01IE 2 Q1 0.01IE 1E1 = 20.13 mA 0.06 VC2 = 20 \times 0.1 = 2 V 9 - (2IE1 + 0.7) 9 - VB1 = 80 80 Finally, with the resistance R connected between E1 and C2, it will conduct a current that we can initially estimate as \Rightarrow IE1 = 1.22 mA 9 V VE 2 D2 Q2 IC1 VB1 ID1 0.05 IE1 100 V2 0.06 IE1 D1 IE 2 2 k ID2 80 k 0.01IE 2 Q1 0.01IE 1E1 = 20.13 mA 0.06 VC2 = 20 \times 0.1 = 2 V 9 - (2IE1 + 0.7) 9 - VB1 = 80 80 Finally, with the resistance R connected between E1 and C2, it will conduct a current that we can initially estimate as \Rightarrow IE1 = 1.22 mA 9 V VE 2 D2 Q2 IC1 VB1 ID1 0.05 IE1 100 V2 0.06 IE1 D1 IE 2 2 k ID2 80 k 0.01IE 2 Q1 0.01IE 1E1 = 20.13 mA 0.06 VC2 = 20 \times 0.1 = 2 V 9 - (2IE1 + 0.7) 9 - VB1 = 80 80 Finally, with the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 and C2 is the resistance R connected between E1 a V140 k VE1 2 k Figure 3 VC2 100 Chapter 4-29 9V IE 2 100 2 k 80 k V2 VE2 (ID1 IB1) (IC1 IB2) VC1 VB1 D1 ID1 VE2 D2 IC1 Q2 IB2 Q1 IB1 V1 40 k IC2 I IE1 VE1 R VC2 2 k 100 2 k Figure 4 I= 2.44 - 2 VE1 - VC2 = = 0.22 mA R 2 This is a substantial amount compared to IE1 = 1.22 mA, requiring that we redo the analysis with R in place. () For (b) Vo = Vi (1 / R + sC R Vo sRC = Vi 1 + sCR Vo = Vi s s + 1 RC which is of the form shown in Table 1.2 for the high-pass function, with K = 1 and $\omega 0 = 1/RC$. i1 isig Rsig 7.55 Refer to Fig. \therefore use R = 207 (c) Line regulation = 7 mV = 33 207 + 7 V vS vO R ±25% change in v S = ± 5 V VO changes by ±5 × 33 = ±0.165 mV ±0.165 × 100 = 1/RC. $\pm 1.65\%$ 10 corresponding to Using the constant voltage drop model: (d) Load regulation = - (rZ R) ideal = -(7 207) = -6.77 V/A VO = -6.77 25 V. 4 (e) P = V 2 /R = 202 /(1 × 103) = 0.4 W Thus, the resistor should have a 1 -W rating. \therefore Maximum v o = i × 10 k = 0.1 × 10 = 1 mA Each diode exhibits 0.7 V drop at 1 mA current. vo = 22.7 V/V and gain in dB 20 log 22.7 = vs Av 2 = 27.1 dB = 9.09 V/V (b) Case S-B-A-L (see figure above): Av 3 = v o v ia v ib v s 100 ×
100 × 10 = $100 \times 100 + 10$ K $100 \times 100 \times 1$ factor of 210 = 1024. (b) For an integrator with RF, the 0.1-mA current flows through the parallel combination of C and RF. (2)-(6): ID1 × 40 = IE1 × 2 IE3 = 0.276 mA IC4 = 0.134 ID1 = The base current of Q4 can be obtained from IB4 = IE4 - IC4 = 0.134 - 0.116 = 0.018 mA = 0.102 mA But IE4 = 0.134 ID1 = 0.05IE1 IB3 = 0.276 mA IC4 = 0.134 ID1 = 0.05IE1 IB3 = 0.154 mA I = 0.102 mA But IE4 = 0.134 ID1 = 0.05IE1 IB3 = 0.154 mA I = 0.102 mA But IE4 = 0.134 ID1 = 0.05IE1 IB3 = 0.154 mA I = 0.102 mA But IE4 = 0.134 ID1 = 0.05IE1 IB3 = 0.154 mA I = 0.018 mA Thus, Finally, the collector current of O3 can be found as IE1 = IC3 = I + IB4 = 0.102 + 0.018 = 0.120 [sforced 4 0.069 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V The forced 3 = 9 - 0.7 = 0.069 mA 0.07 mA 80 + 40 VB1 = VE1 + 0.7 = 3.5 V IC3 0.120 = 0.8 = IB3 0.154 IC1 = IE1 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V The forced 3 = 9 - 0.7 = 0.069 mA 0.07 mA 80 + 40 VB1 = VE1 + 0.7 = 3.5 V IC3 0.120 = 0.8 = IB3 0.154 IC1 = IE1 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V The forced 4 0.069 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V The forced 3 = 9 - 0.7 = 0.069 mA 0.07 mA 80 + 40 VB1 = VE1 + 0.7 = 3.5 V IC3 0.120 = 0.8 = IB3 0.154 IC1 = IE1 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V The forced 3 = 9 - 0.7 = 0.069 mA 0.07 mA 80 + 40 VB1 = VE1 + 0.7 = 3.5 V IC3 0.120 = 0.8 = IB3 0.154 IC1 = IE1 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V The forced 3 = 9 - 0.7 = 0.069 mA 0.07 mA 80 + 40 VB1 = VE1 + 0.7 = 3.5 V IC3 0.120 = 0.8 = IB3 0.154 IC1 = IE1 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V The forced 3 = 9 - 0.7 = 0.069 mA 0.07 mA 80 + 40 VB1 = VE1 + 0.7 = 3.5 V IC3 0.120 = 0.8 = IB3 0.154 IC1 = IE1 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V The forced 3 = 9 - 0.7 = 0.069 mA 0.07 mA 80 + 40 VB1 = VE1 + 0.7 = 3.5 V IC3 0.120 = 0.8 = IB3 0.154 IC1 = IE1 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V The forced 3 = 9 - 0.7 = 0.069 mA 0.07 mA 80 + 40 VB1 = VE1 + 0.7 = 3.5 V IC3 0.120 = 0.8 = IB3 0.154 IC1 = IE1 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V The forced 3 = 9 - 0.7 = 0.069 mA 0.07 mA 80 + 40 VB1 = VE1 + 0.7 = 3.5 V IC3 0.120 = 0.8 = IB3 0.154 IC1 = IE1 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V The forced 3 = 9 - 0.7 = 0.069 mA 0.07 mA 80 + 40 VB1 = VE1 + 0.7 = 3.5 V IC3 0.120 = 0.8 = IB3 0.154 IC1 = IE1 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V IC1 = IE1 = 1.38 mA 1.4 mA 0.05 VE1 = IE1 × 2 = 2.77 V 2.8 V IC1 = IE1 × 2 = 2.77 V 2.8 V IC1 = IE1 × 2 = 2.77 V 2.8 V IC1 = IE1 × 2 = 2.77 V 2.8 V IC1 = IE1 × 2 = 2.77 V 2 IC4 0.116 = = 6.4 IB4 0.018 V2 = 9 - IC1 × 2 = 9 - IC1 × 2 = 9 - IC3 × 2 6.2 V Both β forced values are well below the β value of 50, verifying that Q3 and Q4 are in deep saturation. Now, for the circuit under consideration, all resistors are nominally equal to 10 k, but each has a tolerance of ±x%. Thus, it reaches 40 dB at a frequency four decades higher than fb, If an input step of amplitude 1.6 V (10 times as large compared to the previous case) is applied, the output will be slew-rate limited and thus linearly rising with a slope equal to the slew rate, as shown in the following figure. From the circuit VD = VDD - ID RD = 15 - 0.5 × 16 = +7 V, as assumed Finally, VGS = 1.5 V, thus VOV = 1.5 - Vt = 1.5 $-1 = 0.5 \text{ V} 1 1 2 = \times 4 \times 0.52 = 0.5 \text{ mA ID} = \text{k n VOV} 2 2$ which is equal to the given value. 7.45(b)] that the total effective resistance between the MOSFET source terminal and ground is 1 ro1 ro3. Thus, $\Rightarrow \text{Re} = 350 3 = 1.5 \text{ k Rs} = 2 \text{ mA/V} = 40.4 \text{ k Gv} = -\beta = -100 \text{ RD}$ RL Gv = Av = -1 + Rs gm = $-\text{Rin} = (\beta + 1)(\text{re} + \text{Re}) = 101 \times (50 + 350) 2020$ $= -5 \text{ V/V } 0.5 + 1.5 \text{ v}^{\circ} \text{ o} = \text{Gv v}^{\circ} \text{ sig} = 5 \times 0.2 = 1 \text{ V} \text{ (unchanged) } 1 = 10 \text{ mA/V } 0.1 \text{ k But Ex: } 6.24 \text{ From the following figure we see that } \text{gm} = v^{\circ} \text{sig} = ^{\circ} \text{ib } \text{Rsig} + v^{\circ} \pi + ^{\circ} \text{ie } \text{Re } \beta + 1 v^{\circ} \pi v^{\circ} \pi \text{ Rsig} + v^{\circ} \pi + \text{Re } (\beta + 1) \text{re re } \text{Rsig} \text{ ev}^{\circ} \text{sig} = v^{\circ} \pi 1 + + r \pi \text{ re } 10 = -19.8 \text{ V/V } 10 + 101 \times 0.4 \text{ Ex:}$ $6.251 = \text{Rsig} = 100 \text{ gm} \Rightarrow \text{gm} = \text{RC} \text{ RL} \text{Rsig} + (\beta + 1)(\text{re} + \text{Re}) 10 = = \text{Gv} = 0.5 \times 10 \times 2 = 10 \text{ V/V} \text{ Exercise } 6-71 = 200 \text{ gm} \text{ Rx} = 5 \text{ mA/V} \text{ But gm} = k \text{ n Av } o = \text{gm} \text{ RC} = 40 \times 5 = 200 \text{ V/V} \text{ Ro} = \text{RC} = 5 \text{ k RL} 5 = 100 \text{ V/V} = 200 \times \text{Av} = \text{Av } o = 100 \text{ mA } \text{ VT} \text{ VT} = 25 \text{ mA } \text{ re} = 100 \text{ mA } \text{ VT} \text{ VT} = 25 \text{ mA } \text{ re} = 100 \text{ mA } \text{ re} = 25 \text{ mA } \text{ re} = 100 \text{ mA } \text{ re} = 25 \text{ mA } \text{ re} = 100 \text{ mA } \text{ re} = 25 \text{ mA } \text{ re} = 100 \text{ mA } \text{ re} = 100 \text{ mA } \text{ re} = 25 \text{ mA } \text{ re} = 100 \text{ re} = 100 \text{ mA } \text{ re} = 100 \text{ re} = 10$ RL + Ro 5+5 W VOV L Thus, $5 = 0.4 \times W \times 0.25$ L Ex: 6.27 W = 50 L 1 W 2 ID = k n VOV 2 L 1 = $\times 0.4 \times 50 \times 0.252$ 2 = 0.625 mA Rin = re = 50 RL = 1 k to 10 k Rin × Av Gv = Rin + Rsig = $25 \times 100 = 0.5$ V/V 25 + 5000 \Rightarrow IE = VT 25 mV = 0.5 mA re 50 IC IE = 0.5 mA Gv = RC RL re + Rsig \Rightarrow Correspondingly, Gv = RL RL = RL + Ro RL + $0.2 \text{ will range from Gv} = \text{RC} \text{ RL } 40 = (50 + 50) 1 = 0.83 \text{ V/V } 1 + 0.2 \text{ to RC} \text{ RL} = 4 \text{ k Gv} = 10 = 0.98 \text{ V/V } 10 + 0.2 \text{ Ex: } 6.28 \text{ Refer to Fig. Thus } 1 = 1.2 \times 0.5 \times \text{VOV} \Rightarrow \text{VOV} \Rightarrow 2.7 \text{ VOV} \Rightarrow \text{VOV} \Rightarrow 2.7 \text{ VOV} \Rightarrow \text{VOV} \Rightarrow 2.7 \text{ VOV} \Rightarrow 1.0 \text{ L} = 1.2 \times 0.5 \times \text{VOV} \Rightarrow 1.0 \times 0.5 \times 0.5 \times \text{VOV} \Rightarrow 1.0 \times 0.5 \times 0.5$ \times 60t) + 0.1 sin(2 π × 1000 t) 2.50 v O = 2 sin(2 π × 1000t) 1 M 2.48 10 V 1 k v x1 1x vI vO (a) Source is connected directly. 2.25) with RF = 100 R = 1 M. The short-circuit current will be 1.9 2 × Av o × 1.9 + 0.1 2 + 0.111 io = Gm v i \Rightarrow Av o = 11.1 V/V Thus Gm is defined as io Gm = v i RL = 0 The values found about are
limit values; that is, we require Rin ≥ 1.9 M and is known as the short-circuit transconductance. Thus the signal current in the drain of Q3 to ground. Source is 30 mV rms with 0.5-M source resistance. P7.50. If both W and L are doubled, k n remains unchanged. A decrease in VD by 100 mV corresponds to a junction temperature increase of 50° C. The value obtained in Example 9.8 is a better estimate of fH as it takes into account the effect of CL. (e) The transistor will be at the edge of conduction when IE 0 and VBE = -3 + 0.5 = -2.5 V IE = In this case, VB = VE - 0.7 = 0.3 V VE = -3 V VC = +3V (f) The transistor reaches the edge of saturation when VCE = 0.3 V but IC = 0.3 V bu < VB, confirming our implicit assumption that the transistor is operating in the active region. 6.6. VCC – VCE Av = – VT 5–1 = –160 V/V = – 0.025 The transistor enters saturation when v CE \leq 0.3 V, thus the maximum allowable output voltage swing is 1 – 0.3 = 0.7 V. We use vn-drift = 1350 × 1 \therefore 1 µm = 10–4 cm 2 × 10–4 = 6.75 × 106 cm/s = $6.75 \times 104 \text{ m/s}$ (b) Time taken to cross 2-µm length = 2 × 10-6 30 \text{ ps} 6.75×104 (c) In n-type silicon, drift current density Jn is Ex: 1.31 Equation (1.50), 2s 1 1 + V0 W = q NA ND 2s NA + ND = V0 q NA ND 1 q NA ND V0 = W2 2 s NA + ND Jn = qnµn E 1V 2 × 10-4 = 1.6 × 10-19 × 1016 × 1350 × = 1.08 × 104 A/cm2 Ex: 1.32 In a p+n diode NA ND 2s 1 1 Equation (1.50), W = + V0 q NA ND (d) Drift current In = AJn thus = 27 μ A -8 Note that 0.25 μ m = 0.25 x 10 2 Ex: 1.29 Jn = qDn 2 cm. From Example 8.7, we obtain IC1 = IC2 = 0.25 mA IC4 = IC5 = 1 mA 8.111 See figure. During the negative half cycle of the input signal v I, the diode is reverse biased. Ex: $6.21 \text{ 2ID } 2 \times 0.25 = 2 \text{ mA/V} = \text{gm} = \text{VOV } 0.25 \text{ Rin} = \infty \text{ Av o} = -\text{gm RD} = -2 \times 20 = -40 \text{ V/V Ro} = \text{RD} = 20 \text{ k RL } 20 = -40 \text{ V/V Ro} = -20 \text{ k RL } 20 \text{ RO} = -20 \text{ k RL } 20 \text{ RO} = -20 \text{ k RL } 20 \text{ RO} = -20 \text{ k RL } 20 \text{ RO} = -20 \text{ k RL } 20 \text{ RO} = -20 \text{ k RL } 20 \text{ RO} = -20 \text{ k RL } 20 \text{ RO} = -20 \text{ k RL } 20 \text{ RO} = -20 \text{ k RL } 20 \text{ RO} = -20 \text{ k RL } 20 \text{ RO} = -20 \text{ RO} = -20 \text{ RO} = -20 \text{ RO} = -20 \text{ R$ belongs to Exercise 6.20c. 4.26(b) we obtain IC = 4.6 mA Thus, RC = To establish a reverse-bias voltage of 2 V across the CBJ, VC = +6 V = +10 = 2.26 k 4.6 Ex: 4.26 From the figure we see that 10 V 10 - 6 = 8 k RC = 0.5 and 3.3 = 6.6 k RE = 0.5 where we have assumed α 1. P7.67. Thus to avoid op-amp saturation and the attendant clipping of the peak of the output sinusoid, we must limit the peak amplitude of the input sine wave to approximately 7 V/1000 = 7 mV. (d) The minimum allowable VO is the value at which Q3 leaves the saturation region: VOmin = VG3 - Vt = VG3 + VG3 + VG3 - Vt = 0.8 + 0.8 - 0.5 = 1.1 V (e) Diode-connected transistor Q4 has an incremental resistance 1/gm4. 1.14 (a) Between terminals 1 and 2: 1 1 k 1.5 V VTh 2 1 k RTh 1 k 1 0.5 k 0.75 V 2 (cont'd on the next page) Chapter 1-6 12.31 k 0.77 V Now, subtracting Eq. (1) from Eq. (3) yields I 40I2 = 20 3 k \Rightarrow I2 = 0.5 mA Substituting in Eq. (2) gives 2I1 = 5 - 7 × 0.5 mA Now, when a resistance of 3 k is connected between node 4 and ground, $I = \Rightarrow I1 = 0.75 \text{ mA } 0.77 \ 12.31 + 3 \ I3 = I1 + I2 = 0.05 \text{ mA} = 0.75 + 0.5 = 1.25 \text{ mA } 1.16$ (a) Node equation at the common mode yields $V = I3 \ R3 \ I3 = I1 + I2 \ Using the fact that the sum of the voltage drops across R1 and R3 equals 10 V, we write <math>10 = I1 \ R1 + I3 \ R3 = 10I1 + (I1 + I2) \times 2 = 12I1 + 2I2 \ R1 \ 10 \ k \ I2 = 0.5 \ mA$ I3 = 1.25 mAV = 2.5 V Thus, I0 - V5 - VV + = 1052 I1 V I1 = 0.75 mA 10 - V5 - VV + = R1 R2 R3 5 V I2 To summarize: (b) A node equation at the common node can be written in terms of V as 10 V R2 5 k = 1.25 × 2 = 2.5 V I3 \Rightarrow 0.8V = 2 R3 2 k \Rightarrow V = 2.5 V Now, I1 , I2 , and I3 can be easily found as I1 = That is, 12I1 + 2I2 = 10 (1) 10 - 2.5 10 $-V = 10\ 10 = 0.75\ mA\ 5 - 2.5\ 5 - V = 5\ 5\ Similarly$, the voltage drops across R2 and R3 add up to 5 V, thus I2 = 5 = I2\ R2 + I3\ R3 = 0.5\ mA = 5I2 + (I1 + I2) \times 2\ I3 = which yields 2I1 + 7I2 = 5 (2) Equations (1) and (2) can be solved together by multiplying Eq. (2) by 6: 12I1 + 42I2 = 30 (3) V 2.5 = 1.25\ mA = R3\ 2\ Method (b) is much preferred, being faster, more insightful, and less prone to errors. The largest value for RC while the BJT
remains in the active mode corresponds to VC = +0.4 V VB 4 V VE 3.3 V RE 0.5 mA Since the emitter and collector currents remain unchanged, then from Fig. Thus ID RSmax = 10 k RD V2 = -1.5 + 0.5 = -1 V 0.2 V (c) VCS = 2.5 - IRS - VSD VGS 0.6 V which yields 0.6 V RSmax = 10 k RS V3 = 2.5 - 0.5 = 2 V (d) VCS = 1.25 - IRS - VSD - (-1.25) 1 V = 2.5 - (-1.25) 1 V =by its Thévenin equivalent results in the circuit shown below. Assuming VBE 0.7 V, then VE = -0.7 V, and -0.7 - (-15) = 2.1 mA IE = 6.8 IC = α IE 2.1 mA Thus, VC = $15 - 2.1 \times 5.1$ 4.3 V Chapter 4-8 + 30 + 2.7 k VC 1.5 0.255 2.7 0.81 V 5 6 I I I 0.005 mA B E C 0.8 V 1 a VE 0.8 V 2 0.8 (1.5) 2.7 0.26 mA 1.5 V 2.7 k 3 IE 1.5 V (b) 1.5 0.8 2 0.35 mA 3 6 IE IB IE IC 0.007 mA IB 1 0.8 V 2 k VE 0.8 V 2 VC 1.5 2 0.343 0.81 V 5 2 k IC a 0.35 4 0.98 0.35 0.343 1.5 V 3 V (c) 3 IE 3 1.8 0.12 mA 10 10 k VE 1.8 V 2 1 V 6 1 0.8 V IB IC/50 2.4 A 4 IC a 0.12 0.98 0.12 0.118 mA VC 0.118 2 0.236 V 5 2 k 3 V (d) 4 IC a 0.15 0.147 mA 8.2 k VC 3 0.147 8.2 1.8 V 5 1.5 V 0.15 6 IB 50 3 A IB 3 V IE E 4.7 0.8 V 1 0.7 0.15 mA 4.7 a VE 1.5 0.8 0.7 2 4.7 k Chapter 4-9 In all circuits shown in Fig. which yields Rmax = 5 k. P2.64 and Eq. (2.19): R4 R2 R3 1 - Acm = R3 + R4 R1 R4 100.100 100 1 - = 100 + 100 100.100 Acm = 0 Refer to 2.17: \Rightarrow Ad = R4 R2 = R1 R3 R2 = 1 R1 (b) v A = v B K $\times 4 \text{ K} + 1100 \text{ k}$ Since Ad = K Ad CMRR = A cm vcm = K + 1 4 which in dB becomes K + 1 CMRR = 20 log 4 vcm 100 k 100 k A B 100 k Q.E.D. For Ad = 100 V/V and = 0.01, 101 CMRR = 20 log = 68 dB 0.04 v A = v cm 100 100 + 100 vO Chapter 2-19 v cm v cm and v B = 2 2 \Rightarrow -5 V \leq v cm \leq 5 V the range of v Icm will be vA = $-3 \text{ V} \leq v \text{ Icm}$ $\leq +3$ V (c) The circuit becomes as shown below: 2.65 Refer to Fig. 8.40. Load regulation = -120 mV/mA 3.59 6.8 = VZ0 + 5 × 0.02 VZ0 = 6.7 V \therefore R = 8 - 6.7 = 5.2 k 0.25 LINE REGULATION = 750 VO = VS 750 + 5200 mV V = 126 9V±1V 3.60 10 V R VO I R IZ VO VZ IZ IL GIVEN PARAMETERS VZ = 6.8V, rz = 5 (a) IZ = 20 mA RL Chapter 3-22 11 $VI = 1.5\ 0.03 = 0.15\ (1.5\ 0.03) + 0.167\ For\ VS = +1\ V\ (10\%\ high), VO = +0.15\ V\ and\ VO = 7.65\ V.\ (1)\ and\ (2)\ simultaneously, we obtain RE = 3.81\ k\ 4.3 = 0.86\ mA\ 50\ 4+51\ 4.3 = 0.99\ mA = 50\ 4+151\ IEmin = IEmax\ RB = 49.2\ k\ Substituting\ theses\ values\ in\ Eqs.\ 1\ IC = = 0.01\ mA\ \beta\ 100\ 0.7\ 0.7\ RB2 = = IB2\ 0.01 = 70\ k\ IB = IO\ aIE\ 1.5 = 2IB\ RB1$ + 0.7 0.8 = 2 × 0.01 × RB1 IE /(b1) RB1 = 40 k 3 - 1.5 1.5 RC = 1.47 k = IC + 2IB 1.02 For $\beta = \infty$: 0.7 0.7 IB = 0, IB2 = = 0.01 mA RB IE VBB RE VC = 0.01 RB1 + 0.7 = 1.1 V 3 - 1.1 = 1.29 = RC 1.47 IC = 1.28 mA IC + 0.01 = 6.103 where VBB = VCC R2 R1 + R2 and RB = (R1 R2) I Now, VC IB RB VBB = IC IE = IE RB + VBE + IE RE β + 1 VBB - VBE RE + (R1 R2)/(β + 1) IC = α IE = α VCC [R2/(R1 + R2)] - VBE RE + (R1 R2)/(β + 1) Chapter 6-39 To obtain IO = 0.5 mA, 6.105 0.5 = VCC R1 I IO 0 Q1 10 VCC = 2RE 2RE = RE = 10 k R1 = R2 = 8.6 k 6.106 VB 5 V I Q2 IO RE IE R2 50.7 R R 0.7 V VCC - VBE1 - VBE2 R1 + R2 VBE RE 2 VCC Q.E.D IO = 2RE Thus, VCC IO RE = 2 VCC + VBE VB = 2 VCC I = (VB - 2VBE)/R2 = - VBE R2 2 But since I must be equal to IO, we have VCC /2 - VBE VCC = 2RE R2 Thus, VCC = 10 V and VBE = 0.7 V, 10 - 1.4 = 0.86RE R1 = R2 = RE 10 IO = α IE 0.5 mA IE = 0.5 mA 5 - 0.7 = 8.6 k 0.5 = $0.7 - VECsat = 0.7 - 0.3 \Rightarrow R = v Cmax = +0.4 V 6.107$ Refer to the equivalent circuit in Fig. 7.11. To determine the bias current I, which is the drain currents (I) and have the same VGS, VGS = Vt + VOV ro5 = Thus REE IR = 15 - (-5) - 2 VGS = 1.24 M 144I = 20 - 2 Vt - 2 VOV Rid, Ro, Ad, IB, and the range of VICM will be the same as in Problem 8.100. For proper current-source operation, the minimum required voltage at the output is the value needed to keep a minimum of 0.4 V across the current source, thus VCM max = +2.5 - 0.4 - VSG = +2.5 - 0.4 - 1.15 = +0.95 V The lowest value of VCM is limited by the need to keep Q1 and Q2 in saturation, thus VCM min = VD1,2 - |Vtp | = -1.5 - 0.8 = -2.3 V Thus, -2.3 V \leq VICM \leq +0.95 V 8.3 VDD 1 V VCM max = VD1,2 + Vtn = 0.6 + 0.4 = 1.0 V 5 k vD1 G1 VSmin = -VSS + VCS = -1 + 0.2 = -0.8 V VCM min = VSmin + VGS RD RD (f) To maintain the current-source operating properly, we need to keep a minimum voltage of 0.2 V across it, thus vid = -0.8 + 0.6 VCS1 iD1 iD2 Q1 Q2 vS = $-0.2 V ID1 = ID2 1 = \times 0.5 = 0.25 mA 2 G2 VGS2$ I 0.16 mA VSS 1 V 8.2 Refer to Fig. Also, all transistors are I /2 operating at the same |VOV | and have equal dc currents, thus all have the same 2(I /2) gm = = I /|VOV |. ID2 = IC1 - 0.01IE2 Thus, (b) We next consider the situation with β = 100, first with R disconnected. 2 Peak current Vs - VD Vs sin (π /2) - VD = = R R If v S is 12 V(rms), $\sqrt{\sqrt{then Vs}} = 12 2 \sqrt{122} - 0.7$ Peak current = 163 mA 100 Nonzero output occurs for angle = $2(\pi - 2\theta)$ The fraction of the cycle for which v O > 0 is $2(\pi - 2\theta) \times 100 2\pi$ 0.7 $2\pi - 2 \sin - 1\sqrt{12} 2 \times 100 = 2\pi = (Vs \sin \varphi - 2VD) d\varphi \cos(\pi - \theta) \approx -1\pi - 2\theta \approx \pi$. B C rp vp E rp 2.5 k, C B rp ro gmvp ib E ro 100 k, gm 40 mA/V b 100 C C gmvp B vp ro ai B ro re re i E E re 24.75, gm 40 mA/V 100 $\beta = 2\pi - 1\pi - 2\theta \approx \pi$. B C rp vp E rp 2.5 k, C B rp ro gmvp ib E ro 100 k, gm 40 mA/V b 100 C C gmvp B vp ro ai B ro re re i E E re 24.75, gm 40 mA/V 100 $\beta = 2\pi - 1\pi - 2\theta \approx \pi$. $= 0.99 \alpha = \beta + 1.100 + 1$ VT α VT 0.99×25 mV = = 24.75 re = 1E IC 1 mA 6.40 gmvbe B ib vbe vbe re ro 100 k, a 0.99 ib = v be g - gm Q.E.D 6.41 Refer to Fig. With R5 replaced with a 1-mA constant-current source with a high output resistance of Q8, which is Ri4 = $(\beta + 1)(re8 + R6) = 101 \times (0.005 + 3) = 303.5$ k Refer to Fig. This resistance is given by VT /IB, which is rn. V2 = 2.7 - VEB = 2.7 - 0.7 = +2 V R 0.2 mA 0.4 mA 0.5 mA Q2 1 5 1 mA 10 0.8 mA 2 mA 20 V3 = 0 + VEB = +0.7 V Thus, Q3 and Q4 are operating in the active mode, and each is carrying a collector current of I /2. The transfer characteristic is given in Fig. E2.21. μ n (W/L)3,4 (c) μ n = 4 μ p and all channel lengths are equal, W1,2 Ad = 2 W3,4 For Ad = 10, W1,2 10 = 2 W3,4 For Ad = 10, W1,2 Hor Voltage across each pair $0.25 = 2\ 0.7 + 0.025\ \ln 2$ (a) $3\ V\ 10\ k = 1.296\ V\ V\ SPECIAL\ NOTE$: There is another possible design utilizing only 6 diodes and realizing a voltage of $1.313\ V$. For $\omega = 1\ rad/s$, the integrator transfer function has magnitude $Vo\ 1 = V\ 1\times 10-3 = 1000\ V/V$ i and phase $\varphi = 90^\circ$. Z2 Vo = Vi Z1 + Z2 where 1 1 and Z2 = R2 voltage of $1.313\ V$. For $\omega = 1\ rad/s$, the integrator transfer function has magnitude $Vo\ 1 = V\ 1\times 10-3 = 1000\ V/V$ i and phase $\varphi = 90^\circ$. Z2 Vo = Vi Z1 + Z2 where 1 1 and Z2 = R2 voltage of $1.313\ V$. For $\omega = 1\ rad/s$, the integrator transfer function has magnitude $Vo\ 1 = V\ 1\times 10-3 = 1000\ V/V$ i and phase $\varphi = 90^\circ$. Z2 Vo = Vi Z1 + Z2 where 1 1 and Z2 = R2 voltage of $1.313\ V$. For $\omega = 1\ rad/s$, the integrator transfer function has magnitude $Vo\ 1 = V\ 1\times 10-3 = 1000\ V/V$ i and phase $\varphi = 90^\circ$. Z2 Vo = Vi Z1 + Z2 where 1 and Z2 = R2 voltage of $1.313\ V$. For $\omega = 1\ rad/s$, the integrator transfer function has magnitude $Vo\ 1 = V\ 1\times 10-3 = 1000\ V/V$ i and phase $\varphi = 90^\circ$. Z1 = R1 sC1 sC2 It is obviously more convenient to work in terms of admittances. Thus Rs = 1 = 0.5 k 2 Neglecting ro, Gv is given by Gv = - Ex: 6.41 Refer to Fig. With a load resistance RL = 1 k connected to the output terminal, the voltage gain v o /v b2 can be found as vo RL = v b2 RL + re1 = 0.9975 V/V v b1 Rin 456 = = 0.82 V/V v sig Rin + 20.82 V/V v sig Rin + 20.82 V/V v b1 Rin 456 = = 0.82 V/V v sig Rin + 20.82 V/V v sig Rin + Rig 456 + 100 vo (e) = $0.82 \times 0.9975 \times 0.995 = 0.814$ V/V v sig (d) Exercise 7-1 Ex: 7.1 In the current source of Example 7.1 (Fig. Reference to Fig. It represents internal feedback, internal to the Rs Vs Ri Ci Vi Chapter 1-22 1 sCi 1 Ri + Vi sCi (= 1 Vs Ri Sci Rs + $| 1 \text{ Ri} + \text{sCi Ri} | 2 \text{ Ri} + \text{sCi Ri} | 1 + \text{sCi$ × 10-6 (10 + 40) × 103 = 3.18 Hz 1 K 40 |T (j ω 0)| = $\sqrt{}$ = 0.57 V/V 10 + 40 2 2 1.64 Using the voltage divider rule, Ri = Rs + Ri Ri Rs + Ri Rs + Ri Rs + Ri Rs + Ri Rs + Ri Ri R Observe that the transistor is operating in the active region and note the analysis performed on the circuit diagram. Since the circuit is to be used as a common-base amplifier, we can dispense with RB altogether and ground the base; thus RB = $0.3 \times v = 10 - 2.5 - 2.5 = 5
\text{ mV} = 5 \text{ mV} = 0.5 \text{ mV$ 10 k 2.5 mV D1 The current through each diode $0.5 \mu\text{A} = 0.25 \mu\text{A} 2$ The signal current i is $0.5 \mu\text{A}$, and this is 10% of the dc biasing current. Thus, to obtain ID = 2 mA, we write $2 = (2) 25 = \text{k n} \times 0.5 \times 0.05 \text{ VGS} = 0.5 + 0.25 = 0.75 \text{ V} 1 2 \text{ ID} = 0.2 = \times 1.6 \times \text{VOV} 2 \Rightarrow 1.6 \times \text{VOV} 2$ VOV = 0.5 V and $VDS \ge 0.5 V 2$ (1) \Rightarrow Vt = 0.5 V 5.16 Vtn = 0.5 V, kn = 1.6 mA/V2 1 2 ID = 0.05 = $\times 1.6 \times VOV 2 \Rightarrow VOV = 0.25 V$ kn 25 = kn (1 - Vt) $\times 0.05 5.20$ For the channel to remain continuous, v DS \le v GS - Vt Thus for v GS = 1.0 V to 1.8 V and Vt = 0.4, v DS \le 1 - 0.4 That is, v DSmax = 0.6 V. So we select RG2 = 22 M and determine RG1 from 4V RG1 = RG2 5V \Rightarrow RG1 = 0.8 KG2 = 0.8 × 22 = 17.6 M Substituting in Eq. (2) and solving for ro gives ro = 25,000 = 25 k RG1 = 18 M Thus 1 25,000 = 25 k RG1 = 18 M THUS 1 25,000 = 25 k RG1 = 18 M required value of 5 V. P7.95(a). (c) In (b), the transistor is operating in saturation, thus ID = 5.7 VDS sat = VOV VOV = VGS - Vt = 1 - 0.5 = 0.5 V \Rightarrow VDS sat = 0.5 V 2 1 4 mA $\times \times (0.5 V)$ 2 2 V iD = 0.5 mA iD = 5.8 Lmin = 0.25 μ m tox = 6 nm m2 cm2 = 460 $\times 10-4 V$ s V s ox 34.5 pF/m (a) Cox = = tox 6 nm pF F = 5.75 $\times 10-3 2$ m μ m2 μ n = 460 k $n = \mu n \cos 265 \mu A/V2 20 W = k n = 21.2 m A/V2 L 0.25 \therefore 0.5 m A = ID = VOV = 0.22 V 1 k p | VOV | 2 2 1 \times k p \times 0.42 2 0.5 = \Rightarrow k p = 6.25 m A/V2 In saturation: 1 W 1 2 2 = k n VOV VOV iD = k n 2 L 2 (b) For 1 = k n VOV 100 1 2 k n VOV 2 For VD = -20 mV$, the transistor will be operating in the triode region. P6.104. 6.24(b). For this to happen, the minimum value of VDS3 is VOV = 0.15 V. VB = -0.364 V 50 × 0.48 = 0.47 mA IC = 51 VC = $5 - 0.47 \times 7.5$ = 1.475 V 6.102 3 V 6.101 1.01 mA 3 V RC 0.01 mA IE IE/(b 1) 1.5 V RC 1 mA VC RB IC RB Figure 1 IE VC = VCEsat + 1 V = 1.3 V 3 - 1.3 = 0.5 mA IE = $RC \Rightarrow RC = 3.4$ k IE 0.5 IB = 0.005 mA β + 1101 VC = VBE + IB RB (a) From the circuit diagram of Fig. Now, since each of Q1 and Q2 is conducting a current of 0.2 mA, their VBE voltages will be equal: 0.99×0.2 VBE1, 2 = 0.7 + 0.025 ln $1 = 2.5 - 0.99 \times 0.4 \times 5 = 0.660$ V = 0.677 V Thus, VE = +0.5 - 0.677 = -0.177 V which indicates that VBE2 = +0.177 V, too small to turn Q2 on. 1, where vi vi Rin \equiv R1 Rin , where Rin = ii if 6.57 vo Gvo = v sig RL = ∞ Now, setting RL = ∞ in the equivalent circuit in Fig. v O = -Av - = v - -ii R2 ii R2 = v - (1 + A)v - = ii R1 + ii 2.19 Output voltage ranges from -10 V to +10 V and open-loop gain is 5000 V/V \therefore Voltage at the inverting input terminal will -10 10 vary from to (i.e., -2) mV to +2 mV). Thus gm = IC $\alpha(0.2/2)^{4}$ mA/V = VT 0.025 Åd = gm RC 60 = 4 × RC The input resistance Rid is Rid = (β + 1) (2re + 2Re) = 2(100 + 1) (re + Re) = 2.5 - 2 × 101 × (re + 9re) = 2.5 - 2 × 101 × 10re = +1 V To obtain Rid = 100 k, (b) Rid = 2r\pi = 2.100 = 2 × 101 × 10 × re = re 50 = 2.5 - 2.5 + 101 × 10 × re = re 50 = 2.5 + 101 × 10 × re = 100 × re 50 = 2.5 + 101 × 10 × re = 100 × re 50 = 2.5 + 101 × 10 × re 50 = 2.5 + 101 × 100 × re 50 = 2.5 + 101 × $60 \times 10 = 600 \text{ mV} = 0.6 \text{ VVT}$, IE 25 mV 50 = IE \Rightarrow IE = 0.5 mA I = 1 mA Re = 9re = 9 \times 50 = 450 Gain = 100 = 50 k 4 (c) v od = Ad \times v id Since re = = 2 $\times \beta$ gm $\alpha \times 2$ RC 2re + 2Re RC re + Re Thus, there will be ±0.3 V signal swing at each collector. Thus, we would be neglecting the temperature change of the (IB R2) terms in Eq. (2). (a) AM = Vo $= -\text{gm RD Vi} - 20 = -2 \times \text{RD} \Rightarrow \text{RD} = 10 \text{ k} \text{ (b) } \text{fP} = 100 = \text{gm} + 1/\text{RS } 2\pi\text{CS} = 3 \times 10 - 3 + (1/4.5 \times 103) 2\pi\text{CS} \Rightarrow \text{CS} = 3.53 \, \mu\text{F} \text{ (c) } \text{fZ} = 1 = 2\pi\text{CS RS To minimize the total capacitance we select CS so as to place fP2 (usually the highest-frequency low-frequency pole) at 100 Hz. Thus, gm 100 = 2\pi\text{CS} = 3 \times 10 - 3 + (1/4.5 \times 103) 2\pi\text{CS} \Rightarrow \text{CS} = 3.53 \, \mu\text{F} \text{ (c) } \text{fZ} = 1 = 2\pi\text{CS RS To minimize the total capacitance we select CS so as to place fP2 (usually the highest-frequency pole) at 100 Hz. Thus, gm 100 = 2\pi\text{CS} = 3 \times 10 - 3 + (1/4.5 \times 103) 2\pi\text{CS} \Rightarrow \text{CS} = 3.53 \, \mu\text{F} \text{ (c) } \text{fZ} = 1 = 2\pi\text{CS RS To minimize the total capacitance we select CS so as to place fP2 (usually the highest-frequency pole) at 100 Hz. Thus, gm 100 = 2\pi\text{CS} = 3 \times 10 - 3 + (1/4.5 \times 103) 2\pi\text{CS} \Rightarrow \text{CS} = 3.53 \, \mu\text{F} \text{ (c) } \text{fZ} = 1 = 2\pi\text{CS RS To minimize the total capacitance we select CS so as to place fP2 (usually the highest-frequency pole) at 100 Hz. Thus, gm 100 = 2\pi\text{CS} = 3 \times 10 - 3 + (1/4.5 \times 103) 2\pi\text{CS} \Rightarrow \text{CS} = 3.53 \, \mu\text{F} \text{ (c) } \text{fZ} = 1 = 2\pi\text{CS RS To minimize the total capacitance we select CS so as to place fP2 (usually the highest-frequency pole) at 100 Hz. Thus, gm 100 = 2\pi\text{CS} = 3 \times 10 - 3 + (1/4.5 \times 103) 2\pi\text{CS} \Rightarrow \text{CS} = 3.53 \, \mu\text{F} \text{ (c) } \text{fZ} = 1 = 2\pi\text{CS} \text{ RS} \text{ (c) } \text{fZ} = 1 = 2\pi\text{CS} \text{ RS} \text{ (c) } \text{fZ} = 1 = 2\pi\text{CS} \text{ RS} \text{ (c) } \text{fZ} = 1 = 2\pi\text{CS} \text{ (c) } \text{fZ$ Thus VS ID RS VD = +2 V 5 V and 5-2 RD = = 6 k 0.5 ID = 0.5 mA = $6.86 \Rightarrow$ VGS = 1.5 V VDD RG1 RD ID VG 5 V ID RG2 1 × 4(VGS - 1)2 2 RS 3 k Since VG = 0 V, VS = -1.5 V, and -1.5 - (-5) RS = = 7 k 0.5 Maximum gain is obtained by using the largest possible value of RD , that is, the lowest possible value of VD that is consistent with allowing negative voltage signal swing at the drain of 1 V. 7.41(a). (c) If the frequency is lowered by a factor of 10, the gain increases by a factor of 10. The frequency at which the integrator gain magnitude is unity is 1 1 ω int = = -3 = 1000 rad/s CR 10 and phase $\varphi = -90^{\circ}$. gm1 A/V = = VOV 1 VOV 0.2 Since all transistors are operating at the same ID and |VOV|, all have equal values of gm . 3 IR = 0.1 × 30 = 3 V which is greater than |Vtp|. 3.79 Refer to Fig. P6.125. (2) and (3)
gives Thus, IEmin = 0.9 mA 0.99 IEmax = 1.03 IEnominal 0.96 IEmax = 1.04 mA 0.86 IEmin Obviously, this is an acceptable design. (a) To obtain a current transfer ratio of 0.8 (i.e., IO /IREF = 0.8 and IO = 80 μ A), we write IREF IO RE = 0.025 ln 80 \Rightarrow RE = 69.7 0.08 = 3.2 mA gm2 = 0.025 ln 80 \Rightarrow RE = 69.7 0.08 \Rightarrow RE = 6 764.5 k IREF 200 A Rout IO 20 A Q1 VBE2 VBE1 (b) To obtain IO /IREF = 0.1, that is, IO = 10 μ A, we write 100 0.01 RE = VT ln 10 Q2 RE (a) Assuming β is high so that we can neglect base currents, IREF IO RE = VT ln 10 Substituting IO = 20 μ A and IREF = 200 μ A results in 200 0.02 RE = 0.025 ln 20 \Rightarrow RE = 2.88 k (b) Rout = (RE rn 2) + ro2 + gm2 ro2 (RE rn 2) where 0.02 = 0.8 mA/V 0.025 VA 50 = = 2500 k IO 0.02 gm2 = ro2 rn 2 = Relative to the value of ro2, Rout = 1.22 ro2 $\beta 200 = = 250 \text{ k}$ gm $0.8 \Rightarrow \text{RE} = 5.76 \text{ k} 0.01 = 0.4 \text{ mA/V} \text{ gm2} = 0.025 50 = 5000 \text{ k}$ ro2 = 0.01 rn2 = $\infty \text{ Rout} = \text{RE} + ro2 + gm2 ro2 \text{ RE} = 5.76 \text{ k} 9.00 \times 5.76 = 16.5 \text{ M}$ Compared to ro2, 16.5 M Compared to ro2, Rout = 3.3 = ro2 5 (c) To obtain IO /IREF = 0.01, that is, IO = 1 µA, we write 100 0.001 RE = $0.025 \ln 1 \Rightarrow RE = 115 \text{ k} 0.001 = 0.04 \text{ mA/V gm2} = 0.025 50 = 50 \times 103 \text{ k} ro2 = 0.001 \text{ Rout} = (2.9 250) + 2500 + 0.8 \times 2500 \times (2.9 250) + 2500 \times (2.9 250) + 2500 \times (2.9 250) + 2500 \times (2.9 250) \times (2.9 250) + 2500 \times (2.9 250) \times (2.9 250)$ ro2, IO = 5 = 0.7 μ A 7.1 280 Rout = = 5.6 ro2 50 Chapter 7-32 7.86 (a) Refer to the circuit in Fig. ii = 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = Thus, 2 V/1 k v o /RL = ii 0.1 μ A Overall current gain = V = 0.5 × (9.09)n - 1 × 1.67 = 0.833 × and v o = 3 V, the gain must be vs \geq 600, thus = 0.833 × (9.09)n-1 \geq 600 = 8 × 106 W/W \Rightarrow n=4 (This takes into account the power dissipated in the internal resistance of the source.) Thus four amplifier stages are needed, resulting in vo = 0.833 × (9.09)3 = 625.7 V/V vs and correspondingly = vo vs 2V = 400 V/V 0.005 V (b) The smallest Ri allowed is obtained from 0.1 μ A = × 0.1 × 10-6 $\sqrt{25}$ mV = 8s + Ri = 50 k Rs + Ri (c) If (Av o vi) has its peak value limited to 3 V, the largest value of RO is found from Ro Rs 10 k v o = 625.7 × 5 mV = 3.13 V 1.47 (a) Required voltage gain = 5 × 10 $\sqrt{2}$ ii vs 5-mV peak = 3× Ri vi vo Av ovi RL 1 k RL 1 = 2 \Rightarrow Ro = RL = 500 RL + Ro 2 (If Ro were greater than this value, the output voltage across RL would be less than 2 V.) Chapter 1-16 This figure belongs to 1.48. Thus the maximum allowable voltage at the emitters of Q3 and Q4 is VCC - 0.3 = 5 - 0.3 = +4.7 V. If 1 mA is drawn away from the circuit, ID will be 2.9 mA, which would give VD = 0.794 V, giving an output voltage of 1.98 V. If v Id decreases below -4 mV, the op-amp output decreases correspondingly. This has no correspondence in the equivalent-circuit model of Fig. Use Eq. (3.5): i2 v 2 = v 1 + 2.3VT log i1 a) ID = 1., v Nn is Rf Rf Rf v ON = $-vN1 + vN2 + \cdots + v$ Nn RN 1 RN 2 RNn Then we set v N 1 = v N 2 = $\cdots = 0$, then: RN = RN 1 RN 2 RN 3 \cdots RNn The circuit simplifies to that shown below. Here, = 0.1 + 0.4 = 0.5 V iD1 = v D2 = $-2.5 + 0.5 \times 4 = -0.5$ V which verifies that Q2 is operating in saturation, as implicitly assumed Thus, the differential amplifier rejects the undesirable supply ripple. 2, vi vo - vi - ii = RG1 RG2 vi 1 (1 - Av) = 1 + RG1 RG2 (1 - Av defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 100 \times 10 \times 10 = 100$ we have: A = $100 \times 10 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V and VIB = 0.935 V. Thus VE = $-1.5 \times 10 = 104$ V/V, or equivalently, 80 defined by VIA = 0.89 V/V and VIB = 0.935 V. Thus VE = -1.5×10^{-10} V/V, or equivalently, 80 defined by VIA = 0.89 V/V and VIB = 0.935 V. Thus VE = -1.5×10^{-10} V/V and VIB = 0.935 $0.25 \times 10-6$ vi2 100vi2 100 k vL 100 Ex: 1.16 Refer the solution to Example 1.3 in the text. The circuit takes the form shown in the figure below. (1) and (2) with VT = 25 mV, we obtain v D (mV) iD (mA) small exponential signal model a b c d - 10 - 5 + 5 + 10 - 0.2 + 0.2 + 0.4 - 0.33 - 0.18 + 0.22 + 0.49 Across each diode the voltage drop is ID VD = VT ln IS $4 \times 10 - 3 = 25 \times 10 - 3 \times \ln 4.7 \times 10 - 16 = 0.7443$ V Voltage drop across 4 diodes = $4 \times 0.7443 = 2.977$ V so change in VO = 2.977 - 3 = -23 mV. To obtain the input common-mode range, we note that for v I 1 = v I 2 = v Icm, v + = v - = 10100
v Icm × 11100 + (100 10) = 0.833 v Icm For v + and v - in the range $-2.5 V \le v + , v - \le +2.5 V v G = i1 R2 + 0 + i1 R2 = 2i1 R2$ Thus, we can find the current through RG as v G/RG = 2i1 (R2/RG). P5.52(c). The reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V 2 vo = 0.646 × 0.993 Gv = v sig = 0.646 V/V which is much reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V 2 vo = 0.646 × 0.993 Gv = v sig = 0.646 V/V which is much reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V 2 vo = 0.646 V/V which is much reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V 2 vo = 0.646 V/V which is much reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V 2 vo = 0.646 V/V which is much reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V 2 vo = 0.646 V/V which is much reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V 2 vo = 0.646 V/V 2 vo = 0.646 V/V which is much reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V 2 vo = 0.646 V/V which is much reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V 2 vo = 0.646 V/V which is much reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V 2 vo = 0.646 V/V 2 vo = 0.646 V/V which is much reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V which is much reduced Rin will result in a reduction in v b /v sig , Rin vb 18.21 = v sig Rin + Rsig 28.21 = 0.646 V/V 2 vo = 0.646 V/V 2 v relative to the value obtained with bootstrapping. 1), we can write R1 0.5 VGS = VD = VD R1 + R2 0.5 + 2 VD = 5VGS = 5 × 0.8 = 4 V 1 VDS 2 ID = k n VOV 1 + 2 VA 1 4 ID = × 5 × 0.22 1 + 2 60 Chapter 6-44 This figure belongs to Problem 6.114(c). Average value of the output signal is given by $\left[\begin{array}{c} (\pi - \theta) \ 1 \ 2 \times VO = (VS \sin \phi - VD) \ d \phi \end{array} \right] 2\pi = 8 n VOV 1 + 2 VA$ Ex: 3.21 R C D2 Vp t Vr{ assume ideal diodes t = 163 mA PIV = Vs - VD + VS $\sqrt{4}$ = 12 2 - 0.7 + 12 2 = 33.2 V T 2 The ripple voltage is the amount of voltage reduction during capacitor discharge that occurs Exercise 3-7 when the diodes are not conducting. IDN = 1 W k (VGS - Vt) 2 nL VI = -2.5 V: Again if we assume that Qp is turned on, then VO > -2.5 V and VGS1 < 0, which implies that the NMOS QN is turned off. Since ro5 is much larger than the input resistance of the Q7 - Q8 mirror (1/gm7), most of io5 will flow into Q7, resulting in an output short-circuit current io8 : gm8 1 1 - io8 = io5 gm7 gm7 ro7 1 = 2 1 - io5 gm7 ro7 1 = 2 1 - io5 gm7 ro7 N/SS and the output resistance is ro8. P7.15. The signal waveforms will be as shown. Another 2 pins are required for power supplies. 2 The purpose of this problem is to show the huge imbalance that exists in this circuit. 2 (c) At one collector the signal voltage is $-\alpha$ ie RC $-\alpha$ ie R equation at the output: $v \circ - v \operatorname{gs} v \circ v \circ + + + \operatorname{gm} v \operatorname{gs} = 0 \operatorname{RD} \operatorname{ro} \operatorname{R2}$ 1111 $v \circ + + = -\operatorname{gm} 1 - v \operatorname{gs} \operatorname{RD} \operatorname{ro} \operatorname{R2}$ 11 $v \circ = -\operatorname{gm} (\operatorname{RD} \operatorname{ro} \operatorname{R2}) 1 - v \operatorname{gs} \operatorname{gm} \operatorname{R2} (1) \operatorname{R2} \operatorname{R1} + v \circ (2) \operatorname{R1} + \operatorname{R2} \operatorname{R1} + \operatorname{R2} \operatorname{Substituting} \operatorname{for} v \operatorname{gs} \operatorname{from} \operatorname{Eq} (1) \operatorname{yields} \operatorname{R2} \operatorname{R1} v \circ = -\operatorname{Av} \operatorname{sig} - \operatorname{Av} \circ \operatorname{R1} + \operatorname{R2} \operatorname{R1} + \operatorname{R2} \operatorname{R1} + \operatorname{R2} \operatorname{R1} + \operatorname{R2} \operatorname{Substituting} \operatorname{for} v \operatorname{gs} \operatorname{from} \operatorname{Eq} (1) \operatorname{yields} \operatorname{R2} \operatorname{R1} v \circ = -\operatorname{Av} \operatorname{sig} - \operatorname{Av} \circ \operatorname{R1} + \operatorname{R2} \operatorname{R1$ Thus, R1 R2 v sig = -A vo 1 + A R1 + R2 R2 - A vo R1 + R2 R2 + R2 R1 + R2 R2 + R1 v sig 1+A R1 + R2 v gs = v sig R2 2 M = 0.107 mA Next, we express v gs in terms of v sig and v o using superposition: RD ID From the voltage divider (R1, R2 : see Fig. 5.15 For triode-region operation with v DS small, iD k n (v GS - Vt) v DS Thus 1 iD /k n = v 20V 2 rDS = which describes the MOSFETs operation in the saturation region, that is, $1 = v DS \ge v OV Slope VOV 1 2 V 2 OV v DS 1 = iD k n (v GS - Vt) 1 1 = k n (1.2 - 0.8) 0.4 k n \Rightarrow k n = 2.5 mA/V Chapter 5-5 1 2.5(VGS - 0.8) rDS = 5.19 iD = k n (v GS - Vt) v DS (k) \Rightarrow VGS = 2.8 V For a device with twice the value of W, k n will be$ twice as large and the resistance values will be half as large: 500 and 100, respectively. DC voltage drop across RB = 0.2 V and IB RB = $0.2 \text$ Substituting for IRB from Eq. (1) yields RB × $0.025 \times 101 \text{ RB} = 10\ 0.22 \times 101 + 0.025 \times 101\ 0.025 \text{ RB} = 90\ \text{k}\ 0.2 \times 101\ \text{I} = 0.22\ \text{mA}\ 90\ \text{To}\ \text{maximize}$ the open-circuit voltage gain between base and collector while ensuring that the instantaneous collector voltage does not fall below (v B - 0.4) when v be is as high as 5 mV, we impose the constraint (RC 2) = 1.416 VC - | Av o | × 0.005 = VB + 0.005 - 0.4 RC = 4.86 k where We can select either 4.7 k or 5.1 k. But VO = Vx - IL RL = -IR1 - IL - IL RL = -IR1 - IL conduction interval. To determine the bias current I, which is the current in the collector of Q5, we first find the reference current through the 6.65-k resistor: 9 - (-5) - 0.7 = 2 mA IREF = 6.65 Assuming Q5 and Q6 are matched, we have I = 2 mA (a) gm1,2 I/2 1 mA = 40 mA/V = VT 0.025 V Rid = $2\pi\pi = 2\beta/gm1,2 2 \times 100 = 5 \text{ k} 40$ (b) Ad = Gm Rc = W6 can be determined using Eq. (8.172): (W/L)7 (W/L)6 = 2 (W/L)4 (W/L)5 (60/0.5) (W /0.5)6 = 2 (10/0.5) (00/0.5) = W6 = 20 \mu m For all devices we can evaluate ID as follows: ID8 = IREF = 225 μ A (W/L)8 I = ID5 = 225 μ A (W/L)8 I = ID5 = 225 μ A (D/L)8 I = ID5 = 225 μ A (With ID in each device known, we can use 1 W |VOVi |2 IDi = μ Cox 2 L i to determine |VOVi | and then |VGSi | = |VOVi | + |Vt | The values of gmi and roi can then be determined from 2IDi gmi = |VOVi | |VA | IDi where roi = Gm = gm1, 2 = 40 mA/V A1 = -gm1 (ro2 ro4) Ro = ro2 ro4 = -0.9 × (80 80) = -36 V/V Chapter 8-38 The results for Problem 8.105 are summarized in the following table. If β varies in the range 50 to 150 and we wish to keep | Gv | within ±20% of a new nominal (10/100) + (1/gm) That is, 10 8 = 0.1 + (1/gm) 0.2 + (1/gm) 1 = 0.3 or gm = 3.33 mA/V = gm 10 Gv = 25 V/V = nominal 0.1 + 0.3 10 Gv = min 0.2 + 0.3 = 20 V/V (-20% of nominal) We need to check the value obtained for $\beta = 150$, 10 Gv = = 27.3 V/V max 10/150 + 0.3 Chapter 6-24 which is less than the allowable value of 1.2 Gv nominal = 30 V/V. The corresponding value of v I is v I = v O - iR v I = 3.7 + 1 × 0.5 = +4.2 V For v I ≥ 4.2 V, the voltage of 1.2 Gv nominal = 30 V/V. diode D1 remains 0.7 V and v O saturates at +3.7 V. The current IB can be found from IB = Ex: 4.19 VCC 10 V VBB IB IC RB 10 k Assuming operation in the active mode, IC = β IB = 50 × 0.1 = 5 mA RC 10 k VBE 0.7 V VBB - VB 1.7 - 0.7 = 0.1 mA = RB 10 VCE (a) For operation in the active mode with VCE = 5 V, Thus, VC = VCC - RC IC = 10 - 1 × 5 = 5 V which is greater than VB, verifying that the transistor is operating in the active mode, as assumed. Observe that the output transistor is split into three transistors having base-emitter junctions with area ratio 1:2:4. 8.16 For a CS amplifier biased at a current ID and utilizing a drain resistance RD, the voltage gain is |A| = gm RD v Dmin \geq v Gmax - Vtn where gm = v Gmax = VCM + Vpeak (input) Thus, Thus, W L Equating the gains in Eqs. 100 + 10 For RL = 100 k, io = 10 μ A × 0.9 μ A For io = 0.8 is , 100 = 0.8 100 + RL \Rightarrow RL = 25 k 100 K 100 K + 1 M Exercise 1-2 Ex: 1.5 f = 1 1 = -3 = 1000 Hz T 10 ω = 2 π f $= 2\pi \times 103$ rad/s Ex: 1.6 (a) T = 1.1 = s = 16.7 ms f 60.1.1 (b) T = -3 = 1000 s f 10 (c) T = 1.1 = 6 s = 1 \mu s f 10 Ex: 1.7 If 6 MHz is allocated for each channel 4, it will go from channel 14 to channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD =
0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1K ID Ex: 1.7 If 6 MHz is allocated for each channel 69. VD = 0.7 V, ID = 1.1 ID Ex: 1.7 ID Ex: $0.3 = 0.025 \ln 2$. Thus we can write IE = VE = VE 1 IC = 5 - (VE + 0.2) = 0.5 - 0.1(VE + 0.2) = 0.5 - 0.05(VE + 0.7) = 0.25 loop: VBB = IB RB + VBE + IE RE 1.2 = IE \times 7.2 + 0.7 + IE \times 1 β + 1 \Rightarrow IE = 1.2 - 0.7 = 0.47 mA 7.2 1 + 101 IC = α IE = 0.99 \times 0.47 = 0.46 mA VC = +3 - 0.46 \times 1 = +2.54 V Since VB = IE RE + VBE = 0.47 + 0.7 = 1.17 V, we see that VC > VB - 0.4, and thus the transistor is operating in the active region, as assumed. To achieve this we have to shunt RL with a resistor R so that (R RL) $\leq 2 k. 9.10$, we obtain $\tau C1 = CC1 [(RB r \pi) + Rsig] = CC1 (Rin + Rsig) = 1 \times 10 - 6 (5.7 + 5) \times 103 = 10.7 \text{ ms}$ RB Rsig $\tau CE = CE RE re + \beta + 1 = 20 \times 10 - 6 Rin = RB1 RB2 r \pi$ where RB1 = 33 k, RB2 = 22 k IC 0.3 mA = 12 mA/V = VT 0.025 V gm = VT 25 mV re = 83.3 = IE 0.3 mA r \pi = \beta 120 = 10 P RSig TCE = CE RE re + \beta + 1 = 20 \times 10 - 6 Rin = RB1 RB2 r \pi where RB1 = 33 k, RB2 = 22 k IC 0.3 mA = 12 mA/V = VT 0.025 V gm = VT 25 mV re = 83.3 = IE 0.3 mA r \pi = \beta 120 = 10 P RSig TCE = CE RE re + \beta + 1 = 20 \times 10 - 6 Rin = RB1 RB2 r \pi where RB1 = 33 k, RB2 = 22 k IC 0.3 mA = 12 mA/V = VT 0.025 V gm = VT 25 mV re = 83.3 = IE 0.3 mA r \pi = \beta 120 = 10 P RSig TCE = CE RE re + \beta + 1 = 20 \times 10 - 6 Rin = RB1 RB2 r \pi = gm 12 Thus, Rin = 33 22 10 = 5.7 k Rin AM = - gm (RC RL) Rin + Rsig 3.9 × 10 (33 22 5) × 103 83.3 + 121 TC2 = CC2 (RC + RL) = 1 × 10-6 (4.7 + 5.6) × 10-3 2.2 × 10-3 10.3 × 10-3 = 102.7 Hz 9.9 Refer to the data given in the statement for Problem 9.8. RB = RB3 20 10 = 5.7 k Rin AM = - gm (RC RL) Rin + Rsig 3.9 × 10 (33 22 5) × 103 83.3 + 121 TC2 = CC2 (RC + RL) = 1 × 10-6 (4.7 + 5.6) × 103 = 10 ms RB2 = 33 k 22 k = 13.2 k IC IE 0.3 mA gm = IC 0.3 mA = 12 mA/V VT 0.025 V re = VT 25 mV = 83.3 = IE 0.3 mA r = β 120 = 10 k = gm 12 From Fig. Now let us evaluate VO for both 10-mA and 15-mA sources. (a) For VB = -1 - 0.7 = -1.7 V IE = -1.7 + 3 VE - (-3) = = 1.3 mA 1 1 Assuming active-mode operation we have Figure 1 IC = αIE IE = 1.3 mA Figure 1 shows the circuit with the value of VB that results in operation at the edge of saturation. 1.36 There will be 44,100 samples per second with each sample represented by 16 bits. = 0.5. v1 Here the first inverting amplifier simply inverts v 1, resulting at its output in 100 k v1 100 k - v 1 = -2 sin(2π × 1) k - v 1 = -2 sin(2\pi × 1) k - v 1 = -2 si $60t - 0.01 \sin(2\pi \times 1000t) 100 \text{ k} 100 \text{ k} 00 \text{ k} 0$ and Q2 have a threshold voltage Vt + Vt = 0.6 + 0.01 = 0.61 V. We also assumed t. The solution will be identical to that for (a) above with = 5.625 mA Transistor Q4 will carry I2 but will retain the same VGS as before, thus V2 remains unchanged at 2.5 V. Thus V5 = $-5 + 10 \times 1.5 = -5 + 2 \times 1.5 = -2$ V Since VDG < 0, the MOSFET is indeed in saturation. For D2, v I = v O - iD × 1 k Chapter 3-37 3.89 From the figure we see that \sqrt{v} Oav = -5 2 = -7.07 V 3.90 vO (V) 0.8 (a) to 55.4 10 V 10 V 2 1 1 vI (V) 2 (b) 20 V 0V 0.8 (c) 0V 1t is a soft limiter with a gain K 1 and L+ 0.7 V, L- -0.7 V 20 V (d) 0V 3.88 20 V R (e) 1.5 V 10 V 10 V (f) Here there are two different time constants involved. If W and L are also halved, rDS is halved, factor = 0.5. Condition 2: rDS, 2 = 5.4 kn = 5 mA/V2, Vtn = 0.5 V, iD = kn v OV v DS 1 = kn v O condition 1 is met, condition 2 will be met since the over-drive voltage can always be reduced to satisfy this requirement. (a1I/2) (a2I/2) VO Q1 To compensate for a total offset of 11 mV by appropriately varying RD, we need to change RD by RD obtained from RD VOV \times 11 mV = 2 RD Q2 I 2 I 2 I RD 11 \times 2 \Rightarrow = = 0.0733 RD 300 or 7.33% 8.67 VOS = VT RC RC and the collector voltages will be unequal, VC1 = VCC - $\alpha 1$ (I/2)RC = 25 × 0.1 = 2.5 mV 8.68 VOS = VT IS IS VC2 = VCC - $\alpha 2$ (I/2)RC and the collector voltage VOS can be obtained by dividing VO by the differential gain Ad := 25 × 0.1 = 2.5 mV 8.69 With both input terminals grounded, a mismatch RC between the two collector resistors gives rise to an output voltage I RC VO = α 2 = Ad = gm RC (1) I /2 IRC RC = VT 2VT Thus, VOS = VT (α 1 - α 2) With a resistance RE connected in the emitter of each transistor, the differential gain becomes Substituting, we obtain $\alpha \times 2$ RC α RC | Ad | = = 2(re + RE) RE + re α 1 = (2) The input offset voltage VOS is obtained by dividing VO in (1) by | Ad | in (2), I RC VOS = (re + RE) 2 RC 8.70 See figure. (8.40). There are 4 pairs of diodes in parallel. Thus 0.03 V-1 = 0.01 V-1 3 If v DS is increased from 1 V to 5 V, the drain current will change from λ = ID = $100 \ \mu\text{A} = \text{ID} (1 + \lambda \times 1) = 1.01 \text{ ID to ID} + \text{ID} = 1.05 \text{ ID Chapter 5-8 where ID is the drain current without channel-length modulation taken into account. Chapter 5-7 5.25 The cutoff-saturation boundary is determined by v GS = Vt , thus v GS = 0.4 V at the boundary. 1 that ID = <math>200 \ \mu\text{A}$. (c) V1 = -II R = -IR V2 = -I2 R = -2IRQ.E.D. V3 = -I3 R = -4IR 2.29 (a) R1 = R V4 = V3 - R R R 2 = (R R) + = + R 2 2 R R 3 = (R R) + = + R 2 2 R R 4 = (R R) + = RmA vI Assuming linear operation in the triode region, we can write vO 50 mV = 1 mA = iD = rDS 50 W (v GS - Vt) v DS iD = k n L 1 = $0.5 \times W \times (1.3 - 0.4) \times 0.05$ L W = 44.4 L 1.3 - 0.05 VDD - v O = R = iD 1 \Rightarrow = 1.25 k Refer to the circuit in the figure above, RG1 = 1.25 k Refer to the circuit in the figure above. To determine VS, we use 1 W ID = k p (VSG - $|Vt||^2 2 L 0.5 = 1 \times 4 \times (VSG - 1.5)^2 2 = VSG = 2 V$ Thus, VS = VG + VSG = 6 + 2 = 8 V RS = 10 - 8 = 4 k 0.5 5.51 (a) Refer to the circuit of Fig. 4.5(d) is shown in Fig. 2.44 Refer to the circuit in Fig. 7.18. P8.20. Chapter 4-12 E (b) (c) For operation deep in saturation with β forced = 10: iE vEB B VCE = 0.2 V DB (IS/b) biB ro C iB iC IC = VCC - VCE 10 - 0.2 = 9.8 mA RC 1 IB = IC 9.8 = 0.98 mA = \beta forced 10 VBB = IB RB + VBE iC 1 mA = 100 = iB 10 μ A iC
0.08 mA β ac = = 80 iB v CE constant 1.0 μ A 4.43 β = iC = iB × β ac + v CE ro where ro = VA 100 = = 100 k IC 1 Thus, iC = 2 × 80 + 2 × 103 = 180 μ A 100 = 0.18 mA = 0.98 × 10 + 0.7 = 10.5 V 4.45 Refer to the circuit in Fig. Ex: 7.23 Referring to Fig. R1 Connect C and O together, and D to ground. Thus all have equal values for ro : ro = |VA | 20 = = 200 k ID 0.1 (c) For Q2, RL = ro2 = 200 k, Rin = = ro + RL 1 + gm ro 200 + 200 = 2.2 k 1 + 0.9 × 200 (d) Rout = ro + Rs + gm ro Rs = 200 + 0.05 + 0.9 × 200 × 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout ro + gm ro Rs = 200 + 0.05 Rout r Rout /ro 1 2 2.9 10 2 10 $\beta/2$ 34 β 1000 51 92 = 209 k Rin 2.2 vi = 0.98 V/V = (e) vsig Rin + Rs 2.2 + 0.05 Observe that Rout ranges from ro to (β + 1)ro, with the maximum value obtained for Re = ∞ . (2) In this problem, iD1 = ID = 1 mA. (a) for the dc analysis. I i1 = i2 = i3 = i4 = = 0.5 mA 2 v = 700 + 25 ln(0.5) 683 mV = 1.005 V The same result can be obtained from the figure above where the signal across the two series diodes is 5 mV, thus Calculation for different values of v O = -83 + 683 + 0 = 0 V 1 For v O = 1 V, iO $680 1.005 + 2 0.2 0.6 0.4 \sim 687 677 2.010 + 5 0.5 0.75 0.25 \sim 693 665 5.028 + 9 0.9 0.95 0.005 \sim 700 568 10.09 9.99 0.999 0.$ O = -0.680 For phase shift of -45° , we obtain $-45 = -\tan -1.2\pi \times 100 \times 103 \times 10$ $0.025 \times 10 - 9 \times I + 0.685 + 1 = 1.005$ $V \Rightarrow I = 157$ μ A Similarly, other values are calculated as shown in the table. Rsig Rout vsig vi Rin Gv ovsig RL vo (a) Rsig Ro vsig vi Rin This figure belongs to Problem 6.58. VOS RIB, Also Eq. (2.46) holds: R3 = R1 R2 Chapter 2-31 5-k resistance in series with R3. This will reduce the allowed peak amplitude of the input sinusoid to 9.5 mV. Thus, at the output resistance (ro6 ro8) and thus produces an output voltage vo = ro6 vice 1 gm7 ro7 RSS. vicm 1 gm7 ro7 RSS this current flows into the output resistance (ro6 ro8) and thus produces an output voltage vo = ro6 vice 1 gm7 ro7 RSS. ro8 1 v icm RSS gm7 ro7 ro6 ro8 1 RSS gm7 ro7 ro6 ro8 1 RSS gm7 ro7 ro6 ro8 1 RSS gm7 ro7 Ad = |VA|/I 1 2 |Acm| = |VA|/I [I/|VOV|] [2|VA|/I] |Acm| = 1 1 |VOV| 1 VOV × = 2 2 |VA| 4 VA VA 2 CMRR = 4 VOV Q.E.D. (e) The lower limit on VICM is determined by Q1 and Q2 remaining in saturation, thus VICMmax = VDD - |VSC| + |Vt| = VDD - |VOV| The lower limit on VICM is determined by Q1 and Q2 remaining in saturation, thus VICMmax = VDD - |VOV| I VA|/I 1 2 |Acm| = 1 1 |VOV| I VOV × = 2 2 |VA| 4 VA VA 2 CMRR = 4 VOV Q.E.D. (e) The lower limit on VICM is determined by Q1 and Q2 remaining in saturation.on VICM is determined by the need to keep the bias current source in saturation, i.e. maintaining a minimum voltage across it of |VOV| + |VGS| = -VSS + |VV| + |VSS| = -VSS + |VV| + |VS| = -VSS + |VV| = -VSS + $VDD - |VOV| \le vO \le -VSS + |VOV| Exercise 9-1 Ex: 9.1 AM = - = -RG gm (RD RL) RG + Rsig 10 \times 2(10 10) 10 + 0.1 = -9.9 V/V 1 fP 1 = 2 \pi CC 1 (Rsig + RG) = 1 2 \pi \times 1 \times 10 - 6 (0.1 + 10) \times 106 = 0.016 Hz fP 2 = gm + 1/RS 2 \pi CS (2 + 0.1) \times 10 - 3 = 334.2 Hz 2 \pi \times 1 \times 10 - 6 1 fP 3 = 2 \pi CC 2 (RD + RL) = 1 2 \pi \times 1 \times 10 - 6 (10 + 10) \times 103$ = 8 Hz fZ = = 1 2 \pi CS RS 1 2 \pi × 1 × 10-6 × 10 × 103 fL = = 1 2 \pi 1 2 \pi 1 2 \pi 1 7 C 1 + 1 7 C 2 1 1 1 + + × 103 7.44 0.071 13 = 2.28 kHz 1 fZ = 2 \pi CE RE = 1 = 31.8 Hz 2 \pi × 1 × 10-6 × 5 × 103 Since fZ is much lower than fL it will have a negligible effect on fL. Thus VEB2 = VEB1 and the voltage that appears at X will be equal to V. The 1 mA will split in = 1 = 3.69 branches. 2.16.) Pot has 20 turns, and for each turn: v O = Acm = R2 R4 and differ by 1%. Using the information in Fig. Thus v O flattens, as shown. slope 1 vI v A = -0.7 V Keeps D2 off so no current flows through R 3.83 3 V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through D1 (b) v I = +3 V D1 vO = 0 V v A = -0.7 V Keeps D2 off so no current flows through R 3.83 3 V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through D1 (b) v I = +3 V D1 vO = 0 V v A = -0.7 V Keeps D2 off so no current flows through R 3.83 3 V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through D1 (b) v I = +3 V D1 vO = 0 V v A = -0.7 V Keeps D2 off so no current flows through R 3.83 3 V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through D1 (b) v I = +3 V D1 vO = 0 V v A = -0.7 V Keeps D2 off so no current flows through R 3.83 3 V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through D1 (b) v I = +3 V D1 vO = 0 V v A = -0.7 V Keeps D2 off so no current flows through R 3.83 3 V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through D1 (b) v I = +3 V D1 vO = 0 V v A = -0.7 V Keeps D2 off so no current flows through R 3.83 3 V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through D1 (b) v I = +3 V D1 vO = 0 V v A = -0.7 V Keeps D2 off so no current flows through R 3.83 3 V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through D1 (b) v I = +3 V D1 vO = 0 V v A = -0.7 V Keeps D2 off so no current flows through R 3.83 3 V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through D1 (b) v I = +3 V D1 vO = 0 V v A = -0.7 V Keeps D2 off so no current flows through R 3.83 3 V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through D1 (b) v I = +3 V D1 vO = 0 V v A = -0.7 V Keeps D2 off so no current flows through R 3.83 3 V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through R 3.83 a V \Rightarrow v - = 0 V Virtual ground as feedback loop is closed through R 3.83 a V \Rightarrow v - = 0 V Virtual ground as feedback loop is clos -0.7 V v- = 0 V R = 0.5 k vI vo i (c) v I = -1 V D2 v O = +1 V v A = 1.7 V v - = 0 V 3 V ~ Virtual ground as negative feedback loop is closed through D2 and R. Q.E.D. 6.43 The large-signal T model of Fig. To limit the range of | Gv | to ±20% of a new nominal value, we connect a resistance Re and find its value as follows. This results in the waveform shown in Fig. 1 we see that R1 + R2 = VCC 3 VCC =
= 30 k 0.1 mA 0.1 3 V R2 = 1.2 R1 + R2 R2 B 20 k R1 = 30 - 12 = 18 k VC IC For $\beta = 1.00$, to obtain the collector current, we replace the voltage divider with its Thévenin equivalent, consisting of R2 12 = $3 \times = 1.2 \text{ V} \text{ R1} + \text{R2} \text{ R2} \text{ R2} + 12 3 \text{ V} \text{ Writing a loop equation for the EBJ}$ loop, we have = IE × 2.2 + 0.7 + 3 V \Rightarrow IE = IC RC 2.2 k 3 = IE RE + VEB + IB RB RB = R1 R2 = 12 18 = 7.2 k VBB vE VB \Rightarrow R2 = 12 k VBB = 3 × 2.2 k IE RC 1 k VC RB (1) IE × 20 β + 1 3 - 0.7 = 0.86 mA 20 2.2 + 41 VE = 3 - 0.86 mA 20 2.2 + 41 VE = 3 - 0.7 = 0.86 mA 20 2.2 + 41 VE = 3 - 0.86 mA 20 2.2 + 41 $0.86 = 0.84 \text{ mA } 41 \text{ VC} = -3 + 0.84 \times 2.2 = -1.15 \text{ V}$ Figure 2 Refer to Fig. Correspondingly, IE = 4 - 0.7 = 0.995 \text{ mA } 48 3.3 + 51 \text{ For }\beta = 150, IE = RC = 4 - 0.7 = 0.995 mA 48 3.3 + 151 Thus, IE varies over a range of 1.1% of the nominal value of 1 mA. P5.47. The circuit is shown in Fig. As a differential amplifier, the voltage gain is found from $\alpha \times 10^{-1}$ for $\beta = 150$, IE = RC = 4 - 0.7 = 0.995 mA 48 3.3 + 51 For $\beta = 150$, IE = RC = 4 - 0.7 = 0.995 mA 48 3.3 + 151 Thus, IE varies over a range of 1.1% of the nominal value of 1 mA. P5.47. The circuit is shown in Fig. As a differential amplifier, the voltage gain is found from $\alpha \times 10^{-1}$ for $\beta = 150$, IE = RC = 4 - 0.7 = 0.995 mA 48 3.3 + 51 For $\beta = 150$. Total resistance in collectors vo = vi Total resistance in emitters $\alpha \times RC = 2re$ 1 W µp Cox |VOV | 2 2 L 1 × 4 × |VOV | 2 2 = 1.416 mA/V |VOV | 0.353 | Ad | = gm RD = 1.416 × 4 = 5.67 V/V RD RD | Acm | = 2RSS RD $\alpha RC = 2re$ (b) The circuit in Fig. Ro = Rop = 50 (20 k) = 1 M Finally, Av max = -(8) mA/V) (2.5 M 1.0 M) Av max = -5714 V/V Ex: 7.27 For the two current sources designed in Example 7.6, we have gm = IC 10 μ A mA = = 0.4 VT 25 mV V A 100 V = = 10 M, IC 10 μ A for $\beta = 150$: 3 - 0.7 IE = = 0.56 mA 120 3.3 + 151 VC = 3- IE RC = 3 - 0.56 × 3.3 = 1.15 V IE = VC = 5 - 0.52 × 7.5 = 1.1 V β = 50: 5 - 0.7 = 0.48 mA 43 8.2 + 51 VE = -5 + 0.48 × 8.2 = -1.064 V IE = Allowable negative signal swing at the collector = 1.15 - 0.3 = 0.85 V. Chapter 1-7 1.17 Find the Thévenin equivalent of the circuit to the left of node 1. Peak current occurs when φ = Vs 2V sin-1 D VS $= 1 - \theta [-Vs \cos \varphi - VD \phi]\pi \varphi = \theta \pi Vs - VD$, π input t $0 \theta 2$ output 2VD b. re2 $\alpha \times$ Total resistance in collector vo = - vsig Total resistance in collector vo = - vsig Total resistance in collector vo = - vsig Total resistance in emitter = The figure shows the circuit prepared for signal analysis. = 2VT IREF vx = ix × Q.E.D. For IREF = 100 μ A = 0.1 mA, 2 × 25 mV = 500 0.1 mA Rin = 7.23 IREF C3 IB3 aie3 ix B3 x B1 i b1 re1 ie1 ib2 B2 Q21 IO aie2 E3 IO1 b IO2 IO3 IOn IE3 Q1 C2 re3 aie1 vx IC1 Out ie3 C1 Q3 X Q22 Q23 Q2n nIO b ve re2 ie2 IO1 = IO2 = IO3 ··· = IOn = IO = IC1 The emitter of Q3 supplies the base currents for all transistor, so IE3 = In this equivalent circuit, re1 = re2 = re = re3 = VT $\alpha VT = IE3$ (n + 1) IO β IREF = IB3 + IO = VT $\alpha VT = IE3$ $2(1 - \alpha)$ IREF IO = IREF ie1 = ie2 = ie (n + 1) IO + IO β (β + 1) 1 1 n+1 (n + 1) 1+1+ β 2 β (β + 1) For the deviation from unity to be kept $\leq 0.2\%$ ie3 = ib1 + ib2 = $2(1 - \alpha)$ ie n+1 ≤ 0.002 β 2 From the figure we obtain ix = α ie1 + ($1 - \alpha$)ie3 \Rightarrow nmax = $0.002 \times 1502 - 1 = 44 = \alpha$ ie + ($1 - \alpha$) × $2(1 - \alpha)$ ie = ie [α + $2(1 - \alpha)$ 2] 7.24 For I = 10 μ A: But 2(1 - α)ie = ie [α + $2(1 - \alpha)$ i $-\alpha$)2 α . iD RD vDS Thus, the large-signal gain is 0.61 -3.175 = -11.7 V/V 1.61 -1.39 ! vgs VGS mA W = 1 2 VDD = 5 V, k n L V RD = 24 k, Vt = 1 V (a) Endpoints of saturation transfer segment: whose magnitude is slightly less (-2.5%) than the incremental or small-signal gain (-12 V/V). v D2 - v D1 = 0.8 -0.4 = 0.4 V v D1 = VDD - iD1 RD = 1 - $0 \times 5 = 1 \text{ V}$ (c) iD1 = 0.16 mA and iD2 = 0 with Q2 just cutting off, thus v D2 = VDD - iD2 RD = 1 - 0.16 × 5 = 0.2 V v GS2 = Vtn = 0.4 V iD1 = 1 ×
0.4 × 10 (v GS1 - Vtn)2 2 v D2 - v D1 = -0.8 V Summary of the results is shown in the following table on the next page. and, as a check, ID = 400 (g) Refer to Fig. 9.9 except with RE = ∞ (i.e. omitted). IS = 10-15 A = 10-12 mA Use the iterative analysis procedure: 1 - 0.7 = 0.3 mA 1. 4.48 For β forced = 2, IC = 2 IB 3.5 - VB = 2.38 V 4.49 Refer to the circuit in Fig. Thus Q4 and Q5 are matched and their W/L ratios are equal while Q7 has twice the (W/L) ratio of Q4 and Q5. This means the voltage at the output of A1 and A2 is the same as v Icm. Using diode exponential model we have $i2 v 2 - v 1 = VT \ln i1$ and v 1 = 0.7 V, i1 = 1 mA, $v = 0.7 + VT \ln 1$ From the results of (a) above, for I = 1 mA, v = 0.995; thus the nal will be = 700 + 25 ln(i) v^ i = v^ o /0.995 = 1/0.995 v O = 0, iO = 0, and the current I = 1 mA divide equally between the D3, D4 side and the D1 , D2 side. Thus, RD RD × = $-0.002 \text{ RD} \times 25 \text{ RD} \text{ RD} = -0.022 \text{ v} \times 25 \text{ RD} \text{ RD} = -0.022 \text{ r} \times 25 \text{ RD} = -0.02$ = |Ad| = gm RD RD 2RSS (W/L) W/L RSS = 200 k For the current source transistor to have ro = 200 k, VA × L 0.1 mA 200 × 0.1 = 4 µm L = 5 200 = 8.54 It is required to raise the CMRR by 40 dB, that is, by a factor of 100. I 0.1 = 4 mA/V β 100 = 25 k = gm 4 |VA| 5 = = 50 k ro1 = ro2 = I 0.1 Rin = rn 1 = 25 k rm 1 = $r\pi 2 = Ro = gm2 ro2 (ro1 r\pi 2) = (4 \times 50)(50 25) = 3.33 \text{ M Av } o = -gm Ro = -4 \times 3.33 \times 103 = -13,320 \text{ V/V gm1} = = 4 \times 50(50 25) = 3.33 \text{ M Av } o = -gm1 Ro = -1 \times 3.33 \times 106 = -3330 \text{ V/V Comment: The highest voltage gain (13,320 V/V) is obtained in circuit (a).}$ 2 Rf RP RP vN1 + vN2 + · · · 1 + RN RP1 RP2 We require v O = -9vI3 + vI1 + 2vI2 + 4vI4 Equating the coefficients of vI3, we have Rf = 9 RN (b) v O = -4vN1 + vP1 + 3vP2 Rf = 4, RN 1 = $10k \Rightarrow Rf = 40kRN1$ Rf RP RP = $1=1\Rightarrow51+RN$ RP1 RP1 RP2 RP2 RP2 RN Selecting RN = $10k \Rightarrow Rf = 90k$. Input Steps Code +2.5 V +5 b1 is the MSB (c) iOmax = 10 V 10 k 1 1 1 1 + 2 + 3 + 4 21 2 2 2 0101 - 3.0 V -6 1110 + 2.7 +5 0101 - 2.8 -6 1110 1.34 (a) For N bits there will be 2N possible levels, from 0 to VFS. I 0.1 = 4 mA/V = VT 0.025 2ID2 2I 2 × 0.1 = 1 mA/V gm2 = = 25 k gm1 4 5 |VA| = ro1 = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = = 50 k I 0.1 |VA| 5 ro2 = 5 $k I 0.1 Rin = r\pi I = 25 k gm 1 = Ro = gm 2 ro 2 ro 1 = 1 \times 50 \times 50 = 2.5 M 7.73 Refer to Fig. 1 + j 2\pi \times 10 \times 103 \times 0.01 \times 10 - 6.104 = 10 - 4 (1 + j 6.28) I + 6.282 4 = (247.3 - j 1553) vs 1 (c) Y = + j \omega C R 1 + j 2\pi \times 10 \times 103 \times 100 \times 10 - 12 = 100 \times 103 - 5 = 10 (1 + j 0.628) Z = 105 1 + j 0.628 (d) Z = R$ $+ j\omega L = 40 1 + 1.23 (2) 1 + (Rs/10) = 41 + (Rs/100) Rs$ is Thévenin equivalent v oc = v s Rs \Rightarrow RS = 50 k Substituting in Eq. (2) gives Norton equivalent v s = 60 mV The Norton current is can be found as is = isc = is v s = is Rs vs 60 mV = 1.2 μ A = Rs 50 k 1.26 Rs Thus, v oc isc (a) v s = v oc = 1 V vs v oc 1V = = 10 k isc 0.1 mA io vo is = isc = 0.1 mA io mA Rs = (1) = 10 Rs 10 Dividing Eq. (1) by Eq. (2) gives = (100 + j628), Rs = Rs 100 and vs = 100 + j6.28 × 100 vs RL + Rs Rs vo = vs 1 + RL 1 + = 100 + j2\pi × 10 × 103 × 10 × 10 - 3 RL vo Thus, vs = (71.72 - j45.04) k v o = v s - io Rs is io Rs vo Chapter 1-10 Highest value = 1 V 1 2π Period T = = 10 - 3 s f0 $\omega 0$ 1 Frequency f = = 1 kHz I vo Open-circuit (io 0) vs voltage Slope Rs vs is Rs 0 io Short-circuit (vo 0) current 1.27 Case ω (rad/s) f (Hz) T (s) a 3.14 × 1010 5 × 109 0.2 × 10 - 9 b 2 × 10 3.18 × 10 c 6.28 × 104 1 × 104 1 × 104 1 × 104 1 × 105 1 × 105 1 × 105 1 × 105 1 × 105 1 × 105 1 × 105 1 × 105 1 × 10 - 10 1 × 10 10 1.31 The two harmonics have the ratio 126/98 = 9/7. amplifier by a resistance Rp1 as in the following figure. At this point v O = VO . = VCC (β forced IB + IB) (a) For active-mode operation with VC = 2 V: = (β forced + 1)VCC IB IC = VCC - VC 10 - 2 = 8 mA RC 1 IB = 8 IC = 0.16 mA β 50 VBB = IB RB + VBE = 0.16 × 10 + 0.7 = 2.3 V (b) For operation at the edge of saturation: $VCE = 0.3 V IC = VCC - VCE 10 - 0.3 = 9.7 mA = RC 1 IB = 9.7 IC = = 0.194 mA \beta 50$ (2) For VCC = 5 V and β forced = 10 and Pdissipated $\leq 20 mW$, we can proceed as follows. For Q1, Q2, Q3 and Q4: 1 W I 2 = μ n Cox VOV 2 2 L 0.1 = 1 2 × 5 × VOV 2 (b) Ad = gm1,2 (Ro4 Ro6) gm1,2 = 2(I/2) I = VOV VOV Ro6 = gm6 ro6 ro8 Chapter 8-29 Q7 Q8 Q5 Q6 For |VOV| = 0.2 V and |VA| = 10 V, we have 10 2 Ad = 2 = 5000 V/V 0.2 Ro6 Ro4 Q3 vo Q4 VBIAS Q1 Q2 I Since all transistors are operated at a bias current (I/2) and have the same overdrive voltage |VOV| and the same overdrive voltage |VOV| and the same overdrive voltage |VA|, all have the same overdrive voltage |VA|, all have the same overdrive voltage |VA| and the same |VA| and |VA| an D1 D1 Z vO R 0.5 k vO D4 D2 vI 1 k (a) D2 D3 vO (V) 3.7 3.5 slope 1 (a) 2.5 2.3 (Not to scale) 1.8 2.5 D1 ON D2 OFF 3.5 4.2 D1 & D2 OFF (b) D1 OFF D2 ON vI (V) The limiter thresholds and the output saturation levels are found as $2 \times 0.7 + 6.8 = 8.2 \text{ V}$. where gm = Thus, $1/\text{re 1} 1 1 + \text{re ro Rsig IC 1 mA} = 40 \text{ mA/V} = \text{VT } 0.025 \text{ V gm ro} = 40 \times 100$ = 4000 rn = and i1 = isig VA 100 V = 100 k = IC 1 mA Rout = ro + (RE rn)(1 + gm ro) At the emitter node we see that there are three parallel resistances to ground: re , ro , and Rsig . (c) For | Gv | to be within $\pm 20\%$ of nominal (i.e., ranging between 64 V/V), the corresponding allowable range of β can be found as follows: 10 64 = (10/ $\beta min + 0.025 \Rightarrow \beta min = 76.2\ 10\ 96 = (10/\beta max) + 0.025 \Rightarrow \beta max = 126.3\ (d)$ By varying IC, we vary the term 1/gm in the denominator of the | Gv | expression. I 100 A VSG4 = VDD - VSG4 = 3.3 - 1 = 2.3 V 7.61 Refer to Fig. For v I ≤ 3.5 V, i = 0 and v O = v I .
P8.42(a). 6. 8.15(a). They are shown in the figure. For condition 1, we want to decrease W/L as much as possible (so long as it is greater than or equal to 1), while still meeting all of the other constraints. Vsig re + Re + 1 sCE Gain (dB) Re 0 Vo = $-\alpha$ Ie RC 40 dB Re 900 Thus, α RC Vo = $-\alpha$ Ie RC 40 dB Re 900 Thus, α Ie obtain AM = $-100\ 100 = = 10\ V/V\ Re\ 10\ 1 + re\ (2)\ Figure\ 2\ f\ (Hz)\ (log\ scale)\ Chapter\ 9-6\ This\ figure\ belongs\ to\ Problem\ 9.11,\ part\ (a).\ 1)$ is applied at the integrator. Thus or 69.5 dB VICM min = $-4.7 + VBE1.2 = -4.7 + 0.7 = 30 = 3000\ 0.01\ cm = -4.7 + V8.100\ The\ upper\ limit\ on\ VICM\ is$ determined by the need to keep Q1 in the active mode. Also, the equivalent circuits in Fig. P1.82, = $5 \times 4 = 20 \ \mu\text{m} = 10 - 4 \ \text{cm}$, we get since 1 nm = $10 - 7 \ \text{cm} = 20 \times 10 - 8 \ \text{cm} = 10 - 7 \ \text{cm} = 20 \times 10 - 8 \ \text{cm} = 10 - 4 \ \text{cm}$. $500 + 10 \times 1200 \times 10 \times 10 - 4$ 16 1.81 Electric field: = Hence 4 = 160 µA E = -4.5 \times 1017 Jp = -qDp dp dx = -1.6 × 10-19 × 12 × (-4.5 × 1017) = 0.864 A/cm2 3V 3V = 10 µm 10 × 10-6 m 3V 10 × 10-4 cm = 3000 V/cm 1.83 Use Eq. (1.45): Dp Dn = +VT µn µp Dn = µn VT and Dp = µp VT where VT = 25.9 mV. I = IC = $\alpha IE = 0.99 \times ro = 10^{-10} \times 10^$ ground, resulting in the circuit shown in the figure. 4.13 See table below. Ro = 100 Thus, Ex: 6.30 1 = 100 \Rightarrow gm = 10 mA/V gm IC = 5 mA But gm = VT VT 25 mV = 5 = IE IC 5 mA Rsig = 10 k RL = 1 k 2ID VOV Rin = (β + 1) (re + RL) Thus, 10 × 0.25 = 1.25 mA 2 RL 1 = 0.91 V = 1 × v^{o} o = v^{o} i × RL + Ro 1 + 0.1 ID = v^{o} gs = v^{o} i re = 1 gm 1 + RL qm Ex: 6.29 Ro = 200 =1 × 0.1 = 91 mV 0.1 + 1 = 101 × (0.005 + 1) = 101.5 k Gv o = 1 V/V Rout = re + Rsig β + 1 10,000 = 104 101 RL RL = Gv = Rsig RL + Rout RL + re + β + 1 = 5 + = 1 = 0.91 V/V 1 + 0.104 Exercise 6-8 vπ = vsig v^{2} sig v^{2} si sig v^{2} sig v^{2} si sig v Correspondingly, $v^{\circ} = Gv \times 1.1 = 0.91 \times 1.1 = 1 \text{ VVS} = -5 + 6.2 \times 0.49 = -1.96 \text{ V VD} = 5 - 6.2 \times 0.49 = +1.96 \text{ V RG}$ should be selected in the range of 1 M to 10 M to have low current. VO VZ rZ When the load is removed and VS = 11 V, we can use the zener model to determine VO . 2.20(b), when v Icm is applied, v - for both A1 and A2 is the same and therefore no current flows through 2R1. P5.57. Also, note that the current source has a voltage of -0.677 + 2.5 = 1.823 V across it, more than sufficient for its proper operation. Referring to the sketch of the output voltage, we see that max -v O = 4.5 - 0.3 = 4.2 V VCE = 0.3 + |Av| 0.005 = 1.08 V = 5 - 0.5 = 4.5 V Chapter 6-5 This figure belongs to Problem 6.13. Thus the current should be 20 mA, leading to R = 15 - 5.6 = 470 20 mA Maximum power dissipated in the diode occurs when IL = 0 is Pmax = 20 × 10-3 × 5.6 = 112 mV Exercise 3-5 a. (1), (2), and (3) into IE = IB + IC gives 4.55 For the solutions and answers to parts (a) through (e), see the corresponding circuit $1.194 \times 1010 \text{ rad/s}$ 1.21 (a) Z = 1 k at all frequencies (b) $Z = 1 \text{ /j}\omega C = -j \text{ At } f = 60 \text{ Hz}$, $1 2 \text{ nf} \times 10 \times 10 - 9 Z = -j265 \text{ k}$ At f = 100 kHz, Z = -j0.265 G At f = 1 GHz, Z = -j0.16 M At f = 1 GHz, $Z = -j15.9 \text{ (d)} Z = j2 \text{ nf} \times 10 \times 10 - 9 Z = -j265 \text{ k}$ At f = 100 kHz, Z = -j0.265 G At f = 100 kHz, Z = -j0.16 M At f = 1 GHz, Z = -j0.16 M At f = 1 GHz, Z = -j0.16 M At f = 1 GHz, Z = -j0.16 M At f = 1 GHz, Z = -j0.16 M At f = 100 kHz, Z = -j0.16 M At (a) T = 10-4 ms = 10-7 s At f = 60 Hz, Z = j3.77 1 = 107 Hz f = T At f = 1 GHz, Z = j6.28 k At f = 1 GHz, Z = j6.28 k At f = 1 GHz, Z = j6.28 k At f = 1 GHz, Z = j6.28 k Chapter 1-9 1.22 (a) $Z = R + 1 j\omega C$ (b) v s = v oc = 0.1 V is = isc = 1 $\mu A 1 = 10 + j2\pi \times 10 \times 10 - 9 3$ v oc 0.1 V = 0.1 M = 100 k = isc 1 $\mu A Rs = (1 - j1.59)$ k (b) Y = = 1 + j $\omega C R 1.24$ The observed output voltage is 1 mV/ $\circ C$, which is one half the voltage specified by the sensor, presumably under open-circuit conditions: that is, without a load connected. v C1min = 0.005 (b) If the bias current is realized using a simple current source, 50 VA REE = ro | current source = = 100 k I 0.5 RC RC | Acm | = 2REE RC 5 × 0.1 = 2 × 100 = 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMRR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 v/V | Ad | 50 CMR = = = 2 × 104 | Acm | 2.5 × 10-3 = gm RC = 18 × 10 = 180 V/V gm = At each collector there will be a sine wave of 180 × 2.5 = 450 mV = 0.45 V amplitude superimposed on the dc bias voltage of 5 - 0.45 × 10 = 0.5 V. L = Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4
V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRo = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 0.36 µm IRO = 32.4 V L = 3Lmin = 32.4 (V/V) (µm2) (mA/V) (k) (V/V) (µm2) (mA/V) (k) (V/V) (µm2) I = 0.01 mA W/L = 10 n 1.0 81 I = 1.0 mA W Substituting $|VA| 3,240 - 162 0.26n Ro = Ron Rop = 400 k L 2|VA| 2 L IRo = |VOV| Q.E.D. Av = -gm1 Ro = -2 \times 400 = -800 V/V Now, for L = 0.36 \mu m, IRo = 2 \times 52 \times 0.362 = 32.4 V 0.2 L = 0.36 \mu m, IRo = 2 \times 52 \times 0.362 \mu m, IRo = 2 \times 52 \times 0.362 \mu m, IRo = 2 \times 52 \times 0.362 \mu$ VD4 2ID 2I 2I = = 10I |VOV| |VOV| 0.2 Av = gm (Ro /2) VG3 Q3 (a) The price paid is the increase in circuit area. = 0.025 V v D2 = -2.5 V v Voltage gain = v id 0.025 v S = +0.5 + 0.8 = +1.3 V and thus v SG2 = 1.3 V which results in Chapter 8-4 1 × 4 (1.3 - 0.8)² 2 = 0.5 mA The upper limit on VCM is determined by the need to keep Q1 and Q2 in saturation, thus which is the entire bias current. A similar description applies for v I $\leq -3.5 \text{ V}$. If specified to a single digit, we use 2 k. This resistance will be much smaller than the two other resistances between the drain of Q1 and ground, namely, Ro1 = ro and Ro2 = ro. First find t1 and t2 0.7 2.5 = T t1 4 \Rightarrow t1 = 0.07 T T t2 = - t1 2 T = - 0.07 T 2 t2 = 0.43 T 1 v O (ave.) = x area of shaded triangle T T 1 - t1 = x (2.5 - 0.7) × T 4 T 1 - 0.07 = x 1.8 × T 4 T v 3.66 ideal 0.7 V 12 : 1 vS 10 Vrms O R 120 Vrms 60 Hz 1 k vO Chapter $3-26 \sqrt{v^{0}} = 102 - 0.7 = 13.44$ V fraction of a cycle for which one of the two 2(3.04) diodes conduct = $\times 100 = 96.8\%$ of the cycle there will be conduction. Thus, the lowest possible dc voltage at the collector is -0.4 V + 2V = +1.6 V. Since VD = VDD - ID RD + 6 V and VG 5 V, and the drain voltage is 2 V above the value that causes the MOSFET to leave the saturation region. 8.15(a) with VCC replaced by (VCC + v r). 1 1 = 1 at wint = . P5.55(c). Across the entire secondary we have 2 × 9.7 = 19.4 V (rms). Observe Av o = R R + 1 gm 1.81 + 1.24 = 0.81 V/V Chapter 7-33 Ro = R// 1 gm (b) Increasing the bias current by a factor of 10 (i.e., to 2 mA) results in = 1.81 k// 1 2.4 mA/V gm = 80 mA/V re = 0.0125 k = 0.339 k When a load resistance of 2 k is connected to the output, the total resistance between the output node and ground become R RL = 1.812 = 0.95 k. The value of Re is found from the 0.5 equation above to be Re = 67.7 RC RL Rin Rin + Rsig re + Re Gv = $-0.99 \times 18201010 + 100.05 + 0.0677 = -39.8$ V/V Ex: 6.43 Refer to Fig. Ro = Since ID = W = L gm1 = gm2 = gm3 = gm4 = 2 mA/V ro1 = ro2 = ro3 = ro4 = |VA| 2 (1.375 V) 2 |VA| = \cdot |VOV|/2 ID (0.3 V) $(100 \ \mu\text{A}) = 126 \ \text{k} \ \text{W} 1 \ \mu \ \text{Cox} 2 \ \text{p} \ \text{L}$ $|\text{VOV}| 2 \ 1 + \text{VSD}| \text{VA}| 2 (100 \ \mu\text{A})$ $0.3 \ \text{V} 2 \ 2 \ 90 \ \mu\text{A}/\text{V} (0.3 \ \text{V}) \ 1 + 1.375 \ \text{V} \ \text{W} = 20.3 \ \text{L} \ \text{vSD} 3 \ \text{can} \ \text{go} \ \text{as} \ \text{lov} \ \text{val} = 10 \ \text{k} = \text{ID} \ 0.2 \ \text{Ron} = (\text{gm} \ 2 \ \text{ro} \ 2 \ \text{val} \ \text{val} = 10 \ \text{k} = 10 \ \text{val} \ \text{val} \ \text{val} = 200 \ \text{k} \ \text{Rop} = 200 \ \text{val} \ \text{val} = 200 \ \text{k} \ \text{Rop} = 200 \ \text{val} \ \text{val} = 200 \ \text{k} \ \text{Rop} = 200 \ \text{val} \ \text{val} = 10 \ \text{val} \ \text{val} = 10 \ \text{val} \ \text{val} = 10 \ \text{val} = 10 \ \text{val} \ \text{val} = 10 \ \text{val} = 10 \ \text{val} \ \text{val} = 10 \ \text{val} = 10 \ \text{val} = 10 \ \text{val} \ \text{val} = 10 \ \text{v$ $-2 \times 100 = -200 \text{ V/V Ex}$: 7.21 gm1 = gm2 = gm = 0.1 mA ID = 1 mA/V VOV (0.2/2) V 2 Exercise 7-5 ro1 = ro2 = ro = (a) ID1 = I and ID2 = I VA 2V = 20 k = ID 0.1 mA so, gm ro = 1 mA/V (20 k) = 20 (a) For RL = 20 k, Rin2 = RL + ro2 20 k + 20 k = 1.9 k = 1 + gm2 ro2 1 + 20 · Av1 = -gm1 (ro1 Rin2) = -1 mA/V (20 1.9) = -1.74 V/V or If we use the approximation of Eq. (7.83), Rin2 \approx RL 1 20 k 1 + = + = 2 k gm2 ro2 gm2 20 1 mA/V then Av1 = -1 mA/V (20 k 2 k) = -1.82 V/V Continuing, from Eq. (7.80), Av = -gm1 [(gm2 ro2 ro1) RL] Av = -1 mA/V {[(20) (20 k)] 20 k} = -19.0 V/V Av 2 = Av - 19.0 = 10.5 V/V = Av 1 - 1.82 (b) The minimum voltage required across current source I1 would be |VOV| = 0.2 V, since it is made with a single transistor. P4.61(b). In fact, Q1 1 3 has |v qs| = v id while Q2 has |v qs| = v id while Q2 has |v qs| = v id . The results are summarized in the following table: Q3 ro2 = ro4 = = -12 V/V Finally, Q6 must conduct a current equal to that of Q7, that is, 400 μ A, thus 1 W 400 = × 100 × × 0.152 2 L 6 W = 356 L 6 Q2 2 × 0.2 = 2.67 mA/V 0.15 A1 = -gm1,2 (ro2 ro4) = $2.67(9 \ 9)$ Transistor Q8 conducts a current of 200 μ A, thus W1 W = $32.9 \ \text{L} \ 8 \ 2 \ \text{L} \ 5 \ \text{Transistor} \ Q1$ (d) gm1,2 = (a) With the inputs grounded and the output at 0 V dc, we have Q8 IE1 = IE2 = $1 \times 0.4 = 0.2 \text{ mA} \ 2 \ \text{ID} \ (\mu\text{A}) \ 200 \ 200 \ 200 \ 200 \ 200 \ 400 \ 400 \ 200 \ IE3 = IE4 \ 0.2 \text{ mA} \ W/L \ 32.9 \ 32.9 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \ 178 \
178 \ 17$ $65.8\ 32.9\ IE5\ 0.5\ mA\ IE6 = 1\ mA\ (b)$ The upper limit on VICM is determined by the need to keep Q1 and Q2 in saturation, thus (b) The short-circuit transconductance of the first stage is VICM max = VD1, 2 + |Vt| = 1.2 - 0.15 = 1.05\ V The lower limit on VICM is determined by the need to keep Q1 and Q2 in saturation, thus (b) The short-circuit transconductance of the first stage is VICM max = VD1, 2 + |Vt| = 1.2 - 0.15 = 1.05\ V The lower limit on VICM is determined by the need to keep Q1 and Q2 in saturation, thus (b) The short-circuit transconductance of the first stage is VICM max = VD1, 2 + |Vt| = 1.2 - 0.15 = 1.05\ V The lower limit on VICM is determined by the need to keep Q1 and Q2 in saturation, thus (b) The short-circuit transconductance of the first stage is VICM max = VD1, 2 + |Vt| = 1.2 - 0.15 = 1.05\ V The lower limit on VICM is determined by the need to keep Q1 and Q2 in saturation, thus (b) The short-circuit transconductance of the first stage is VICM max = VD1, 2 + |Vt| = 1.2 - 0.15 = 1.05\ V The lower limit on VICM is determined by the need to keep Q1 and Q2 in saturation, thus (b) The short-circuit transconductance of the first stage is VICM max = VD1, 2 + |Vt| = 1.2 - 0.15 = 1.05\ V The lower limit on VICM is determined by the need to keep Q1 and Q2 in saturation, thus (b) The short-circuit transconductance of the first stage is VICM max = VD1, 2 + |Vt| = 1.2 - 0.15\ E^{-1} Q5 in saturation, thus VICM = |VOV 5| + VGS1, 2 = 0.15 + 0.15 + 0.35 = 0.65 V IC1, 2 0.2 mA = 8 mA/V VT 0.025 V The voltage gain of the first stage can be obtained by multiplying Gm by the total resistance at the output node of the stage, i.e., the common collectors of Q2 and Q4 and the base of Q5. 8 6.62 (a) See figure on next page. Thusincluding Q4 Chapter 7-31 has no effect on the value of Ro, which can be found from Eq. (7.96): Ro = gm3 ro3 ro2 where 2ID 2 × 0.18 = 1.2 mA/V = VOV 0.3 VA 18 ro2 = ro3 = = = 100 k IREF 0.18 Thus, Ro = $1.2 \times 100 \times 100 = 12$ M (f) For VO = 1 V, we obtain VO 1V IO = = = 0.08 µA Ro 12 M IO = 0.04% IO gm3 = 7.85 Refer to Fig. We note that vgs = vbs = -vx and = 0.585 V ix = -gmb vbs + From the circuit we see that the voltage across R is VBE = 0.585 V, thus Thus, IO R = VBE 0.585 = 58.5 k R = 0.01 0.01 = 0.4 mA/V (b) gm3 = 0.025 40 = 4000 k ro3 = 0.01 \beta 100 = = 250 k rm 3 = gm3 0.4 (1) ix = gmb vx + vx vx - gm vx + ro1 ro3 vx vx + gm vx + ro1 ro3 from which we obtain vx 1 = ro1 ro3 Ro = ix gm + gmb Q.E.D. Rout = (R rn 3) + ro3 + gm3 ro3 (R rn 3) + ro3 + gm3 ro3 (R rn 3) 7.89 The dc level shift provided by a source follower is equal to its VGS. Observe that the gain realized is proportional to the offset voltage one is willing to accept. (e) From parts (c) and (d), the allowable range of signal swing at the output is from 0.4 V to 1.55 V - VOV or 1.35 V. But rd = ID ID \therefore ID = 5 mA 15 - 3 = 2.4 k. v O = 10 × R vI vO iL = 1 10 mV 1001 vO 10 mV = = 10 μ A 1 k 1 k Current supplied by the source is 10 μ A. Now, using 1 W 2 VOV ID = μ n Cox 2 L Chapter 7-14 The MOSFET will remain in saturation as long as VDG \ge -Vt. vi ie = RE + re RE v o1 = ie RE = v i RE + re Chapter 6-19 This figure belongs to Problem 6.53. 1 + (RL /ro) 1 + (RL /ro) Rin = = re 1 + [RL /(β + 1)ro] 1 + (RL /101ro) (a) ID1 = ID2 = ID3 = 100 µA Using ID1 0.1 = 1 2 = k n (W/L)1 VOV 1, we obtain 2 1 2 × 4 × VOV 1 2 RL /ro 0 1 10 100 1000 ∞ Rin /re 1 2 10 50.8 91.8 101 Observe that the range of Rin is re to (β + 1)re. Rsig 1 k vb vo vsig vp Rin 10 k Rib rp gmvp RC -vi 0.15 Chapter 6-18 This figure belongs to Problem 6.51. Ap = v 20 /RL = ii2 Ri Ro \geq RLmax 52 /(2 × 103) 2 200 10-6 × 5 × 103 200 + 5 = 2.63 × 106 W/W or 64.2 dB Thus Ro = 10 nV, iomin = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 100 100 Gm 100 + 10 1.58 Gm = 1.21 × 10-1 100 Fm V s = 10 mV, iomin = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 = 10-2 Ri Ro Gm Ri + Rsmax Ro + RLmax 10-3 Ri Ro Gm Ri +

A/V = 121 mA/V In 100 k vi 1.57 Ro = 2 k v o = 10 × Out Gmvi 100 k Gm 121 mA/V Open-circuit output voltage 10 V = Short-circuit output voltage 10 V = Short-circuit output current 5 mA 2 = 5V 2+2 The node equation at E yields the current through RE as ($\beta ib + ib$) = ($\beta + 1$)ib . P2.65. VCC RC RC vod Rsig/2 Rsig/2 Q1 vsig 2 Q2 Re VCM vsig 2 VEE Substituting for RC from (2), for Re from (1), and for re = VT /(I /2), we obtain $\alpha(120VT / \alpha I) = \beta$, we have $\beta + 12\beta RC$ Gv = 2($\beta + 1$)(re + Re) + Rsig $\alpha \times Total$ resistance in collectors v od = v id Total resistanc $v_0 = v_1$ Total resistance in emitters 0.99×25 2re + 2 × 0.25 where VT 25 mV = 250 = re = IE 0.1 mA v od $2\alpha(\beta + 1)RC = v sig 2(\beta + 1)(re + Re) + Rsig Since \alpha = 2 RC 4RC = 6(re + Re) + Rsig Since \alpha = 2 RC 4$ $2.78 = 4.135 \text{ mA 10 k 5 V 0 IE IB Q2 on IE Thus, the power dissipated in the circuit is P = 15 V \times 4.135 \text{ mA} = 62 \text{ mW 5 V VE}$ IE 1 1 k Exercise 4-7 From the figure we see that Q1 will be off and Q2 will be on. Thus, v B1 - v B2 = v BE1 + iE1 Re - iE2 Re - v BE2 = (v BE1 - v BE2) + Re (iE1 - iE2) 200 = 20 + Re (iC1 - iC2) = 20 + Re (iA3 - 62) \Rightarrow Re = 180 mV = 2.37 k 76 μ A (d) Without Re, v id = 20 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 3.8 mA/V Gm = 20 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow iC1 - iC2 = 76 μ A 76 μ A = 0.38 mA/V Gm = 200 mV \rightarrow the same linearity. (e) When v I < 0, D1 is conducting and the circuit becomes a voltage divider where the negative peak is vO 1 k × -5 V = -2.5 V 1 k + 1 k 5V 5 V t (j) vO 5V Vp + = 5 V, Vp - = -5 V, f = 1 kHz D1 conducts when v I < 0. VC = $3 - 0.2 \times 10 = 1$ V VT 25 mV = 125 = re = IE 0.2 mA Replacing the BJT with the T model of Fig. This requires our using the largest possible v GS,1 voltage. RG RD vo Design 1: VOV = 0.2 V, VGS = 0.6 V ID = 0.8 mA vi Now, Av = -k n VOV RD Thus, \Rightarrow RD = 12.5 k Refer to the solution of Example 6.3. From vo Eq. (6.47), Av = -gm RD (note that RL vi is absent). $4 \text{ VT } 25 \text{ mV} \Rightarrow 5=$. ISBN: 978-0-19-933916-7 Exercise Solutions (Chapters 1-17) Problem Solutions (Chapters 1-17) Problems included in the book Microelectronic Circuits, International Seventh Edition by Adel S. P5.52(g). Furthermore, it must be that C is now the dominant determinant of the amplifier 3-dB frequency (i.e., it is dominating over whatever may be happening at node B or anywhere else in the amplifier). P7.95. $5V \le 2 \text{ mV}$ (c) N 2 -1 (b) Av = 2N - 1 ≥ 2500 For N = 12, Resolution = 5 = 1.2 mV 212 - 1 Quantization error = 1.2 = 0.6 mV 2 1.35 (a) When bi = 1, the ith switch is in position 1 and a current (Vref /2i R) flows to the output. This will disable the controlled source gm vi. 2 n L OV = 0.5 V 1 VOV = 0.5 V 1 VOV = 0.5 V 1 VOV = 0.5 V = 0.5 V = 0.05 V = 0.saturation VDG \leq |Vtp | = 1 V \Rightarrow VD \leq VG + 1 (d) Given $\lambda \sim = 0$ ID = 1 W k |VOV | 2 = 75 µA 2 pL \therefore |VOV | = 0.5 V = VSG - |Vtp | \Rightarrow VSG = |VOV | + |Vtp | = 1.5 V VG = 5 - |VSG | = 3.5 V VD \leq VG + 1 = ≤ 4.5 V Exercise 5-2 (e) For $\lambda = -0.02$ V-1 and |VOV | = 0.5 V, ID = 75 µA and ro = 1 = 667 k | λ |ID (f) At VD = 3 V, VSD = 2 V 1 W k |VOV | 2 (1 + |VD|) = 1.5 V VG = 5 - |VSG | = 3.5 V VD \leq VG + 1 = ≤ 4.5 V Exercise 5-2 (e) For $\lambda = -0.02$ V-1 and |VOV | = 0.5 V, ID = 75 µA and ro = 1 = 667 k | λ |ID (f) At VD = 3 V, VSD = 2 V 1 W k |VOV | 2 (1 + |VD|) = 1.5 V Exercise 5-2 (e) For $\lambda = -0.02$ V-1 and |VOV | = 0.5 V, ID = 75 µA and ro = 1 = 667 k | λ |ID (f) At VD = 3 V, VSD = 2 V 1 W k |VOV | 2 (1 + |VD|) = 1.5 V Exercise 5-2 (e) For $\lambda = -0.02$ V-1 and |VOV | = 0.5 V, ID = 75 µA and ro =
1 = 667 k | λ |ID (f) At VD = 3 V, VSD = 2 V 1 W k |VOV | 2 (1 + |VD|) = 1.5 V Exercise 5-2 (e) For $\lambda = -0.02$ V-1 and |VOV | = 0.5 V, ID = 75 µA and ro = 1 = 667 k | λ |ID (f) At VD = 3 V, VSD = 2 V 1 W k |VOV | 2 (1 + |VD|) = 1.5 V Exercise 5-2 (e) For $\lambda = -0.02$ V-1 and |VOV | = 0.5 V, ID = 75 µA and ro = 1 = 667 k | λ |ID (f) At VD = 3 V, VSD = 2 V 1 W k |VOV | 2 (1 + |VD|) = 1.5 V Exercise 5-2 (e) For $\lambda = -0.02$ V-1 and |VOV | = 0.5 V, ID = 75 µA and ro = 1 = 667 k | λ |ID (f) At VD = 3 V, VSD = 2 V 1 W k |VOV | 2 (1 + |VD|) = 1.5 V Exercise 5-2 (e) For $\lambda = -0.02$ V-1 and |VOV | = 0.5 V = 0.5 λ ||VSD |) 2 nL = 75 μ A (1.04) = 78 μ A ID = Saturation mode (v GD = 0 < Vtn) : VD = 0.7 V = 1.8 - ID RD 1 W μ Cox (VD - Vtn) 2 = 0.032 mA 2 n L 1.8 - 0.7 \therefore R = 34.4 k 0.032 mA ID = Ex: 5.10 At VD = 0 V, VSD = 5 V 1.8 V ID = 75 μ A (1.10) = 82.5 μ A ro = VDS 3V = 667 k = ID 4.5 μ A R2 R1 which is the same value found in (c). 2 for the Bode plot. 4 vO (a) v O = v S + 0.7 V, v O = 0, For v S ≤ -0.7 V for v S ≥ -0.7 V VZ = VZ0 + rZ IZ vO 25 V 0.7 V 0 vS 207 slope 1 VZ IL 0 (b) 10 V vS vO t 0.7 V 25 - VZ = 9.825 + 7 × 207 207VZ = 207 (9.825) + 7 (25) - 7VZ 10 V 0.7 V u Chapter 3-25 3.65 (c) The diode conducts at an angle 0.7 θ = sin -1 = 4° and stops 10 0.7 V at $\pi - \theta = 176^{\circ}$ vS R 1 k vO Thus the conduction angle is $\pi - 2\theta = 172^{\circ}$ or 3 rad. A node equation at 2 results in the current leaving node 2 as 4I. 2, we see that VSD = VSG - 3 5.55 (a) Refer to the circuit in Fig. This occurs when v S is at its maximum negative value - Vp. The 1 10 actual closed-loop gain is G = . 10 V IE = VCC - VBE RB RC + β + 1 10 - 0.7 RB 7.7 $+ 101 \Rightarrow RB = 162 \text{ k} 1 = \text{Selecting standard 5\% resistors}$ (Appendix J), we use RC RB = 160 k vo and RC = 7.5 k The resulting value of IE is found as 10 - 0.7 = 1.02 mA + 101 and the collector voltage will be IE = RE vi 5V To establish IE = 1mA, IE = 5 - VBE RE 1 mA = 5 - 0.7 RE VC = VCC - IE RC = 2.3 V Ex: 6.37 Refer to Fig. Thus the 3 component of v o due to v 2 will be Ri Rs + Ri 10 k 10 k = 2 2 = vs 1+2 3 v o 2 = v 2 v o = Gm v i (RL Ro) 10 10 × Gm2 × 10 + 10 3 = v 2 × 0.5 × 20 × 1 vi = 60 20 + 1 20 2 = 60 × v s 21 3 Overall voltage gain = vo = 38.1 V/V vs 1.52 i 2 ix vx Gmvi Consider first the path for the signal requiring higher gain, namely v 2. Thus $\sqrt{\sqrt{VOV}}$ 7 OV 7 = 2VOV 1, 2 = 2VOV Chapter 8-34 and $gm7 \sqrt{21} 21 2I = = \sqrt{= VOV 7 V 2VOV OV ro7} = ro9 = VAI 1 gm ro3$ $1 = 0.98 A/A = 1 1 + 1 \times 50 Rom = ro4 = 50 k Thus, \sqrt{2} \sqrt{2} 21 VA 2VA = = VOV I VOV I RSS 1 + Am = 1 and \sqrt{2} 1 2|VA + I 1 2VA \times \times \times 2 \times \times CMRR = VOV 2 I VOV VOV I$ VA $3\sqrt{=2} 2 Q.E.D.$ VOV For k (W/L) = 4 mA/V2 and I = 160 μ A, Ro2 $= ro2 + 2RSS + 2gm2 ro2 RSS = 50 + 50 + 2 \times 1 \times 50 \times 25 = 2600 \text{ k Acm} = -(1 - Am) Gmcm (Rom Ro2) Acm = -(1 - 0.98) \times 0.02 \times (50 2600) = -0.0196 \text{ V/V Ad} = 25 = 1274 \text{ CMRR} = Acm 0.0196 \text{ or } 62.1 \text{ dB } 1 \times 4 \times |VOV| 2 2 \Rightarrow |VOV| = 0.2 \text{ V Alternatively, using the approximate expression in Eq. (8.157), we obtain For |VA| = 5 \text{ V: Acm} - (1 - 0.98) \times 0.02 \times (50 2600) = -0.0196 \text{ V/V Ad} = 25 = 1274 \text{ CMRR} = Acm 0.0196 \text{ or } 62.1 \text{ dB } 1 \times 4 \times |VOV| 2 2 \Rightarrow |VOV| = 0.2 \text{ V Alternatively, using the approximate expression in Eq. (8.157), we obtain For |VA| = 5 \text{ V: Acm} - (1 - 0.98) \times 0.02 \times (50 2600) = -0.0196 \text{ V/V Ad} = 25 = 1274 \text{ CMRR} = Acm 0.0196 \text{ or } 62.1 \text{ dB } 1 \times 4 \times |VOV| 2 2 \Rightarrow |VOV| = 0.2 \text{ V Alternatively, using the approximate expression in Eq. (8.157), we obtain For |VA| = 5 \text{ V: Acm} - (1 - 0.98) \times 0.02 \times (50 2600) = -0.0196 \text{ V/V Ad} = 25 = 1274 \text{ CMRR} = Acm 0.0196 \text{ or } 62.1 \text{ dB } 1 \times 4 \times |VOV| 2 2 \Rightarrow |VOV| = 0.2 \text{ V Alternatively, using the approximate expression in Eq. (8.157), we obtain For |VA| = 5 \text{ V: Acm} - (1 - 0.98) \times 0.02 \times (50 2600) = -0.0196 \text{ V/V Ad} = 25 = 1274 \text{ CMRR} = Acm 0.0196 \text{ or } 62.1 \text{ dB } 1 \times 4 \times |VOV| 2 2 \Rightarrow |VOV| = 0.2 \text{ V Alternatively, using the approximate expression in Eq. (8.157), we obtain For |VA| = 5 \text{ V: Acm} - (1 - 0.98) \times (1 - 0.$ 0.080 = For case(a), $CMRR = 2 \times 5 \ 0.2 \text{ and } 2 = 1250 \text{ or } 62 \text{ dB CMRR} = 25 = 1250 \ 0.02 \text{ or } 61.9 \text{ dB For case}(b)$, $\sqrt{CMRR = 2211 = -0.02 \text{ V/V} = -2\text{gm3} \text{ RSS } 2 \times 1 \times 25 5 \ 0.2 3 = 4.42 \times 104 \text{ or } 93 \text{ dB Ad } 8.98 \text{ CMRR} = Acm CMRR = 60 \text{ dB or equivalently } 1000.$ 1.3 (a) $V = \text{IR} = 5 \text{ mA} \times 1 \text{ k} = 5 \text{ VP} = \text{I } 2 \text{ R} = (5 \text{ mA})2 \times 1 \text{ k} = 25 \text{ mW}$ (b) $R = V/I = 5 \text{ mA} \times 1 \text{ k} = 25 \text{ mW}$ (b) $R = V/I = 5 \text{ mA} \times 1 \text{ k} = 2211 \text{ mA} \times 1 \text{ k} = 25 \text{ mW}$ (b) $R = V/I = 5 \text{ mA} \times 1 \text{ k} = 5 \text{ mA} \times 1 \text{ mA} = 5$ $V/1 \text{ mA} = 5 \text{ k P} = \text{VI} = 5 \text{ V} \times 1 \text{ mA} = 5 \text{ mW} \text{ Req} = 10 = 5 \text{ k} 100 + 10 1.01 \text{ a} 1\% \text{ reduction}; (b) 100 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 \times 100 10 = 9.9 \text{ k} 100 + 10 1.1 \text{ a} 9.1\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 \times 100 10 = 9.0\% \text{ k} 100 + 10 1.01 \text{ a} 1\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 50\% \text{ reduction}; (c) 10 \text{ k results in Req} = 10 = 5 \text{ k} 10 + 10 \text{ a} 10 \text{ k} 10 \text{ s} 100 \text{ k} 10 \text{ s} 100 \text{ s}$ get Thus, (4) (6) 4\beta RC 2(2\beta + 1)(re + Re) + 2(\beta + 1)(re $v^{sig} \leq -v^{sig} + 0.7$ Satisfying this constraint with equality gives $v^{sig} = 0.154$ V and the corresponding output voltage $v^{d} = |$ Gv $|v^{sig} = -2.5 + 0.3$ RD | Gv | = gm RD = 2RD Thus -2.5 + 0.3RD | Gv | = gm RD = 2RD Thus -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD | = gm RD = 2RD Thus -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + |$ Vtp | = -2.5 + 0.3RD + 2RD $v^{sig} = -v^{sig} + 1.5$ $0.05 = -0.05 + 0.7 \ 0.4$ RD = $3.15 \Rightarrow$ RD = $7.875 \ k \ Gv = -gm \ RD = -2 \times 7.875 = -15.75 \ V/V \ 6.110 \ Refer to Fig. iL Vp = IL R d Vp cos <math>\omega t + IL \ dt = -C \sin(-\omega t) \times \omega Vp + IL = C = -C \sin(-\omega t) \times \omega Vp + IL \ Sub(b) \ to get \ 2Vr \Rightarrow iD, max = C \omega Vp + IL \ Vp \ Substituting \ \omega = 2\pi f \ and \ using (a)$ together with Vp /R IL results in Vp Q.E.D. iDmax = IL 1 + 2π 2Vr Ex: 3.23 D4 ac line voltage D1 vO vS R D2 C D3 + IL Since the output is approximately held at Vp , Vp \approx IL \cdot Thus R Vp \Rightarrow iD,av \sim + IL = π IL 2Vr iD,max = C sin($-\omega t$) $\approx -\omega t$. (1) where A = 104 V/V and VOS = 5 mV. If a potentiometer is used, the total resistance of the potentiometer must be at least 1.6 k. T = $0 \circ C = 273$ K: ni = 1.52×109 cm-3; N = 3.3×1013 ni $\circ T = 20$ C = 293 K: -5×398) = 7.3×1012 /cm3 pn = $n2i = 2.23 \times 108$ /cm3 ni = 8.60×109 cm-3; N = 5.8×1012 ni
T = $75 \circ C = 348$ K: N = 1.4×1011 ni = 3.70×10 cm; ni 11 At 398 K, ni = BT 3/2 e-Eg /2kT - 3 T = $125 \circ$ C = 398 K: N = 1.1×1010 ni 1.75 Use Eq. (1.2) to find ni , ni = BT 3/2 e-Eg $/2kT - 5 \times 300$) = 7.3×1015 (300)3/2 e $-1.12/(2 \times 8.62 \times 10$ In phosphorus-doped Si, hole concentration drops below the intrinsic level by a factor of 108. R R Chapter $3-17 \div VT$ VO = V + VT + (V + - 0.7) (b) At no load, ID = rd = R V VO rd VO mr d mVT = = V + mr d + R mVT + IR = -1 ID ID + V + -0.7 VT × ID VT + -0.7 VT × ID VT + V + -0.7 VT × ID VT + 0.7 mA 5 mV VT V + $-0.7 \le \times$ ID VT + V + -0.7 mA i.e., (c) For m = 1 VO VT = = 1.75 mV/V V + VT + V + -0.7 For m = 4 VO mVT = = 8.13 mV/V V + mVT + $15 - m \times 0.7$ ID ≥ 4.99 mA ID 5 mA R = 15 - 0.7 V + -0.7 = ID 5 mA R = 2.86 k 3.52 V Diode should be a 5-mA unit; that is, it conducts 5 mA at at = 1.75 mV/V V + = 1.75VD = 0.7 V, thus $5 \times 10-3 = IS = 0.7/0.025$. C1, C2, and the transmission is not a function of frequency. Then we have (refer to the solution of x 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 To find the contribution of v 2 to v O), we set v 1 = v 3 = 0, then: v O = 4v 2 \Rightarrow R1 = 5 k Rc 10 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 Ra × = 2, \Rightarrow = 2 R1 Rb R1 10 Ra × = 2, \Rightarrow = 2 R1 Rb $=1 \times =1 \Rightarrow R2$ Rb R2 10 To find the contribution of v 3 to v O we set v 1 = v 2 = 0, then 9 k v 3 = -9v 3 1 k Combining the contributions of v 1, v 2, and v 3 to v O we have: v O = 6v 1 + 4v 2 - 9v 3. iC C Chapter 4-6 V7 - 0.7 + 10 V7 + 9.3 = (1) 3 3 Since IB = 0, the collector current will be equal to the current through the 9.1-k resistor, 4.24 = +10- V7 9.1 Since $\alpha 1$ 1, IC = IE = I6 resulting in IC = 4.25 (a) Refer to Fig. 7.41(b) indicates that the incremental resistance of Q4 would appear in series with the gate of Q3 and thus carries zero current. Exercise 6-1 Ex: 6.1 Refer to Fig. 7.41(b) indicates that the incremental resistance of Q4 would appear in series with the gate of Q3 and thus carries zero current. Exercise 6-1 Ex: 6.1 Refer to Fig. 7.41(b) indicates that the incremental resistance of Q4 would appear in series with the gate of Q3 and thus carries zero current. $10 V 1 \times 1.5(-V2 - 0.9)2 2 (V2 + 2.5) = V22 + 1.8 V2 + 0.81 1.5 VSG VSD$ R IR V22 + 0.467 V2 - 2.523 = 0 \Rightarrow V2 = -1.84 V Thus, I ID = V2 + 2.5 = -1.84 V Th series with positive input to minimize the output offset voltage) is R3 = R1 R2 = R1observe that at the input side of the g-parameter model, we have the controlled current source g12 I2. Also, ro = . 1.1a: For circuit a. 6.55(b). 3) the MOSFET will be operating in the triode region, and VSD = VSG - 10 V Since we expect VSD to be very small, we can 2 neglect the VSD term in the expression for ID and write ID k p (VSG - |Vt|)VSD $0.1 = 0.2(VSG - 1)(VSG - 10) 2 \Rightarrow VSG = 10.055 V VSD = VSG = 10.055 V VSD = VSG = 10.055 V 0.1 \text{ mA Fig. Both are operating in saturation and since they are identical, they have equal VGS : 1 3 × 270 × × 1 2 1 VGS1 = VGS2 = Thus, = 405 \mu A$ (b) Refer to the circuit in Fig. Note that the choice of the collector node to begin the analysis is by a factor of 4. Thus maximum reverse voltage = VO + Vp = 12 + 13.7 = 25.7. The same applies to D2. It follows that Chapter 4-15 VC = $VE + VCEsat = 0.3 + 0.2 = 0.5 V IC = 3 - VC 3 - 0.5 = 2.5 mA 1 1 IB = IE - IC = 3.3 - 2.5 = 0.8 mA \beta forced = IC 2.5 = 3.1 = IB 0.8 (d) When VB = 0 V$, IE = 2.3 mA. Denoting the emitter voltage of Q1, VE1 , and the current through R as I, the analysis proceeds as follows: IC2 = $10.1VE1 - 21.2I \alpha$ ID2 × 2 = IE2 × 0.1 IE2 = $2(0.395VE1 + 1.2I) = 0.1(10.1VE1 - 21.2I) \Rightarrow I = 0.05VE2$ Voltage drop across 80-k resistor = $(0.03 VE1 + 0.01I) \times 80 = 9 - VE1 - 0.7$ Substituting I = 0.05 VE2 gives V1 = VE1 VE1 = 2.41 V VE1 V1 = 0.025VE1 ID1 = 40.40 $VE1 + I = 0.5VE1 + I IE1 = 2 IE1 IB1 = 0.005VE1 + 0.01I 101 I = 0.12 mA I80 k = ID1 + IB1 = 0.03VE1 + 0.01I IC1 = 1.31 mA VC2 = VE1 - 1 \times 2 = VE1 - 2I IO1 = 1.09 mA IC2 = -I + IB2 = VC2 = 10VE1 - 21I 0.1 IC2 = 0.1VE1 - 0.21I 101 IC1 = 0.495VE1 + 0.99I ID2 = IC1 - IB2 = 0.395VE1 + 1.2I Substituting these quantities in the$ equations above gives VB1 = 2.41 + 0.7 = 3.11 V IE1 = 1.325 mA VC1 = $9 - 1.09 \times 2 - 0.7 = 6.12$ V VE2 = 6.82 V 9 - 6.82 = 21.8 mA 0.1 = $0.99 \times 21.8 = 21.6$ mA IE2 = IC2 VC2 = 2.17 V Exercise 5-1 Ex: 5.1 ox 34.5 pF/m = 8.625 fF/µm2 = Cox = tox 4 nm Similarly, VDS = 1 V results in saturation-mode operation and ID = 0.25 mA. The results are as follows: β forced The emitter-base voltage VEB is found as the voltage drop across the diode DB, whose scale current is ISB = IS / β , it is conducting a 10- μ A current. The circuit is a current divider, and the current of the controlled source. Thus, IC = $\beta IB = 50 \times 0.023 = 1.15$ mA To obtain VC = 2 V, we select RC according to RC = RB = 180 300 = 112.5 k Next we write an equation for the loop containing the EBJ to obtain IE = RB 10 k 300 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA Now, if the transistor is replaced with another having $\beta = 100$, then IC = 100 × 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA Now, if the transistor is replaced with another having $\beta = 100$, then IC = 100 × 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA Now, if the transistor is replaced with another having $\beta = 100$, then IC = 100 × 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA Now, if the transistor is replaced with another having $\beta = 100$, then IC = 100 × 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA Now, if the transistor is replaced with another having $\beta = 100$, then IC = 100 × 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA Now, if the transistor is replaced with another having $\beta = 100$, then IC = 100 × 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA Now, if the transistor is replaced with another having $\beta = 100$, then IC = 100 × 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15
mA Now, if the transistor is replaced with another having $\beta = 100$, then IC = 100 × 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA Now, if the transistor is replaced with another having $\beta = 100$, then IC = 100 × 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA Now, if the transistor is replaced with another having $\beta = 100$, then IC = 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA Now, if the transistor is replaced with another having $\beta = 100$, then IC = 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA NoW, if the transistor is replaced with another having $\beta = 100$, then IC = 100 k VBB V10 V12 IC V11 IB IB VC 2V = 1.74 k = IC 1.15 mA NoW, if the transistor is replaced with another having $\beta = 100$, then IC = 100 k VBB V10 V12 IC V11 IB IB V $0.023 = 2.3 \text{ mA } 3 - 0.75 - 0.7 = 0.212 \text{ mA } 112.5 6.2 + 101 \text{ which would imply VC} = 2.3 \times 1.74 = 4 \text{ VV11} = +3 - 0.212 \times 6.2 = +1.7 \text{ VV10} = 1.7 - 0.7 = +1 \text{ V which is impossible because the base is at } 2.3 \text{ V. } \nu p - drift = \mu \text{ E} = 480 \times 3000 - 3 \text{ (c) nn} \approx \text{ND} = 5 \times 10 \text{ cm}$; $18 \text{ pn} = = 1.44 \times 106 \text{ cm/s}$ $n^2 \text{ i} = 45 \text{ cm} - 3 \text{ nn} \nu n - drift = \mu \text{ E} = 1350 \times 3000 = 1.7 + 1.25 \text{ m}$ 4.05×106 cm/s Using $\mu n = 1200$ cm2/V · s and $\mu p = 400$ cm2/V · s, we have $-3\rho = 1.0 \times 104.05 \times 106$ · cm; R = 33.3. The emitter currents will be different, as shown. Q1 ix Q1 2 aie3 (1 a) ie3 aie2 VEE vx The figure shows the required circuit. k n = μ n Cox 3.45 × 10–11 W = 460×10-4 × ×10 L 6 × 10-9 v OV = 2.5 - 0.5 = 2 V = 2.645 mA/V 2 (a) v GS = 2.5 V Thus, v DS > v OV \Rightarrow saturation region, 1 iD = k n v 2OV 2 1 = × 2.645 × 22 = 5.3 mA 2 v DS = 1 V and v OV \Rightarrow v OV \Rightarrow triode region, 1 iD = k n v DS v OV - v 2DS 2 5.13 See Table below. 1, which can be used to calculate IE . P6.110. 3.51 + 9.9 0.99 1 0 700 Now I varies from Range of phase shift is -84.3° to -5.71° For v I > +10.7, v O will be saturated at +10 V and it is because I = 1 mA. 7.1, VDD = 1.3 V, IO = IREF = 100 μ A, L = 0.5 μ m, VA = 5 V/ μ m, Vt = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = W kn L 2 (100 μ A) = 0.2 V = 5 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 1 W 2 IO = ID = k n VOV 2 L 2I D VOV = W kn L 2 (100 μ A) = 0.2 V = 5 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = VGS = Vt + VOV = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V, k n = 500 μ A/V2 0.5 VDS = 0.4 V \muA/V2 0.5 $0.4 + 0.2 = 0.6 \text{ V} 1.8 - 0.6 \text{ V} \text{D} D - \text{V} \text{G} \text{S} = 12 \text{ k} \text{R} = \text{IREF } 0.1 \text{ mA } 7.3 \text{ V} \text{D} \text{D} \text{V} \text{D} \text{O} \text{O} \text{I} \text{Q} \text{V} \text{O} \text{I} = 20 \text{ \mu} \text{A } \text{r} 25 \text{ K} 7.2 \text{ Refer to Fig}$ For v I \geq 0, the diode conducts and presents a zero voltage drop. v id (mV) 2 v od (V) 0.2 0.498 0.987 1.457 1.90 2.311 2.685 3.022 3.320 v od Gain = v id 100 99.7 5 10 98.7 15 97.1 20 95.0 Using Eq. (8.48), we obtain 1 iE1 = -0.5 I 1 + e-v id /VT Observe that for v id < 10 mV the proportional transconductance gain is nearly constant at about 10. Thus 5.34 Refer to the circuit in Fig. The dc gain of the op amp. Ex: $6.33 \ 2 \Rightarrow VOV \ Ex: 6.31 \ 1 \ W \ ID = k \ n \ (VGS - Vt) \ 2 \ L \ 0.5 = 1 \ \times 1 \ \times (2 - 1.5) \ 2 = 0.125 \ mA \ 2 \ 0.125 - 0.5 \ ID = -0.75 \ = -75\% \ = \ ID \ 0.5 \ 1 \ W \ 2 \ k \ V \ 2 \ n \ L \ OV \ 0.5 \ \times 2 \ = 1 \ = 1 \ = 1 \ V \ \Rightarrow \ VGS \ = 1 \ + 1 \ = 2$ $V ID = 0.5 mA = \Rightarrow VOV 5 - 2 = 6 \ k \ 0.5 \Rightarrow RD = 6.2 \ k \ (standard value).$ P5.55(b). only during half of the period, T/2 = 2f C = 1 1 = 833 \ \mu F = (2fR) \ 0.1 \ 2 \ (60) \times 103 \times 0.1 \ (i) \ VO = Vp - VD - Vr \ 2 \ 0.1 = (13.44) \ 1 - 2 = 12.77 \ V \ 0.01 \ (ii) \ VO = (13.44) \ 1 - 2 \ (b) \ (i) \ Fraction of cycle = = 2Vr \ (b) \ (b) \ (b) \ (c) \ (b) \ (c) $Vp - VD \pi = 13.37 V 2\omega t \times 100 2\pi \times 100 1 2 (0.1) \times 100 = 14.2\% \pi \sqrt{2} 2 (0.01)$ (ii) Fraction of cycle = $\times 100 2\pi = 4.5\% = (c) Use Eq. (3.34)$: (i) iD, avg = 310 mA (ii) $C = 1 = 833 \mu F 2 (0.01) fR 1 (a) VO = Vp - 2VD - Vr 2 1 Vp - 2VD - 2 = Vp - 2VD - 2 =$ $= 12.1 \text{ V} \sqrt{\text{(ii) VO}} = (102 - 2 \times 0.7) \times 0.995 = 12.68 \text{ V} 2\omega \text{t} \times 100 \text{ (b) (i) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.01) \text{ (ii) Fraction of cycle} = 2 \pi \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text{ m} \sqrt{2} (0.1) = \times 100 = 14.2\% \text$ 0.02 3.75 0.7 V Vp - VD 2Vr 1 = 102.5 mA 2 (0.1) 1 13.37 1+ $\pi\sqrt{$ = 1 2 (0.01) (d) Use Eq. (3.35): 1 (i) $^{i}D = IL 1 + 2\pi\sqrt{$ = 0.02 Vp - 2VD 3.74 (i) Vr = 0.1 Vp - VD × 2 = 2fCR Vp - 2VD 1 = 83.3 µF C = Vp - 2VD 2 (0.1) fR 120 Vrms 60 Hz vS R 200 VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V
(ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V ± 1 V (ripple) RL = 200 (a) VO = 12 V $Vp - VD - 1 \Rightarrow Vp = 13 + 0.7 = 13.7 V 13.7 Vrms = \sqrt{9.7 V 2 Vp} - VD$ (b) $Vr = fCR 2 = 13.7 - 0.7 60 \times C \times 200 \Rightarrow C = 13 = 542 \mu F 2 \times 60 \times 200 C vO$ Chapter 3-30 This voltage appears across each half of the transformer secondary. Thus the small-signal resistance of the diode-connected MOS transistor is 1/gm. P7.95(c). v od = v C2 - v C1 = 13.7 V 13.7 Vrms(VCC - iC2 RC) - (VCC - iC1 RC) 25 92.4 30 89.5 35 86.3 40 83.0 The figure shows v od versus v id and the gain versus v id . E3.1. (c) V5V IOA Ex: 3.2 See Fig. 2 From Fig. 5 V I1 IE2 10 k 8.2 k 3.9 k V4 IB2 V7 Q2 IC3 IC1 Q1 IC2 V3 V2 IE1 8.2 k IB3 Q3 I2 V5 IE3 V6 2.4 k 6.2 k -5 V Figure 2 R2 = 5-0 5 - V3 = = 10 k 0.5 0.5 V4 = 0 + 0.7 = 0.7 V Consulting the table of 5% resistors in Appendix J, we select the following resistor values: R3 = 5 - 0.75 - V4 = 8.6 k 0.5 0.5 R4 = 6.2 k R5 = 3.9 k R6 = 2.4 k V6 = V5 - 0.7 = -2.7 V R6 = V6 - (-5) - 2.7 V R6 = V6 - (-5) - 2.7 V R6 = 2.4 k 1 The circuitwith the selected resistor values is shown in Fig. = $3.98 \times 10-3 \Rightarrow CE = 36.2 \mu F$ (d) I = 0.25 mA, RC = $10 \mu F 9.10 \text{ Vo ale Vsig}$ (3) (b) From Eq. (2) we see that Finally, $\tau CE 1 2\pi CE$ (re + Re) Ie 25 mV VT = = 100 I 0.25 mA, RC = $10 \mu F 9.10 \text{ Vo ale Vsig}$ (3) (b) From Eq. (2) we see that Finally, $\tau CE 1 2\pi CE$ (re + Re) Ie 25 mV VT = = 100 I 0.25 mA, RC = $10 \mu F 9.10 \text{ Vo ale Vsig}$ (3) (b) From Eq. (2) we see that Finally, $\tau CE 1 2\pi CE$ (re + Re) Ie 25 mV VT = = 100 I 0.25 mA, RC = $10 \mu F 9.10 \text{ Vo ale Vsig}$ (3) (b) From Eq. (2) we see that Finally, $\tau CE 1 2\pi CE$ (re + Re) Ie 25 mV VT = = 100 I 0.25 mA, RC = $10 \mu F 9.10 \text{ Vo ale Vsig}$ (3) (b) From Eq. (2) we see that Finally, $\tau CE 1 2\pi CE$ (re + Re) Ie 25 mV VT = = 100 I 0.25 mA, RC = $10 \mu F 9.10 \text{ Vo ale Vsig}$ (3) (b) From Eq. (2) we see that Finally, $\tau CE 1 2\pi CE$ (re + Re) Ie 25 mV VT = = 100 I 0.25 mA, RC = $10 \mu F 9.10 \text{ Vo ale Vsig}$ (3) (b) From Eq. (2) we see that Finally, $\tau CE 1 2\pi CE$ (re + Re) Ie 25 mV VT = = 100 I 0.25 mA, RC = $10 \mu F 9.10 \text{ Vo ale Vsig}$ (3) (b) From Eq. (2) we see that Finally, $\tau CE 1 2\pi CE$ (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re) Ie 25 mV VT = = 100 I 0.25 mA (re + Re by a factor of 10, we use Re 1+ CE Re = 10 re \Rightarrow Re = 900 The gain now becomes Figure 1 | AM | = Replacing the BJT with its T model results in the circuit shown in Fig. 9 V 2 k IC1 80 k IE2 100 V2 ID1 VC1 0 VB1 ID1 D1 V1 40 k Q2 0 IC1 Q1 IC2 IE2 IE1 VE1 VC2 100 2 k Figure 1 VE2 D2 $\beta = \infty$, and R is open circuited Chapter 4-28 VE1 = 1.22 × $2 = 2.44 \text{ V} \text{VB1} = 2.44 + 0.7 = 3.14 \text{ V} \text{IC1} = 0.99 \times 1.22 = 1.21 \text{ mA R}$ 2 k 2.8 V Observing that VE2 = V2, we see that the voltage drops across the 2-k resistor and the 100- resistor are equal, thus 2.8 V 0 ID2 × 2 = IE2 × 0.1 \Rightarrow ID2 = 0.05IE2 Figure 2 As the base current of Q2 is approximately 0.01IE2, a node equation at C1 yields Now connecting the resistance R = 2 k between C1 and E2 (see Fig. Rin2 = $2(\beta + 1)(25 + 25) = 2 \times 101 \times 50$ 10 k Effective load of first stage = Rin2 (5 + 5) = 10 10 = 5 k A1 = α Total resistance between collectors of Q1 and Q2 Total = 25 mV = 25 m With 100- resistance in the emitter of each of Q1 and Q2, we have Rid = ($\beta + 1$)(2re1,2 + 2Re1,2) = 101 × (2 × 0.1 + 2 × 0.1) = 40.4 k Chapter 8-42 Thus, Rid increases by a factor of 2. Thus $12 = 211 \text{ max} \Rightarrow \text{iI max} = 12 = 0.57 \text{ mA } 21 \text{ The maximum}$ allowed value for RL can now be found by substituting VO = -10 V, thus Thus, the allowable range of iI is $RL = 2.74 \text{ k} - 0.57 \text{ mA} \le iI \le +0.57 \text{ mA}$ chapter 2-9 (d) Since Rin = 0, the value of the source resistance will have no effect on the resulting iL, 2.33 v2 xR4 vO To obtain an input resistance of 100 k, we select R1 = 100 k. In developing the model of Fig. Replacing the BJT with the T model of Fig. Chapter 8-22 These figures belong to Problem 8.60. Case Transistor a b c d 1 2 3 4 VS VG VD ID (V) (V) (μ) 0 1 2.5 100 0 1.5 2.5 400 5 2 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0.5 450 5 -0. $2 2 \text{ Thus}, 50 = \text{gm1,2} (100 \ 100) \Rightarrow \text{gm1,2} = 1 \text{ mA/V Ad} = 1 2 |VA| 2 2 VOV = 2(|VA|/|VOV|) 2 \text{ But Q.E.D. gm1,2} 2(I/2) = |VOV 1,2| 500 = 2 |VA| 2 0.04 \Rightarrow |VOV 1,2| = 0.2 V \Rightarrow |VA| = 3.16 V \text{ The } (W/L) \text{ ratio for Q1 and Q2 can now be determined from 1}$ DS v DS = 0, v OV = VOV Figure 1 shows the tangent at v DS = 0 for the graph corresponding to v OV = VOV 3. Thus v Dmax = -0.4 V. Chapter 8-27 The gain Ad is found as follows: 8.77 VCC a2I 3 RC VC1 VO RC Q1 VC2 where Q2 I 3 2I 3 2 $\alpha \times$ Total resistance in emitters $\alpha \times 2RC = re1 + re2 Ad = aI 3 re1 = VT 3VT$ $1.5VT VT = = IE1 2I/3 2I I re2 = VT 3VT VT = = IE2 I/3 I thus, I Ad = (a) 2\alpha RC 2\alpha IRC = 4.5 VT / I 4.5 VT (2) Substituting in Eq. (1) gives v id = 0.75 VT = 18.75 mV Now, using large signal analysis: RC v id = VB2 - VB1 = (VB2 - VE) - (VB1 - VE) / VT (3) (VB2 - VE) / VT (4) IC2 = IS2 e Q1 vid Q2 re1 where IS1 = 1.5VT VT = 18.75 mV Now, using large signal analysis: RC v id = VB2 - VB1 = (VB2 - VE) - (VB1 - VE) / VT (3) (VB2 - VE) / VT (4) IC2 = IS2 e Q1 vid Q2 re1 where IS1 = 1.5VT VT = 18.75 mV Now, using large signal analysis: RC v id = VB2 - VB1 = (VB2 - VE) - (VB1 - VE) / VT (3) (VB2 - VE) / VT (4) IC2 = IS2 e Q1 vid Q2 re1 where IS1 = 1.5VT VT = 18.75 mV Now, using large signal analysis: RC v id = VB2 - VB1 = (VB2 - VE) / VT (3) (VB2 - VE) / VT (4) IC2 = IS2 e Q1 vid Q2 re1 where IS1 = 1.5VT VT = 18.75 mV Now, using large signal analysis: RC v id = VB2 - VB1 = (VB2 - VE) / VT (3) (VB2 - VE) / VT (4) IC2 = IS2 e Q1 vid Q2 re1 where IS1 = 1.5VT VT = 18.75 mV Now, using large signal analysis: RC v id = VB2 - VB1 = (VB2 - VE) / VT (4) IC2 = IS2 e Q1 vid Q2 re1 where IS1 = 1.5VT VT = 18.75 mV Now, using large signal analysis: RC v id = VB2 - VB1 = (VB2 - VE) / VT (3) (VB2 - VE) / VT (4) IC2 = IS2 e Q1 vid Q2 re1 where IS1 = 1.5VT VT = 18.75 mV Now, using large signal analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal
analysis: RC v id = 0.75 VT = 18.75 mV Now, using large signal$ 2 IS2. Refer to Fig. Ro = (gm3 ro3)(gm2 ro2) ro1 7.76 Refer to Fig. P8.84, namely, gm ro 1. L (μ m) 0.5 0.25 0.18 0.13 tox (nm) fF Cox μ m2 ox = 34.5 pF/m μ A k n V2 (μ = 500 cm2 /V·s) mA kn V2 W = 10 for L A(μ m2) W for = 10 L VDD (V) 10 5 3.6 2.6 3.45 6.90 9.58 13.3 173 345 4.79 6.65 2.50 0.625 0.324 0.169 Vt (V) ID (mA) for VGS = VDS = VDD , P(mW) P mW A μ m2 Devices Chip ID = P = VDD ID 1 k n (VDD - Vt) 2 2 v DS = 0.2 V Thus, v DS < v OV = triode region, 1 iD = k n v DS v OV - v 2DS 2 1 2 = 2.645[0.2 × 2 - 0.2] = 1 mA 2 (d) v GS = v DS = 2.5 V Wp = 50 L = 20 × 2.5 = and 5 2.5 1.8 1.3 0.7 0.5 0.4 0.4 16 6.90 4.69 2.69 80 17.3 8.44 3.50 32 27.7 EVD = 1 mA 2 (d) v GS = v DS = 2.5 V Wp = 50 L = 20 × 2.5 = and 5 2.5 1.8 1.3 0.7 0.5 0.4 0.4 16 6.90 4.69 2.69 80 17.3 8.44 3.50 32 27.7 EVD = 1 mA 2 (d) v GS = v DS = 2.5 V Wp = 50 L = 20 × 2.5 = and 5 2.5 1.8 1.3 0.7 0.5 0.4 0.4 16 6.90 4.69 2.69 80 17.3 8.44 3.50 32 27.7 EVD = 1 mA 2 (d) v GS = v DS = 2.5 V Wp = 50 L = 20 × 2.5 = and 5 2.5 1.8 1.3 0.7 0.5 0.4 0.4 16 6.90 4.69 2.69 80 17.3 8.44 3.50 32 27.7 EVD = 1 mA 2 (d) v GS = v DS = 2.5 V Wp = 50 L = 20 × 2.5 = and 5 2.5 1.8 1.3 0.7 0.5 0.4 0.4 16 6.90 4.69 2.69 80 17.3 8.44 3.50 32 27.7 EVD = 1 mA 2 (d) v GS = v DS = 2.5 V Wp = 50 L = 20 × 2.5 = and 5 2.5 1.8 1.3 0.7 0.5 0.4 0.4 16 6.90 4.69 2.69 80 17.3 8.44 3.50 32 27.7 EVD = 1 mA 2 (d) v GS = v DS = 2.5 V Wp = 50 L = 20 × 2.5 = and 5 2.5 1.8 1.3 0.7 0.5 0.4 0.4 16 6.90 4.69 2.69 80 17.3 8.44 3.50 32 27.7 EVD = 1 mA 2 (d) v GS = v DS = 2.5 V Wp = 50 L = 20 × 2.5 = and 5 2.5 1.8 1.3 0.7 0.5 0.4 0.4 16 6.90 4.69 2.69 80 17.3 8.44 3.50 32 27.7 EVD = 1 mA 2 (d) v GS = v DS = 2.5 V Wp = 50 L = 20 × 2.5 = and 5 2.5 1.8 1.3 0.7 0.5 0.4 0.4 16 6.90 4.69 2.69 80 17.3 8.44 3.50 32 27.7 EVD = 1 mA 2 (d) v GS = v DS = 2.5 V Wp = 50 L = 20 × 2.5 = and 5 2.5 1.8 1.3 0.7 0.5 0.4 0.4 16 6.90 4.69 2.69 80 17.3 8.44 3.50 32 27.7 EVD = 1 mA 2 (d) v GS = v DS = 2.5 V Wp = 50 L = 20 × 2.5 = and 5 2.5 1.8 1.3 0.7 0.5 0.4 0.4 16 6.90 4.69 2.69 80 17.3 8.44 3.50 32 27.7 EVD = 1 mA 2 (d) v GS = v DS = 0.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 2.5 V Wp = 50 L = 20 × 26.1 20.7 n 4n 7.72n 14.8n Chapter 5-4 This figure belongs to 5.14, part (a). = vI i2 D2 i1 i3 v1 v3 v2 v4 D3 iO vO i4 R 10 k D4 I \therefore DC biasing current I = 0.5 × 10 = 5 μ A c. Of course, the two 100- resistances in the emitters reduce the gain but some of the reduction is mitigated by the increase in Ri2, which increases the effective load resistances of the first stage. $0.05IE2 = IC1 - 0.01IE2 \Rightarrow 0.06IE2 = IC1 - 0.01IE1 \cdot \sqrt{122 - 0.7} = 1.00$ regulation: $VZ0 (\pi - \theta) = 7$ Line regulation = 1 = 2 π 17 V mV mA Ex: 3.20 vS input Ex: 3.19 Vs vS Vs 12 2 VD 0 VD 0 u u 2 t output () VS a. 2, where Rf if vi gmvi R1 vo R2 R2 vo With Rf, 1 49.8 × -10 × 49.8 + 100 1 + 0.1 = -3 V/V Gv = Without Rf, 1 100 × -10 × = -4.5 V/V Gv = 100 + 100 1 + 0.1 6.59 Rsig = 1 M, RL = 10 k gm = 2 mA/V RD = 10 k Gv = -gm (RD RL) Figure 2 vo if = gm v i + R2 = -2(10 10) = -10 V/V 6.60 RD = 2RL = 30 k vo v i = if Rf + vo = gm v i + Rf + vo = gm v iAv o = -gm R2 1 - 1/gm Rf 1 + (R2/Rf) Q.E.D. Finally, to obtain Ro we short-circuit v i in the circuit of Fig. Thus, IE1 = 3 IC2 = Thus, v id = 17.3 mV which is reasonably close to the approximate value obtained using small-signal analysis. If a transistor for which k n = 3 mA/V2 is used, then $1 ID = \times 3(5 - 3ID - 1)2$ $2 = 1.5(16 - 24I + 9ID^2) 9ID^2 - 24.67ID + 16 = 0$ whose physically meaningful solution is ID = 1.05 mA RD ID VG 5 V VS 2 V ID RS 2 k Chapter 6-31 ID = 2V = 1 mA 2 k RD = 3 k 1 ID = k n (VGS - Vt) 2 2 1 = (5 - 2 - Vt) 2 ID = 1 k p (VSG - |Vt|) 2 1 = 1 × 0.5(VSG - 1) 2 2 Vt = 2 V VS = VG + 3 = 3 + 3 = 6 V But = 0 VSG = 3 V If Vt = 1.5 V, then we have RS = VS = ID RS = 2ID VGS = VG - VS = 5 - 2ID 1 ID = x 2(5 - 2ID - 1.5)2 = VG = 4 - |Vt| = 2 V ID = 1.2 mA VS = 2.4 V 6.89 VDD 10 V R2 = VG 2V = 0.2 M = IG 10 μ A R1 = VDD - VG 8V = 0.8 M = IG 10 μ A R1 = VDD - VG 8 -15ID + 12.25 = 0 R1 VDD -VS ID VD 3V ID 1 mA RD ID = 1 kp (VSG -|Vt|) $221 = 1 \times 1.25$ (VSG -2) <math>2VSG = 3.265 V VS = VG + 3.265 = 2 + 3.265 = 5.265 V ID = 1 mA and VD = 3 V RS = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10
- 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 = 4.7 k 1 Thus, VD 3V = 10 - 5.265 =Thus, RD ID 3 = VG + |Vt| - 1 VG + |Vt| = 4 V (a) |Vt| = 4 V (b) |Vt| = 1 V and $k p = 0.5 mA/V2 VG = 3 V VG 3V R2 = 0.3 M = IG 10 \mu A VD - VG 7V R1 = 0.7 M = IG 10 \mu A VD - VG 7V R1 = 0.7 M = IG 10 \mu A VD - VG 7V R1 = 0.7 M = IG 10 \mu A VD - VG 7V R1 = 0.7 M = IG 10 \mu A VD - VG 7V R1 = 0.7 M = IG 10 \mu A VD - VG 7V R1 = 0.7 M = IG 10 \mu A VD = 3 V 0V RG VGS VSS ID RS Chapter 6-32 (a) VGS + ID RS = VSS But ID = SVIDt = 1 W kn (VGS - Vt) 2 L = K(VGS - Vt)$ $2 2Vt 2Vt = - = -VGS - Vt VOV = -ID K ID + ID RS = VSS K Differentiating relative to K, we have 1 aID ID 1 aID 0 + \sqrt{-2 + RS} = 0 K aK 2 ID / K K aK Vt + Q.E.D K = ±0.1, and (b) K = 100 \mu A/V2, K Vt = 1 V. Since For VA = 25 V, vo 25 = -v sig 0.025 VC + |Av| × 0.01 V = +0.4 V VC = -5 + IC RC - 5 + 0.5RC = -1000 V/V then vo 125 For VA = 25 V. vo 25 = -v sig 0.025 VC + |Av| × 0.01 V = +0.4 V VC = -5 + IC RC - 5 + 0.5RC = -1000 V/V then vo 125 For VA = 25 V. vo 25 = -v sig 0.025 VC + |Av| × 0.01 V = +0.4 V VC = -5 + IC RC - 5 + 0.5RC = -1000 V/V then vo 125 For VA = 25 V. vo 25 = -v sig 0.025 VC + |Av| × 0.01 V = +0.4 V VC = -5 + IC RC - 5 + 0.5RC = -1000 V/V then vo 125 For VA = -100 V/V$ $125 V_{c} = -v sig 0.025 - 5 + 0.5RC + gm RC \times 0.01 = 0.4$ Substituting gm = 20 mA/V results in = -5000 V/V RC = 7.7 k The overall voltage gain achieved is vo Rin = × gm RC v sig Rin + Rsig 6.52 5 V RE Rsig 50 vsig 50 × 20 × 7.7 50 + 50 = 77 V/V = 6.53 Refer to Fig. Thus VX = 0 7.16 (a) That is, a virtual ground appears at X, and thus the current I that flows into X can be found from I = 5 - VX 5 - 0 = 0.5 mA 10 k 10 This is the current that will be mirrored to the output, resulting in IZ = $0.5 \text{ mA} . 7.33 . 4 . 2.104 \text{ ft} = 20 \text{ MHz} = 100 \text{ V/V} \text{ R1} f3dB = \text{ft} 1 + \text{R2} R1 = 1 + j \Rightarrow \varphi = -\tan - 1 \text{ R2} 1 + \text{R1} = \text{ft} 2 (d) G = -2 \text{ V/V} \Rightarrow f3dB = \text{ft} R2 1 + R1 = 20 \text{ MHz} = 200 \text{ kHz} 100 \text{ kHz} = 100 \text{ V/V} R1 f3dB = \text{ft} 1 + R2 R1 = 1 + j \Rightarrow \varphi = -\tan - 1 \text{ R2} 1 + R1 = \text{ft} 2 (d) G = -2 \text{ V/V} \Rightarrow f3dB = \text{ft} R2 1 + R1 = 20 \text{ MHz} = 200 \text{ kHz} = 100 \text{ V/V} R1 f3dB = \text{ft} 1 + R2 R1 = 1 + j \Rightarrow \varphi = -\tan - 1 \text{ R2} 1 + R1 = 1 + j \Rightarrow \varphi$ $= 15 \text{ MHz} \text{ f3dB} = \text{ft} \text{ R2} 1 + \text{R1} = \text{f} \text{ f3db} \text{ ft} 1001 \text{ (f)} \text{ G} = +1 \text{ V/V} \Rightarrow \text{f} \text{ f3dB} = \text{f3dB} \text{ ft} 1 + \text{R2} \text{ R1} = \text{ft} 2 \text{ For} \text{ f3dB} = 1 \text{ MHz} \text{ (f)} = 1 \text{ MHz} 2.106 \text{ f3dB} = \text{ft} = 1 \text{ MHz} \text{ (b)} \text{ G} = +50 \text{ V/V} \Rightarrow \text{R2} 1 + \text{R1} = \text{R2} = 50 \text{ R1} 1 + \text{R2} \text{ R1} = \text{ft} 2 \text{ For} \text{ f3dB} = 1 \text{ MHz} \text{ ft} = 2 \text{ MHz} 2.106 \text{ f3dB} = \text{ft} = 1 \text{ MHz} \text{ (b)} \text{ G} = +50 \text{ V/V} \Rightarrow \text{R2} 1 + \text{R1} = \text{R2} = 50 \text{ R1} 1 + \text{R2} \text{ R1} = \text{ft} 2 \text{ For} \text{ f3dB} = 1 \text{ MHz} \text{ ft} = 2 \text{ MHz} 2.106 \text{ f3dB} = \text{ft} = 1 \text{ MHz} \text{ (b)} \text{ G} = +50 \text{ MHz} 1 + \text{R2} \text{ R1} = \text{ft} 2 \text{ For} \text{ f3dB} = 1 \text{ MHz} \text{ ft} = 2 \text{ MHz} 2.106 \text{ f3dB} = \text{ft} = 1 \text{ MHz} \text{ (b)} \text{ G} = +50 \text{ MHz} 1 + \text{R2} \text{ R1} = \text{ft} 2 \text{ For} \text{ f3dB} = 1 \text{ MHz} \text{ ft} = 2 \text{ MHz} 2.106 \text{ f3dB} = \text{ft} = 1 \text{ MHz} \text{ (b)} \text{ G} = +50 \text{ MHz} 1 + \text{R2} \text{ R1} = \text{ft} 2 \text{ For} \text{ f3dB} = 1 \text{ MHz} \text{ ft} = 2 \text{ MHz} 2.106 \text{ f3dB} = \text{ft} = 1 \text{ MHz} \text{ (b)} \text{ G} = +50 \text{ MHz} 1 + \text{R2} \text{ R1} = \text{ft} 2 \text{ For} \text{ f3dB} = 1 \text{ MHz} \text{ ft} = 2 \text{ MHz} 2.106 \text{ f3dB} = \text{ft} = 1 \text{ MHz} \text{ (b)} \text{ G} = +50 \text{ MHz} 1 + \text{R2} \text{ R1} = \text{ft} 2 \text{ For} \text{f3dB} = 1 \text{ MHz} \text{ ft} = 2 \text{ MHz} 2.106 \text{ f3dB} = \text{ft} = 1 \text{ MHz} \text{ (b)} \text{ G} = +50 \text{ MHz} 1 + \text{R2} \text{ R1} = \text{ft} 2 \text{ For} \text{f3dB} = 1 \text{ MHz} \text{ ft} = 2 \text{ MHz} 2.106 \text{ f3dB} = \text{ft} = 1 \text{ MHz} \text{ ft} = 1 \text{ MHz} 1 + 1 \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} \text{ R2} \text{ R1} \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} \text{ R2} \text{ R1} \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} \text{ R2} \text{ R1} \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} \text{ R2} \text{ R1} \text{ R2} \text{ R1} \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} \text{ R2} \text{ R1} \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} \text{ R2} \text{ R1} \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1} = 1 \text{ R2} \text{ R1}$ =1 R1 ft 51 For f3dB = 100 kHz \Rightarrow ft = 100 × 51 = 5.1 MHz f3dB = R2 = 0 R1 For f3dB = 10 kHz, ft = 1 MHz f = f3dB × tan 6° = 21 kHz ft R2 = 1000 R1 For f3dB = R2 = 2 R1 (e) G = -1000 V/V \Rightarrow 100 G(j ω) = ft = R2 = 50 R1 1 + 1 2 = 1 + f 2 with f f3dB f in MHz ft 50 |G| = 0.99 \Rightarrow f = 0.142 MHz For f3dB = 100 kHz, ft = 5 MHz (c) G = +2 V/V \Rightarrow 1 + 1 |G| = R2 = 2 R1 The follower behaves like a low-pass STC circuit 1 1 µs = with a time constant $\tau = 2\pi 2\pi \times 106$ tr = 2.2 $\tau = 0.35$ µs. 1.46 Each of stages #1, 2, ..., (n - 1) can be represented by the equivalent circuit: vo v i1 v i2 v i3 v in vo = $\times \times \times \cdots \times \times$ vs vs v i1 v i2 v i(n-1) v in where Chapter 1-15 This figure belongs to 1.46. Rin = RG1 RG2 = 52.5 = 1.67 M Ro = RD ro = 18200 = 16.5 k 5V = 100 k 0.05 mA The base current through RB1 is IRB1 = IB + IRB2 = 5 + 50 = 55 μ A Since the voltage drop across RB1 is VCC - VB = 10 V, the value of RB1 can be found from 10 V = $182 \text{ k RB1} = 0.055 \mu\text{A}$ The value of RE can be found from \Rightarrow RE = VC = VCC - IC RC 6 = 15 - 0.99 × 0.5 × RC RC 18 k This completes the bias design. From Eq. (2) we Chapter 4-11 can obtain the temperature coefficient of VE by utilizing the fact the VBE changes by - 2.2 $mV/\circ C. v = 0.7 + 2.3 \times 0.025 \log 0.61$ 0.825 V. VB2 = -4.6 V Finally, since Q2 is off, IC2 = 0 IB = 0.039 mA Ex: 4.32 With the input at + 10 V, there is a strong possibility that the conducting transistor Ex: 4.33 VO = +10 - BVBCO = 10 - 70 = -60 V This figure belongs to Exercise 4.32. Recalling that the incremental (small-signal) resistance of a diode-connected transistor is given 1 by ro, the equivalent load resistance of gm Q1 will be From symmetry, a virtual ground appears at the mid point of Rs. v CE (V) v BC (V) iBC (µA) iB (µA) iC (mA) iC /iB 0.4 0.3 0.016 14.46 14.48 1.446 100 0.3 0.4 0.89 14.46 15.35 1.445 94 0.2 0.5 14.46 62.96 1.398 29 48.5 Chapter 4-5 The collector voltage can now be obtained from VC = $-5 + IC \times 8.2 = -5 + 0.5 \times 8.2 = -0.9 V 4.22 IB = 5 IE = 0.238 A = 238 mA \beta + 1.20 + 1 The emitter current can be found as IC = IS eVEB /VT IE = IB + IC = 10 + 500 = 510 \mu A \alpha IE = IS eVEB /VT = 0.51 mA where 20 = 0.95 \alpha = 21 IS = \alpha IE e - VEB /VT 4.21 = 0.95 \times 5e - (0.8/0.025) = 6 \times 10 - 14 A A$ transistor that conducts IC = 1 mA with VEB = 0.70 V has a scale current IS = $1 \times 10-3$ e $-0.70/0.025 = 6.9 \times 10-16$ Referring to the figure we see that IE = IB + IC = IC + IC β 4.23 The two missing large-signal equivalent circuits for the pnp transistor are those corresponding to the npn equivalent circuits in Fig. 10 mV = 10 μ A 1 k 10 μ A + 0.7 = 0.58 V v D = 25 × 10-3 ln 1 mA \therefore iD = iR = v A = v D + 10 mV = 0.58 + 0.01 = 0.59 V For v I = 1 V = 0.36 rad = 20.7 \circ iDav = 1.45 A The diode has 0.7 V drop at 1 mA current. The resulting circuit is shown in Fig. (VIA - 0.8)2 = 0.11 (1 - 0.03 × 2.98) \Rightarrow VIA Note that Q2, Q3 are not matched: = 1.116 V ID1 = 100 μ A W3 ID3 (W/L)3 = = ID2 W2 (W/L)2 = (Note that VSG2 = VSG3) vO 2.98 - 0.33 = vI 1.13 - 1.116 vO = -189.3 V/V vi 10 = 25 μ A \Rightarrow IREF = 25 μ A 40 (b) By referring to Fig. Thus for our 1- μ -m long transistor, VA = 20 V. For vI \leq -4.2 V, vO = -3.7 V. Av = - IC RC VT 1 × RC \Rightarrow RC = 8 k 0.025 - IC RC - 320 = - VC = VCC = 10 - 1 × 8 = 2 V Since the collector voltage is allowed to decrease to +0.3 V, the largest negative swing allowed at the output is 2 - 0.3 = 1.7 V. To keep Q4 in saturation, v Omax = VBIAS + 0.4 = 4.4 V If the dc voltage at the output is 0 V, then the maximum positive voltage swing is 4.4 V. When v I goes negative, v A follows, the diode turns off, and the feedback loop is opened. 400 V4 = 2.5 V Now, compare the part of the circuit consisting of Q2 and the 1-k resistor. 28 v Orms = $\sqrt{=19.8}$ V 2 2.75 |T| = 2.73 See analysis on the circuit (a) has the advantage of infinite input resistance. Now 10 Rin = 100 k, thus R = 100 k and 10-4 s C = 5 = 10-9 F = 1 nF. 6.4(a). Total resistance between collectors Total resistance in the emitter circuit (2RC RL) = α 8.44 Refer to Fig. Thus v O flattens at about 2.3 V. Applying this voltage to the diode gives current ID = 20.1 mA. (4.21) and (4.22), we can express ro as ro = VA IS ev BE /VT 1 + VA which is Eq. (4.18). Thus $r\pi 1 = \beta \text{ gm1 gm1} = IC1 0.52 = 20.8 \text{ mA/V VT} 0.025 r\pi 1 = 100 = 4.81 \text{ k} 20.8 \text{ Rin} = 68 \text{ k} 33
4.81 4 \text{ k} 5.6 \text{ k Rout} = 2.4 \text{ k}$ $re3 + \beta + 1$ where 5V 0.74 V 8.2 k VT 25 mV = = 11.9 IE3 2.1 mA 5.6 = 2.4 0.0119 + 101 re3 = 3.3 k Rout IE2 = 65.5 (c) Refer to Fig. In this problem, VO 20 mV = 20.4 above. P6.120: Rin = 200 k (\beta + 1)(re + Re) For v be to be limited to 5 mV, the signal between base and ground will be 10 mV (because of the 5 mV across Re). VOV = 0.2 V VGS = Vt + VOV = 0.6 + 0.2 = 0.8 V From the voltage divider (R1, R2 : see Fig. and RD + RL 9.4 Refer to Fig. Here we are required to obtain K = 1000 Rin = 2 k Thus, R1 = R3 = 1 k and R2 = R4 = 1 M. Thus iCmax = iCav = 4.8 A. E2.3 we have: v 3 = μ v d and Since we are assuming that the op amp in this transresistance amplifier is also zero. Thus, vBE 0.65 V 0.70 V 0.72 V 0.73 V 0.74 V (V) iC (mA) i k 1 = 0.11 mA 101 Note that the currents in R1 and R2 differ only by the small base current, 0.01 mA. Obviously, case a is preferred because it provides higher voltage gain. 2α RC v od = v id re + Re (5) then the new value of Gv is obtained by replacing β by 2 β in Eq. (4) and substituting for Rsig from (5): Gv = Rid = (β + 1)(2re + 2Re $2(\beta + 1)(re + Re) v id = v sig 2(\beta + 1)(re + Re) + Rsig 1 \alpha RC 2\beta RC = 4(\beta + 1)(re + Re) 2 re + Re If \beta is doubled to 2\beta while Rsig remains at its old value, we get where = Substituting for Rsig = Rid = 2(\beta + 1)(re + Re) into Eq. (4) gives Gv = 120 = 12 V/V 2+8 8.45 Re I 0.99 × 25 vo 25 V/V = vi 2 × 0.25 Rin = (\beta + 1)(2re + 2Re) If v id = 0.97 Vid = 0.97 Vid$ 0.5 v sig, then from (1) we obtain = $2 \times 101 \times (0.25 + 0.25)$ Rid = Rsig = 101 k Chapter 8-18 8.47 Refer to Fig. Ex: 4.17 ro = $0.994 \alpha = \beta + 1.165 + 1$ At IC = 0.1 mA, ro = 1 M Assuming active-mode operation, At IC = 1 mA, ro = 100 k IC = $\alpha \text{ IE} = 0.994 \times 1.66 = 1.65 \text{ mA}$ At IC = 10 mA, ro = 10 k Exercise 4-4 Ex: $4.18 \text{ IC} = \text{VCE ro Ex: } 4.20 \text{ For VBB} = 0 \text{ V}, \text{IB} = 0 \text{ and the transistor is cut off. This, however, does not apply to VOS due to Vt. 1 v I 1 = v Icm - v Id 2 1 v I 2 = v Icm + v Id 2 R2 v O1 = 1 + vI1 R1 R2 R2 0 = 1 + vI2 R1 Current through R1 in the upward direction is i= v - (A2) - v - (A1) v Id = 2R1 2R1 v Id = 2R$ O1 = v - (A1) - iR2 = v Icm - 1 R2 v Id 1 + 2 R1 v O2 = v - (A2) + iR2 = v Icm + R2 1 + v Id R1 Chapter 2-22 v Ocm = 1 (v O1 + v O2) = v Icm 2 Ad 1 = 1 + If 2R1 is reduced to 1 k, Ad increases to 201 V/V while Acm remains unchanged at 0.02 V/V. 7.2, if W2 = 5 W1 and we let L1 = L2, then we obtainIO = ID2 = IREF (W/L)2 = 20 μ A × 5 = 100 μ A (W/L)1 VOmin = VOV = 0.2 V But ro = 0.7 V VG = = 8.75 k ID1 80 μ A 1 W |VOV |2 ID = μ p Cox 2 L R = VA L VA = IO IO 10 × L ⇒ L = 1.5 μ m 0.15 ⇒ VA = 15 V 100 = From Eq. (7.8): IO = VO - VGS (W/L)2 · IREF 1 + VA2 (W/L)1 VGS = Vt + VOV = 0.5 V + 0.2 V = 0.7 V VOV = VDS2min = 0.3 V Thus, ID equal 5IREF will be obtained at VGS = Vt + VOV = 0.5 + 0.3 = 0.8 V 1 W VDS 2 1+ VOV ID = k n 2 L VA W 0.8 1 × 0.09 1 + 150 = × 400 × 2 L 15 VO = VGS = 6.7 k R = IREF 0.15 For VO = VGS + 1 = 1.7 V 1.7 - 0.7 = 105 µA IO = 100 1 + 20 The corresponding increase in IO, IO is, thus, 5 μ A. To keep ID unchanged, the unchanged. P7.55. 10 - 1.6 = 8.4 k IC 1 mA IE = Ex: 6.36 Refer to Fig. P6.118. All transistors are operating at IE = 0.5 mA. \therefore Voltage drop across each diode 1.3 = = 0.65 V. The largest, |Acm|, will occur when R2 and R3 are at their lowest (or highest) values and R1 and R4 are a their highest (or lowest) values, as this will provide the maximum R2 R3 deviation of from unity. 2, 10 V VSG VSD 3V 30 k Here also (see Fig. Therefore, we have: R1 Ex: 2.2 Relevant equations are: $v^3 = A(v^2 - v^1)$; $v Id = v^2 - v^1$, $1 v Icm = (v^1 + v^2) 2 R1 = 100 k and (a) Thus: <math>2v^3 = 0 - 3 = -0.002 V = -2 mVA 10 = v^2 - v^1 = 0 - 3 = -0.002 V = -2 mVA 10 = -0.002 V = -2 mVA 10 = v^2 - v^2 - v^2 = -2 mVA 10 = -0.002 V = -2 mVA 10 =$ (-0.002) = +0.002 V v1 = v2 - v Id = 2 mV 1 v Icm = (-2 mV + 0) = -1 mV 2 - R2 = $-10 \Rightarrow$ R2 = 10 R1 R1 R2 = 10×100 k = 1 M Ex: 2.5 R 10 k (b) -10 = 103 (5 - v 1) \Rightarrow v1 = 5.01 V vi v Id = v 2 - v 1 = 5 - 5.01 = -0.01 V = -10 mV 1 1 (v1 + v2) = (5.01 + 5) = 5.005 V 2 2 v Icm = ii vo 5V (c) v 3 = A(v 2 - v 1) = 103 (0.998 - 1.002) = -4 $V v Id = v 2 - v 1 = 0.998 - 1.002 = -4 mV v Icm = 11 (v 1 + v 2) = (1.002 + 0.998) = 1 V 2 2 (d) - 3.6 = 10 [v 2 - (-3.6)] = 10 (v 2 + 3.6) 3 3 \Rightarrow v 2 = -3.6036 V v Id = v 2 - v 1 = -3.6036 - (-3.6) = -0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is open circuit Rm = i i o = 0.0036 V = -3.6 mV 1 1 (v 1 + v 2) = [-3.6 + (-3.6036)] 2 2 - 3.6 V From Table 1.1 we have: v o ; that is, output is o$ The negative input terminal of the op amp (i.e., v i) is a virtual ground, thus v i = 0: v o = v i - Rii = 0 - Rii = -Rii v o Rii Rm = -R ii io = 0 ii v Icm = thus Ri = Ex: 2.3 From Fig. The missing entry for experiment #3 can be predicted as follows: 1.00 vO = = 0.01 V. P2.47. Thus ID = 1 mA and the output voltage changes by VO = ID × 2rd VO = 2 × VD = -24.2 mV = 1 × 2 × 3.4 which is less than half that obtained with the 10-mA supply. (c) For Rout = 50 ro, Eq. (1) gives Re = 4.8 k. Rin (at the base of Q1) = (\beta 1 + 1)[re1 + rn2] Chapter 7-36 (f) where re1 = 50 vo ic2 rn 2 = (\beta + 1)re2 = 101 × 50 = 101 × 100 rcm 2 = 5.05 k Thus, Q2 Rin = 101(0.05 + 5.05) = 515 k Rin 515 vb1 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 V/V = vsig Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 + 10 rm 2 5.05 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin +
Rsig 515 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 vb2 = 0.98 \text{ V/V} = \text{vsig} Rin + Rsig 515 vb2 = = $6 \text{ k} 1 10 - \text{VE RE} = \text{IE} \Rightarrow \text{RC} = \text{The figure shows the circuit, f02} = 1 2\pi\text{C2}$ (Ro + RL) For f02 ≤ 100 Hz, s $\omega 0$ where 1 ≤ 100 $2\pi\text{C2}$ $(1 + 1) \times 103 \omega 0 = 1/CR \Rightarrow C2 \ge Thus$, $1 = 0.8 \times 10 - 6 2\pi \times 2 \times 103 \times 102$ Select $C2 = 1 \times 10 - 6 = 1 \mu F$. 7.1) we have IO = 100 μ A and we want to reduce the change in output voltage, VO, to 1% of IO. iD = eVD /VT = 0.9 to 1.1 I v D = -2.63 mV to +2.32 mV ± 2.5 mV so the signal voltage across each diode is limited to 2.5 mV when the diode current remains within 10% of the dc bias current. Thus VD = 560 mV. 6.26(b) results in the equivalent circuit model for the amplifier shown on next page. 3-dB frequency at 1 kHz 1 $\therefore \omega 0 = 2\pi \times 1 \times 10 = CR2$ 3 If the integrator is made with an op amp having a finite A0 = 1000, the response to the -1-V step will be that of an STC low-pass circuit. fT = $20 \times 10-3 = 353.7$ MHz $2\pi \times (8 + 1) \times 10-12$ fB = 353.7 fT = = 3.54 MHz $\beta 100 9.18$ See figure below. 6.117 Refer to the circuit of Fig. v oc = is (t) × Rs vo When output terminals are short-circuited, as in Fig. 8 = $1.38 \times RD \Rightarrow RD = 5.06$ k Chapter 8-19 (c) VD1 = VD2 = VDD - ID RD $CMRR = 5 - 0.5 \times 5.06 = 2.47 \text{ V}$ | Ad | = 2gm RSS | Acm | (W/L) W/L where (d) gm = 2ID 2(0.1/2) = 0.5 mA/V = VOV 0.2 For CMRR of 80 dB, the CMRR is 104 ; thus RD 104 = 2 × 0.5 × RSS / 0.02 ΔVD1 ΔVCM Q1 1/gm 2RSS 2 k The figure shows the common-mode half-circuit, RD VD1 = -1 VCM + 2 RSS gm 5.06 VD1 = -1.92 V/V = -1 VCM + 2 RSS / 0.02 ΔVD1 ΔVCM Q1 1/gm 2RSS 2 k The figure shows the common-mode half-circuit, RD VD1 = -1 VCM + 2 RSS gm 5.06 VD1 = -1.92 V/V = -1 VCM + 2 RSS / 0.02 ΔVD1 ΔVCM Q1 1/gm 2RSS 2 k The figure shows the common-mode half-circuit, RD VD1 = -1 VCM + 2 RSS gm 5.06 VD1 = -1.92 V/V = -1 VCM + 2 RSS / 0.02 ΔVD1 ΔVCM Q1 1/gm 2RSS 2 k The figure shows the common-mode half-circuit, RD VD1 = -1 VCM + 2 RSS gm 5.06 VD1 = -1.92 V/V = -1 VCM + 2 RSS / 0.02 ΔVD1 ΔVCM Q1 1/gm 2RSS 2 k The figure shows the common-mode half-circuit, RD VD1 = -1.92 V/V = -1 VCM + 2 RSS / 0.02 ΔVD1 ΔVCM Q1 1/gm 2RSS 2 k The figure shows the common-mode half-circuit, RD VD1 = -1.92 V/V = -1 VCM + 2 RSS / 0.02 ΔVD1 ΔVCM Q1 1/gm 2RSS 2 k The figure shows the common-mode half-circuit, RD VD1 = -1.92 V/V = -1 VCM + 2 RSS / 0.02 ΔVD1 ΔVCM Q1 1/gm 2RSS 2 k The figure shows the common-mode half-circuit, RD VD1 = -1.92 V/V = -1 VCM + 2 RSS / 0.02 ΔVD1 ΔVCM Q1 1/gm 2RSS 2 k The figure shows the common-mode half-circuit, RD VD1 = -1.92 V/V 1.58 (e) For Q1 and Q2 to enter the triode region VCM + VCM = Vt + VD1 + VD1 Substituting VCM = 2.332, Vt = 0.7 V, VD1 = 2.47 V, and VD1 = -1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + VCM = 0.7 + 2.47 - 1.92VCM results in 2.332 + 100 results in 2.R2 15 = 5.357 V = 15 × R2 + R1 15 + 27 VBE = 0.7 V VE = 4.3 V This figure belongs to Problem 6.115. Thus, the two collector currents will be unequal, IC1 = $\alpha 1 I/2 IC2 = \alpha 2 I/2 \beta 1 \beta 1 + 1$ and $\beta 2 \beta 2 + 1 \beta 1 + 2 \gamma VBE = 0.7 V VE = 4.3 V This figure belongs to Problem 6.115. Thus, the two collector currents will be unequal, IC1 = <math>\alpha 1 I/2 IC2 = \alpha 2 I/2 \beta 1 \beta 1 + 1$ and $\beta 2 \beta 2 + 1 \beta 1 + 2 \gamma VBE = 0.7 V VE = 4.3 V This figure belongs to Problem 6.115. Thus, the two collector currents will be unequal, IC1 = <math>\alpha 1 I/2 IC2 = \alpha 2 I/2 \beta 1 \beta 1 + 1$ and $\beta 2 \beta 2 + 1 \beta 1 + 2 \gamma VBE = 0.7 V VE = 4.3 V This figure belongs to Problem 6.115. Thus, the two collector currents will be unequal, IC1 = <math>\alpha 1 I/2 IC2 = \alpha 2 I/2 \beta 1 \beta 1 + 1$ and $\beta 2 \beta 2 + 1 \beta 1 + 1 \beta 2 + 1 \alpha 2 = VOS = VT \beta 1 \beta 2 - \beta 2 (\beta 1 + 1)(\beta 2 + 1) = VT \beta 1 - \beta 2 (\beta 1 + 1)(\beta 2 + 1) \beta 1 - \beta 2 \beta 1 \beta 2 - 1 1 = VT - \beta 1 \beta 2 + \beta 1 - \beta$ $\beta_2 \beta_1 VT Q.E.D.$ For $\beta_1 = 50$ and $\beta_2 = 100$, we have $11 - IRS 22 - re RS + 22(\beta + 1) II + RS I 22 re RS - = + 22(\beta + 1) II + RS I 22 re RS - = + 22(\beta + 1) 8.71$ For the MOS amplifier: RD VOV VOS = 2 RD 200 × 0.04 2 = 4 mV = For the BJT amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RD VOV VOS = 2 RD 200 × 0.04 2 = 4 mV = For the BJT amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RD VOV VOS = 2 RD 200 × 0.04 2 = 4 mV = For the BJT amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RD VOV VOS = 2 RD 200 × 0.04 2 = 4 mV = For the BJT amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RD VOV VOS = 2 RD 200 × 0.04 2 = 4 mV = For the BJT amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 For the MOS amplifier: RC VOS = VT RC I RS + 22(\beta + 1) 8.71 IRS and - from 2 (β + 1) 4(β + 1) each side, we obtain Subtracting = 25 × 0.04 = 1 mV If in the MOS amplifier the width of each device is increased by a factor of 2. Thus (e) To minimize the total capacitance we choose to make the pole caused by CE the dominant one and make its frequency equal to fL = 100 Hz, $Rin = (\beta + 1)re (\beta + 1)re (\beta + 1)re + Rsig = -\beta(RC RL) (\beta + 1)re + Rsig (\beta +$ remains unchanged at 1 V/V. 3.14 \therefore Fraction of cycle that current flows is R D vI 12 V n - 20 × 100 = 25% 2n Average diode current 17 - 12 = 0.625 A = 8 Peak reverse voltage = vI A 12 V 0 A + 12 = 29 V 2 3.15 conduction occurs V RED 3V ON 0 OFF - 3 V OFF GREEN OFF - D1 conducts OFF - No current flows ON - D2 conducts kT q v I = A sin θ = 12 ~ conduction through D occurs 3.16 VT = For a conduction angle ($\pi - 2\theta$) that is 25% of a cycle where k = 1.38 × 10-23 J/K = 8.62 × 10-5 eV/K 1 $\pi - 2\theta$ = 2 π 4 π θ = 4 A = 12/sin θ = 17 V T = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 8.62 × 10-5 + (273) C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus VT = 273 + x° C q = 1.60 × 10-19 C Thus × x° C), V : Peak-to-peak sine wave voltage x [° C] VT [mV] = 2A = 34 V - 55 0 + 40 + 125 Given the average diode current to be 1 2π 2π A sin ϕ - 12 ϕ R ϕ = 0.75 π = 0.1 ϕ = 0.25 π R = 8.3 A - 12 = 0.6 A Peak diode current = R Peak reverse voltage = A + 12 = 29 V For resistors specified to only one significant digit and peak-to-peak voltage to the nearest volt, choose A = 17 so the peak-to-peak sine wave voltage = 34 V and R = 8.8.25(d) we have RD | Acm | Q.E.D. Ex: 8.14 Ex: 8.11 The transconductance for each transistor is $gm = 2\mu n \cos(W/L)$ ID ID = Thus, gm = VCC 0.8 mA I = 0.4 mA $22 VB3 Q3 Q4 \sqrt{2 \times 0.2 \times 100 \times 0.4} = 4 mA/V vo1 vi1$ The differential gain for matched v O2 - v O1 = gm RD RD
values is Ad = v id = 86 dB Ex: 8.12 From Exercise 8.11, W/L = 100, µn Cox = 0.2 mA/V2, 0.8 mA I = = 0.4 mA 2 2 W ID gm = 2µn Cox L = 2 0.2 mA/V2 (100) (0.4 mA) ID = gm = 4 mA/V Using Eq. (8.88) and the fact that RSS = 25 k. we obtain $2(4 \text{ mA/V})(25 \text{ k})(2 \text{ gm RSS}) = CMRR = \text{ gm } 0.01 \text{ gm } = 20,000 \text{ CMRR}(dB) = 20 \log |ACM| 0.001 \text{ VB4 } Q5 \text{ VB5}$ mA/V Rid = 2(25 k) = 50 k Exercise 8-4 REE = 10 V VA = = 50 k I 200 μ A If the total load resistance is assumed to be mismatched by 1%, then we have | Acm | = RC RC 2REE RC $100 \times 0.01 = 0.01 \text{ V/V} 2 \times 50 \text{ Ad } 200 = 20 \log 10 \text{ CMRR}$ (dB) = $20 \log 10 \text{ Acm } 0.01 = 86 \text{ dB} = \text{Using Eq.}$ (8.96), we obtain RC β ro · RC + 2REE 1+ ro 1+ Ricm = β REE 100 $100 \times 100 = 100 \times 50 \times 100 + 2 \times 501 + 100$ Ricm 1.68 M $1 + 2.3 \times 2 \times 10 - 3 = 3.46$ mV Ex: 8.16 From Eq. (8.120), we get IS 2 RC 2 VOS = VT + RC IS = 2.55 mV $100 \sim 100 = \text{IB} = 0.5 \times 0.1 \text{ } \mu\text{A} = 50$ nA 1 I = 0.4 mA $2 \text{ } 1 \text{ W } \text{V2 } \text{ID} = \mu\text{n } \text{Cox } 2 \text{ L } \text{n } \text{OV}$ Ex: 8.17 ID $= 1.2 \times 0.2 \times 10^{-3}$ $100 \times VOV 2 \Rightarrow VOV = 0.2 V 0.4 = Ex: 8.15$ From Exercise 8.4: $VOV = 0.2 V 0.4 = 4 \text{ mA/V} = 2 \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 50 \text{ k} = \text{ ID } 0.4 \text{ ro} 4 = |VAp| 20 = 10 \text{$ $Ro = ro2 ro4 = 50 50 = 25 k Ad = Gm Ro = 4 \times 25 = 100 V/V$ use Eq. (8.106), $VOV (W/L) VOS = 2 W/L 0.2 \times 0.02 = 0.002 \Rightarrow VOS = 2 = 16 mA/V \Rightarrow 2 mV ro2 = ro4 = The offset voltage arising from Vt is obtained from Eq. (8.109): Ro = ro2 ro4 = 250 250 = 125 k VOS = Vt = 2 mV Finally, from Eq. (8.110) the total input offset is <math>VOS = 1/2$ VOV RD 2 VOV (W/L) 2 2 + + (Vt) 2 RD 2 W/L 2 2 = 2 × 10-3 + 2 × 1 0.5 mA Exercise 8-5 Ro4 $\beta 4 \text{ ro4} = 50 \times 200 = 10,000 \text{ k} = 10 \text{ M}$ Ro5 = 1 $\beta 5 \text{ ro5 } 2$ (a) Using Eq. (8.170), we obtain I6 = where ro5 = Ex: 8.22 Refer to Fig. (a) With v G1 = v G2 = 0, v GS1 = v GS2 = VOV 1,2 + Vtn Chapter 8-8 Thus 8.20 Refer to Fig. Since Rsig re, most of isig flows into the emitter of the BJT. P4.25(b). (1) and (2), we get I = 2ID That is, the differential pair must be biased at a current twice that of the CS amplifier. Since the base of Q2 will be at a voltage higher than -5 V, transistor Q2 will be operating in the active mode. VC RC 1 k IC Ex: 4.14 10 V 5 V IE 5 k VE IB The transistor is operating at a constant emitter current. P6.119. P7.49. (b): Chapter 3-5 Conduction stops at π - θ . The output voltage that results in response to v N 1, v N 2, Thus if we assume that Q3 is operating in saturation, we have ID3 = ID1 = 562.5 μ A Now, VGSN = VOVN + Vt = VOVN + 0.5 \sqrt{VSGP} = |VOVP | + |Vt | = 3 VOVN + 0.5 But This is the same current that flows through Q4, which is operating in saturation and is matched to Q3. (1) and (2) we see that VOVb = 2VOVa Now, gm = 2ID VOV Q.E.D. (1) (2) Chapter 7-24 Thus for the circuit in (a), gm1 = gm2 = 2I 2I I = = VOVb 2 VOVa VOVa 2 × 0.4 × ro1 = ro2 = Thus, 1 gma Q.E.D. 2 Since the channel length in (b) is four times that in (a), gmb = VAb = 4VAa $2\mu n \cos 5.4 \times 0.2 = 1.55 \text{ mA/V} \ 0.36 \text{ VA VL } 5 \times 0.36 = \text{A} = = 9 \text{ k ID ID } 0.2 \text{ Ro} = ro1 + ro2 + gm2 \text{ ro2 } ro1 = 9 + 9 + 1.55 \times 9 \times 9 = 143.6 \text{ k Av} = -gm1 (\text{Ro RL}) \text{ rob} = 4roa \Rightarrow \text{Ro RL} = 64.5 \text{ k Thus } 1.1.1 + = \text{Ro RL } 64.5 \text{ Ava} = -gma \text{ roa } \text{W ID } \text{L} 1.1.1 + = - \text{RL } 64.5.143.6 117 \text{ and } \text{Avb} = -gmb \text{ rob} \Rightarrow \text{RL} = 117 \text{ k } 1 = -gma$ × 4 roa 2 = 2Av a Q.E.D. Rin2 = (b) For the cascode circuit in (c) to have the same minimum voltage requirement at the drain as that for circuit (b), which is equal to VOV b = 2VOV a , we must operate each of the two transistors in the cascode amplifier at VOV = VOV a . The gain decreases as v id further increases, indicating nonlinear operation. B 1, we have $\beta + 1$ VOS = gm 1 RS + re ($\beta + 1$) 1 I RS · 2 gm RS + ($\beta + 1$) re gm Equating the voltage drop from each grounded input to the common emitters, we have I I RS + - re IB1 RS + 2 2 2 RS I I = IB2 RS - + + re 2 2 2 Since ($\beta + 1$) re = rn and rn gm = β , we have I · RS 2 β VOS = Q.E.D. g m RS 1 + β I Subtracting out the re terms, we have 2 IRS - re IB1 RS + 2 2 RS I = IB2 RS - + re 2 2 8.73 Since the only difference between the two sides of the differential pair is the mismatch in VA, we can write VCE1 IC1 = IC 1 + VA1 Chapter 8-26 VCE2 IC2 = IC 1 + VA2 (b) If the area of Q1 and hence IS1 is 5% larger than nominal, then we have IC1 + IC2 = α I VCE2 VCE1 IC 2 + + = α I VA1 VA2 VCE1 VCE2 = IC = α I 2+ + VA1 VA2 IC1 For IC1 IC2 α I = 2 IS1 = 1.05IS and the area of Q2 and hence IS2 is 5% smaller than nominal, IS2 = 0.5× 0.95 = 0.475 mA VCE1 VCE2 1 + 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1 + 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1 + 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+
2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 = 0.5× 1.05 = 0.475 mA VCE1 VCE2 1+ 2VA1 2VA2 1+ Thus, IE1 VA2 1 VCE2 α I 1 VCE1 1+ - 2 2 VA2 2 VA1 Assuming α 1, we obtain IC1 = 0.525 mA IC2 = 0.475 mA To reduce the resulting offset to zero, we adjust the potentiometer so that The voltage VO between the two collectors will be VC1 = VC2 - VC1 \Rightarrow VCC - (RC1 + x)IC1 = VCC - (RC2 + 1 - x)IC2 = IC1 RC - IC2 RC α I VCE1 VCE2 RC x = -2 VA1 VA2 IC1 (RC1 + x) = IC2 (RC2 + 1 - x) (1) I Since we still have IC1 IC2 = α , the 2 differential gain is still given by Ad = gm RC = IC RC α IRC = VT 2VT 0.525(5 + x) = 0.475(5 + 1 - x) \Rightarrow x = 0.225 (2) Dividing (1) by (2) gives VCE2 VCE1 VOS = VT - VA1 VA2 As a first-order approximation, we can assume 8.75 IBmax = IBmin = 400 $2.5 \mu A 2 \times 81400 = 1 \mu A 2 \times 201$ IOS max = 200 200 - 1.5 $\mu A 81201$ VCE1 VCE2 = 10 V and substitute VA1 = 100 V and VA2 = 200 V to determine VOS as 10 10 VOS = 25 - 100 200 = 25 \times 0.05 = 1.25 mV 8.76 A 2-mV input offset voltage corresponds to a difference RC between the two collector resistances, 2 = VT = 25 \times 8.74 Refer to Fig. Use constant voltage drop model: IS = $10-14 \times 1.15T$ VD = 0.7 V = $1.17 \times 10-8$ A Ex: 3.9 At 20° C I = constant voltage drop 5 - 0.7 = 0.43 mA ID = 10 k IV = 1 µA 1 M Ex: 3.11 Since the reverse leakage current doubles for every 10° C increase, at 40° C 10 V I R I = 4×1 µA = 4 µA \Rightarrow V = 4 µA $\times 1$ M = 4.0 V @ 0° C I = 1 µA 42.4 V $1 \Rightarrow$ V = $\times 1$ = 4×1 µA = 4 µA \Rightarrow V = 4 µA \Rightarrow V = 4 µA \Rightarrow V = 4 µA $\times 1$ M = 4.0 V @ 0° C I = 1 µA 42.4 V $1 \Rightarrow$ V = $\times 1$ = $10 \times 10^\circ$ C increase, at 40° C 10 V I R I = 4×1 µA = 4 µA \Rightarrow V = 4 µA $\times 1$ M = 4.0 V @ 0° C I = 1 µA 42.4 V $1 \Rightarrow$ V = $\times 1$ 0.25 V 4 Ex: $3.10 \text{ a. I Re} = 4\text{VT 2 8VT} \Rightarrow \text{Re} = I$ I RC = $60\text{VT} \alpha 2 120\text{VT} \alpha I$ Total resistance in collector circuit Ad = α Total resistance in emitter circuit 2RC RC = α Ad = α 2re + 2Re re + Re RC = (1) (2) Chapter 8-17 This figure belongs to Problem 8.45. (a) If W is halved, k n will be halved and rDS will vary in the range of 5 k to 250. P7.6. For Q2 to operate properly (i.e., in the saturation mode) for drain voltages as high as +0.8 V, and provided its width is the minimum possible, we use |VOV| = 0.2 V Note that all three transistors Q1, Q2, and Q3 will be operated at this value of overdrive voltage. $3.34 \Rightarrow iD2 = 1.01iD1$ V - 0.6 = 1.01 (V - 0.7) V = 10.7 V R 1 k 1V ID 15 V - 3.3 V = 582 20.1 mA VD For V = 3 V and R = 1 k: 3 - 0.7 = 2.3 mA At VD = 0.7 V, iD1 = 1 3 - 0.6 = 2.4 mA At VD = 0.6 V, iD2 = 1.24 iD2 = 1.04 = iD1 2.3 Thus the percentage difference is 4%. $2 \times 25 = -20 \mu$ V 502 (c) For v O to swing negatively (i.e., below the dc bias value of 2.5 V) by 1.5 V, that is, to +1 V with Q4 remaining in saturation, VBIAS should be VBIAS = v Omin + 0.4 = 1.4 V 8.91 Refer to Fig. P7.74(b). 5.5 The transistor size will be minimized. W 20 = 20 k n = 100 μ A/V2 L 1 W k n = k n = 100 \times 20 = 2000 μ A/V2 L 1 W k n = k n = 100 \times 20 = 2000 μ A/V2 L 5.21 = 2 mA/V2 Chapter 5-6 5.23 For operation as a linear resistance, iD = k n (v GS - Vt) v DS iD and rDS = vDS v DS 1 = iD k n (v GS - Vt) 1 2(v -0.8) At v GS = 1.0 V, rDS = v DS = v GS 1 = 2.5 k 2(1 - 0.8) 1 k n (v DS - Vt) 2 2 iD \therefore v DS = + Vt kn iD = At v GS = 4.8 V, rDS = 1 = 0.125 k 2(4.8 - 0.8) Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC = 2.5 - 0.99 × 0.4 × 5 = +0.52 V VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC = 2.5 - 0.99 × 0.4 × 5 = +0.52 V VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will vary in the range of 2.5 k to 125. VC1 = VCC - IC1 RC 8.25 Refer to Fig. P4.61(a). Thus, rDS will from symmetry, we see that the 200- μ A current will split equally between Q1 and Q2 : I6 = 405 μ A ID1 = ID2 = 100 μ A Chapter 5-18 V1 = V2 = 2.5 - 0.1 × 20 = 0.5 V 2 ϕ f = 0.6 V To find V3, we determine VGS of either Q1 and Q2 (which, of course, are equal), and ID1 = 1 W μ n Cox 2 L (VGS - Vt) 2 1 VSB = 0 to 4 V At VSB = 0, Vt = Vt0 = 1.0 V 1 = 1.0 $100 = \times 125 \times 20 \times (VGS - 0.7)2$ 2 At $\Rightarrow VGS = 0.983$ V VSB = 4 V, $\sqrt{\sqrt{Vt}} = 1 + 0.5[$ 0.6 + 4 - 0.6] Thus, = 1.69 V V3 = -0.983 V (b) With VGS1 = VGS2, but (W/L)1 = 1.5(W/L)2, transistor Q1 will carry a current 1.5 times that in Q2, that is, ID1 = 1.5ID2 If the gate oxide thickness is increased by a factor of 4, Cox will decrease by a factor of 4. and Eq. (5.31) indicates that y will increase by a factor of 4, becoming 2. 2 below, Ro \leq 111 Av o \geq 11.1 V/V Rin vi = v sig Rin + Rsig v o = Gm v i (Ro RL) 6.56 The circuit in Fig. For v od = 1 V, we have = (VCC - iC1 RC) = (iC1 - iC2)RC (iE1 - iE2)RC = 0.198RC 1 = 5.05 k 0.198 I VC1 = VC2 = VCC - RC 2 = 5 - 0.5 × 5.05 2.5 V RC = With a signal of 10 mV applied, the voltage at one collector rises to 3 V and at the other falls to 2 V. Thus R = IO1 IO2 IO3 VOmax = VE3 - VECsat IREF 0.7 mA Q3 Q5 Q4 1 2 = 1.8 - 0.3 = 1.5 V 4 7.81 Replacing each of the transistors in the Wilson mirror of Fig. P8.48 can be considered as the cascade connection of an emitter follower Q (biased at an emitter current I/2) and a common-gate amplifier Q2 (also biased at an emitter current of I/2). If The gain of the first stage is 1 + R1 the op amps of the first stage is 1 + R1 the op amps of the first stage of circuit in Fig.2.20(a) is that v Icm is amplified by a R2 gain equal to 1 + in the first stage and R1 therefore a very small v Icm range is acceptable to avoid saturation. Nevertheless, we know that this circuit provides a reasonably high common-mode rejection. I = $10 \,\mu\text{A} \ 2 \ \text{IC1} = \text{IC2} = \alpha \times 10 = 0.98 \times 10 = 9.8 \,\mu\text{A}$ $9.8 \times 10 - 3 \,\text{VBE1} = \text{VBE2} = 0.690 + 0.025 \,\ln 1 \ \text{IE1} = \text{IE2} = 100 \,\mu\text{A}$ 0.574 V Thus, VE = -0.574 V VC1 = VC2 = VCC - IC RC = $1.2 - 9.8 \times 10 - 3 \times 82$ 0.4 V (b) Refer to Fig. This case is the complement of that in (c) above, thus v GS1 = 0.104 - (-0.541) = 0.645 V v GS1 = Vtn = 0.4 V v D1 = VDD - iD1 RD v GS2 = 0.683 V = $1 - 0.12 \times 5 = 0.4$ V v S = -0.683 V v D2 = VDD - iD2 RD = $1 - 0.04 \times 5 = 0.8$ V v id = -0.683 + 0.4 = -0.283 V/ which is -2 VOV, as derived in the text. P2.87. Exercise 2-3 Using the superposition principle to find the contribution of v 1 to v O, we set v 2 = v 3 = 0. Let us choose Ra = Rb = Rc = 10 k. 8.5. gm = 1 = 0.25 = 2(I/2) I = VOV VOV \Rightarrow 1.1 \times 0.25 = x 0.4 \times 2.2 8.12 Since the quiescent power dissipation is P = (VDD + VSS) × I W L 0.252 W = 10 L 8.10 0.1 = 1 2 × 0.2 × 32VOV 2 = VOV = 0.18 V gm = 2 × (0.2/2) = 1.11 mA/V 0.18 VA 10 = 100 k = ro = ID 0.1 Ad = gm (RD ro) = 1.11 × (10 100) = 10.1 V/V 8.11 For vid = 0.1 V W = 40 L I 0.25 = I = 0.25 mA 1 I W 2 = µn Cox VOV 2 2 L = W 1 × 0.2 × 0.252 2 L vid /2 VOV 2 = 0.04 vid /2 = 0.2 VOV 0.1/2 VOV 0.1/2 = 0.2 VOV 0.1/2 VOV 0.1/2 VOV 0.1/2 VOV 0.1/2 VOV VOV then the maximum allowable I is 1 mW = 0.5 mA I = 2V We shall utilize this value. vo = $-
\Rightarrow R2 = 10 \text{ k} \text{ Ex: } 2.9 \text{ Using the superposition principle to find the contribution of v 1 to the output voltage v 0}$, we set v 2 = 0 Ex: 2.11 9 k R2 i 1 k R1 v0 v0 v1 2 k vi v2 3 k v + (the voltage at the positive input of the op amp 3 v 1 = 0.6v 1 is: v + = 2+3 9 k Thus v $O = 1 + v + = 10 \times 0.6v$ 1 = 6v 1 1 k To find the contribution of v 2 to the output voltage v O we set v 1 = 0. Chapter 7-5 This figure belongs to Problem 7.13. ω RC RC 1 For ω int = 10 krad/s, RC = 4 = 10-4 s. At the output node, (b) gm . = vsg isig 50 A RS v o = i[RD (R1 + R2)] v o = iRD Rsig 100 k (1) vo The figure shows the circuit prepared for signal calculations. In the negative direction, v Omin = -VEE + VBE7 + VBE5 - 0.4 = -5 + 0.7 + 0.7 - 0.4 = -4 V Thus, $-4 V \le v O \le +4.4 V$ Gm = gm1,2 0.25 mA = 10 mA/V 0.025 V Ro4 = $\beta4$ ro4 = $50 \times |VA| I/2$ Chapter 8-33 100 V = 20 M 0.25 mA 1 100 1 Ro5 = $\beta5$ ro5 = $\times 100 \times 220.25 = 20 \text{ M} = 50 \times \text{Ro} = \text{Ro} 4$ Ro5 = 20 M 20 M = 10 M Ad = Gm Ro = 10 × 10,000 = 105 V/V 8.94 The overdrive voltage, |VOV | 2 2 2 1 0.1 = × 6.4 × |VOV | 2 2 = |VOV | = 0.18 V Gm = gm1,2 2(I/2) = |VOV | 0.2 = 1.13 mA/V = 0.18 |VAp | 10 = = 100 \text{ k} \text{ ro} 2 = I/2 0.1 ro4 = |VAnpn| 30 = 300 k I/2 0.1 Ro = ro2 ro4 = 100 k 300 k = 75 k But Ro = ro2 ro4 and ro2 = ro4 (Q2 and Q4 have the same ID = and the same ID = and the same ID = 100 \text{ k} 300 k = 75 k But Ro = ro2 ro4 and ro2 = ro4 (Q2 and Q4 have the same ID = and the same ID = and the same ID = and the same ID = 100 \text{ k} 300 k = 75 k But Ro = ro2 ro4 and ro2 = ro4 (Q2 and Q4 have the same ID = and the At f = 3 kHz, |A| = 3 MHz = 103 V/V 3 kHz or 60 dB At f = 12 kHz, which is two octaves higher than 3 kHz, the gain will be $2 \times 6 = 12$ dB below its value at 3 kHz; that is, 60 - 12 = 48 dB. P7.18. k n in the NMOS case and k p (b) If either of the MOSFETs in Fig. 1(a), the overall voltage Gv can be obtained as $Gv = Gv \circ RL + Rout Rf + (R2 RL) vi$ = if 1 + qm (R2 RL) Q.E.D. Q.E.D. This figure belongs to Problem 6.57. 2ID VOV = 0.5 V, qm = 2 mA/V VOV Chapter 6-11 ro = 15 V VA = 100 k ID 0.5 mA vo = -qm (RG RL ro) = -18.2 V/V vi For ID = 1 mA: $\sqrt{1}$ VOV increases by = 2 to 0.5 $\sqrt{2} \times 0.5 = 0.707$ V. For time constant RC T 2 Exercise 3-8 e-t/RC 1 - T1 × 2 RC Ex: 3.24 1 T \therefore VP - $2VD - Vr = Vp - 2VD 1 - \times 2 \text{ RC} \Rightarrow Vr = Vp - 2VD$ ivI i T × 2RC iD vO $\sqrt{4}$ Here Vp = 12 2 and Vr = 1 V iR VD = 0.8 V T = 1 k 1 1 = s f 60 $\sqrt{1} = (12 2 - 2 \times 0.8) \times 12 \times 60 \times 100 \times C \sqrt{(12 2 - 1.6)C} = 1281 \mu\text{F} 2 \times 60 \times 100 \text{ Without considering the ripple voltage}$, the dc output voltage $\sqrt{12 2 - 2 \times 0.8} = 15.4 \text{ V}$ if ripple voltage is included, the output voltage is $\sqrt{Vr} = 14.9 V = 122 - 2 \times 0.8 - 2$ IL = vA vD 14.9 0.15 A 100 The conduction angle ωt can be obtained using \sqrt{Eq} . (3.30) but substituting Vp = 122 - 2 × 0.8 The average and peak diode currents can be calculated using \sqrt{Eq} . (3.30) but substituting Vp = 122 - 2 × 0.8 The average and peak diode currents can be calculated using \sqrt{Eq} . (3.30) but substituting Vp = 122 - 2 × 0.8 The average and peak diode currents can be calculated using \sqrt{Eq} . $2 \text{gm R vi} | VA | 20 = 160 \text{ k} = \text{ID } 0.125 \text{ Av} = -2 \times 0.5(1000 \ 80) = -74.1 \text{ V/V Rin} = \text{gmvgs} \text{ Av} = \text{where gmvgs} = (d) \text{ vi vi} 1 = = \text{R vo ii} (vi - vo)/\text{R } 1 - vi \text{ R } 1000 = 13.3 \text{ k} = 1 - \text{Av} 1 + 74.1 \text{ vi Rin} 13.3 = 0.4 \text{ V/V} = = \text{vsig Rin} + \text{Rsig } 20 + 13.3 \text{ Gv} = vo \text{ vi vo} = \times \text{vsig vsig vi} = 0.4 \times -74.1 = -29.6 \text{ V/V} (e)$ Both Q1 and Q2 remain in saturation for output voltages that ensure that the minimum voltage across each transistor is equal to |VOV| = 0.5 V. Ro = (gm 3 ro3)ro4 For identical transistors, Ro = (gm 7 o)ro = 2|VA| |VA| × |VOV| I Thus, IRo = 2|VA| 2 |VOV| Chapter 7-22 This table belongs to Problem 7.60. 2 T/2 Vr = Vp 1 - e - RC T/2, for CR T/2 RC T/2 Thus Vr Vp 1 - 1 + RC T/2 e - RC 1 - Vr = Vp 2fRC (a) Q.E.D. QSUPPLIED = QLOST iCav t = CV r Vp iD, av - IL t = C = 2fRC 2fR Vp $\pi \omega R$ iD, av = Vp $\pi + IL \omega tR$ where ωt is the conduction angle. Thus f (unity gain) = 1 C2 R2 Assuming $\omega^2 \omega_1$, then 1 3-dB frequency ($\omega 3dB$) = CR1 1 = 2 × 103 2 π CR1 $\omega^2 = 2000$ f3dB = = 20 Hz 100 100 R2 /R1 Vo - Vi 1 + j(ω/ω^2) The resulting Bode plot will be as shown: Design: Gain of 40 dB \Rightarrow f1 = 200 Hz \Rightarrow R2 = 100 R1 1 = 200 2 π C1 R1 2.87 Refer to the circuit in Fig. 6.30 (a) Open-circuit the capacitors to obtain the bias circuit shown in Fig. Exercise 2-7 VO = 2VA 21 VA = VOV 1 VOV 2VA 0.2 \Rightarrow VA = 10 V 100 = VA = VA × L 10 = 5 × L \Rightarrow L = 2 µm 8.55 Refer to Fig. Exercise 2-7 VO = 2VA 21 VA = VOV 1 VOV 2VA 0.2 \Rightarrow VA = 10 V 100 = VA = VA × L 10 = 5 × L \Rightarrow L = 2 µm 8.55 Refer to Fig. Exercise 2-7 VO = 2VA 21 VA = VOV 1 VOV 2VA 0.2 \Rightarrow VA = 10 V 100 = VA = VA × L 10 = 5 × L \Rightarrow L = 2 µm 8.55 Refer to Fig. Exercise 2-7 VO = 2VA 21 VA = 2VA 21 IOS R2 = 10 nA × 10 k = 0.01 V Ex: 2.25 Using Eq. (2.41) we have: 2 mV VOS t \Rightarrow 12 = 2 mV + t CR 1 ms 12 V - 2 mV × 1 ms 6 s \Rightarrow t = 2 mV v O = VOS + RF C R Vi (b) If at room temperature (25° C), VOS is trimmed to zero and (i) the circuit is operated at a constant temperature (25° C). $= vO R2 R2 = 1 + = 2 \Rightarrow = 1 \Rightarrow R1 = R2 vi R1 R1 If v O = 10 V$, then it is desired that $i = 10 \mu A. 6.26(b)$. Since Q1 and Q2 are matched and conducting equal currents I, their VGS values will be equal. vi1 = 0.909 v/V vs vi1 = 0.909 v/V vload) output voltage = Av o v i v i 2 = 9 × v S = 9 × 1 = 9 mV Output voltage with load connected = Av o v i 0.8 = RL RL + Ro 1 \Rightarrow Ro = 0.25 k = 250 Ro + 1 Ex: 1.14 Av o = 40 dB = 100 V/V 2 v2 RL PL = o = Av o v i RL RL + Ro 2 1 = v 2i × 100 × 1000 = 2.5 v 2i 1+1 Pi = v 2i × 100 × 1000 Ap = PL 2.5 v 2i - 4 i 2 = 2.5 × 104 W/W Pi 10 v i 1000 Ap = 100 V/V 2 v2 RL PL = o = Av o v i RL RL + Ro 2 1 = v 2i × 100 × 1000 Ap = PL 2.5 v 2i + 1 Pi = v 2i × 100 Ap = P $10 \log Ap = 44 dB v i3 v i3 v i2 v i1 = x \times s = 90.9 \times 9.9 \times 0.909 v s v i2 v i1 = x \times s = 818 v V v i3 = 818 v s =$ stage 3 (see figure above) vL = v s 1 M 100 k (10) 100 k + 1 k 100 x (100) 100 + 1 k vL =
(0.909)(10)(0.9901)(100)(0.9901)(0.9901)(100)(0.9901)transresistance circuit model, the circuit will be Overall voltage gain = 10 1M × 900 × = 409 V/V 1 M + 100 K 10 + 10 ii Ro For RL = 1000 : Overall voltage gain = is Rs Ri 1000 1M × 900 × = 810 V/V 1 M + 100 K 1000 + 10 Rmii RL \therefore Range of voltage gain = is Rs Ri 1000 1M × 900 × = 810 V/V to 81 Vv 5.99V 1.85V 2.91V 6.23 (a) $ID = 1 kn (VGS - Vt2) 21 \times 5(0.6 - 0.4)2 = 0.1 mA 2 VDS = VDD - ID RD = 1.8 - 0.1 \times 10 = 0.8 V = (b) gm = kn VOV = 5 \times 0.2 = 1 mA/V$ (c) $Av = -gm RD = -1 \times 10 = -10 V/V 1$ (d) $\lambda = 0.1 V-1$, $VA = = 10 V \lambda$ Chapter 6-9 VA 10 = 100 k = ID 0.1 Av = -gm (RD ro) To just maintain saturation-mode operation, v GS max = v DS min + Vt = $-1(10\ 100) = -9.1\ V/V$ which results in ro = VOV + v^{i} i = VDS - | Av | v^{c} i 6.24 Av = $-10 = -gm\ RD = -gm\ RD = -gm\ RD = -gm\ RD = -gm\ RD$ = $-gm\ RD = -gm\ RD = -gm\ RD$ to VOV. (k) f = 1 kHz vO D1 is cut off when v I < 0 5V (g) 1V vO t t 5 V 5 V 4 V Vp + = 1 V, Vp - = -4 V, f = 1 kH3 Vp + = 0 V, Vp - = -5 V, f = 1 kH3 Vp + = 0 V, F = $\ln IS 10 - 12 = 10 - 12 e_{0.6}/0.025 0.03 \text{ mAv} = 0.65 \text{ V}, i 0.2 \text{ mAv} = 0.7 \text{ V}, i 1.45 \text{ mA} = 0.6637 \text{ V}$ Make a sketch showing these points and load line and determine the operating point. 8.3, If RD is doubled to 5 k, RD 5 k I VD1 = VD2 = VDD - RD 2 0.4 mA = 1.5 - (5 k) = 0.5 \text{ V} 2 \text{ VCMmax} = Vt + VD = 0.5 + 0.5 = +1.0 \text{ V} RD 5 k ID ID I 0.8 mA Since the currents ID1, and ID2 are still 0.2 mA each, VSS VGS = 0.82 V So, VCMmin = VSS + VCS + VGS = -1.5 V + 0.4 V + 0.82 V = -0.28 V to +1.0 V = 2ID = W kn L 2 (0.4 mA) 0.2 mA/V2 (100) = 0.2 V Ex: 8.2 (a) The value of v id/that causes Q1 to conduct the entire current is 2 VOV $\sqrt{2} \times 0.316$ $= 0.45 \text{ V gm} = 0.4 \text{ mA} \times 2 \text{ ID} = 4 \text{ mA/V} \text{ VOV} / 2 0.2 \text{ V ro} = VA 20 \text{ V} = 50 \text{ k ID } 0.4 \text{ mA then}, \text{ VD1} = \text{VDD} - \text{I} \times \text{RD Ad} = \text{gm} (\text{RD ro}) = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = \text{VDD} = +1.5 \text{ V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = \text{VDD} = +1.5 \text{ V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = (4 \text{ mA/V}) (5 \text{ k} 50 \text{ k}) = 18.2 \text{ V/V VD2} = 1.5 - 0.4 \times 2.5 = 0.5 \text{ V Ad} = 10.2 \text{ V/V} = 10.2 \text{ V/$ Thus the differential output range is VD2 - VD1: from 1.5 - 0.5 = +1 V to 0.5 - 1.5 = -1 V Ex: 8.3 Refer to answer table for Exercise 8.3 where values were obtained in the following way: I W = VOV = I /k n W/L \Rightarrow 2 L k n VOV 2(I /2) I = VOV VOV \sqrt{v} id /2 2 = 0.1 \rightarrow v id = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV \sqrt{v} id /2 2 = 0.1 \rightarrow v id = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV \sqrt{v} id /2 2 = 0.1 \rightarrow v id = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV \sqrt{v} id /2 2 = 0.1 \rightarrow v id = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV
gm = Ex: 8.5 With I = 200 µA, for all transistors, 200 µA I = 2 VOV 0.1 VOV gm = Ex: 8.5 = 100 uA 22 L = 2(0.18 um) = 0.36 um VL ro1 = ro2 = ro3 = ro4 = A ID ID = (10 V/ um)(0.36 um) = 36 k 0.1 mA 1 W 2, VOV Since ID1 = ID2 = un Cox 2 L W 2ID W = 2 L 1 L 2 un Cox VOV = 2(100 \text{ uA}) = 50 100 \text{ uA}/\text{V2} (0.2)2 \text{ cm} = 10.8 \text{ mA} = 0.4 \text{ mA} 2 2 1 \text{ W ID} = k n (VOV) 2 2 L Ex: 8.4 ID = ID (100 μ A) (2) = = 1 mA/V, VOV /2 0.2 V so Ad = gm1 (ro1 ro3) = 1(mA/V) (36 k 36 k) = 18 V/V Exercise 8-2 Ex: 8.6 L = 2 (0.18 μ m) = 0.36 μ m V · L All ro = A ID VCC Ex: 8.8 2.5 V RC The drain current for all transistors is 200 μ A I = 100 μ A ID = = 2 2 (10 V/ μ m) (0.36 μ m) = 36 k ro = 0.1 mA Referring to Fig. T = $-20 \circ$ C corresponds to a temperature decrease of 40 \circ C, which results in an increase of the diode voltage by 80 mV. Chapter 1-29 Doping Concentration µµ Dn Dp (carriers/cm3) cm2 /V \cdot s cm2 /s cm2 / $1 + V0 \leftarrow Eq. (1.50)$ NA ND $2 \times 1.04 \times 10 - 12$ $1 + \times 0.754$ $1.6 \times 10 - 19$ 1017 1016 1.84 Using Eq. (1.46) and NA = ND = 0.328 \times 10 - 4 cm = $0.328 \times 10 - 4$ cm = Thus the worst-case situation occurs when VSupply is reduced, and ID = $10 \times e(0.645 - 0.7)/0.025 = 1.11 \text{ mA I} = \text{IL} + \text{ID} = 8.6 + 1.11 = 9.71 \text{ mA V} = 3.232 \text{ V}$ which is a reduction of 1.768 V or -35.4%. Input needed is 32 mVrms. We continue in the same fashion to find I3 = 4I and the current from 3 to 4 as 8I. 4.19(a): v CE iC = IS ev BE /VT + ro (1) Now using Eqs. 8.32 (a) VBE = 0.69 + 0.025 ln = 0.632 V 0.11 Chapter 8-13 (b) Using Eq. (8.48), we obtain I iC1 = aiE1 1 + e-v id /VT \Rightarrow I = 2VT gm For v id = 20 mV, 8.35 v id = 10 mA/V iC1 200 μ A = = 138 μ A 1 + e-20/25 iC2 = 200 - 138 = 62 μ A (c) For v id = 200 mV while iC1 = 138 μ A and iC2 = 62 μ A: Since iC1 and iC2 have not changed, v BE1 and v BE2 also would not change. However, above about 1 mA this trend reverses because of the effect of ro . L 10 × 10-3 = 265.3 MHz 2 π (5 + 1) × 10-12 Lmin 3Lmin 4Lmin 5Lmin 0.13 μ m 0.26 μ m 0.39 μ m 0.52 μ m 0.65 μ m gm = IC 1 mA = 40 mA/V = VT 0.025 V rn = β 100 = = 2.5 k gm 40 $ro = VA 50 = 50 k = IC 1 A0 (V/V) 6.5 13 19.5 26 32.5 Cde = \tau F gm = 30 \times 10 - 12 \times 40 \times 10 - 3 = 1.2 pF fT (GHz) 113 28.3 12.6 7.1 4.5 Cje0 = 20 pF This figure belongs to Problem 9.18. (a) Ro1 = ro Ro2 = ro Figure 1 Chapter 7-26 Ro5 = ro Ro = (gm 3 ro3)(ro4 rm3) Ro4 = (gm ro) ro I = 0.2 mA I 0.2 gm 3 = 8 mA/V = VT 0.025 VA 5 ro3 = ro4 = = 0.2 mA I 0.2 gm 3 = 0.2 mA I 0$ $= 25 \text{ k} I 0.2 \beta 50 = r\pi 3 = 6.25 \text{ k} \text{ gm} 3 8 \text{ Ro} 3 = ro 3 + (\text{gm} \text{ ro}) \text{ ro} 2 1 = ro + \text{gm} \text{ ro} \text{ ro} 2 1 1 \text{ ro} (1 + \text{gm} \text{ ro}) (\text{gm} \text{ ro}) \text{ ro} 2 2 \text{ ro} 3 + \text{Ro} 4 \text{ ro} + \text{gm} \text{ ro} \text{ ro} 3 \text{ (m} \text{ ro}) \text{ ro} 3 (c) \text{ When vo is short-circuited to ground, Rin2 becomes}$ equal to 1/gm3. Thus, $v A = 0 V \Rightarrow D = 0000 v A = 1 V \Rightarrow D = 0001 v A = 2 V \Rightarrow D = 0010 v A = 15 V \Rightarrow D = 1111$ (b) (i) +1 V (ii) +2 V (iii) +4 V (iv) +8 V (c) The closest discrete value represented by D is 5 V; thus D = 0101. $\Rightarrow Av o = 484 V/V 1.48$ Deliver 0.5 W to a 100-load. To obtain gm and ro, we use 2ID $2 \times 0.5 = 2 \text{ mA/V gm} = VOV 0.5 VA 100$ = 200 k = ID 0.5 ro = Ex: 6.38 Refer to Fig. For the latter to happen, we need a minimum of 0.3 V across each current source. Maximum output signal swing is achieved by biasing Q1 at the middle of this range; thus VI = 0.913 V The peak-to-peak amplitude at the output will be (VOA - VOB) = 2.47 - 0.335 = 2.135 \text{ V}. proportional to IC. RS RG2 6.85 5 V ID = 1 mA 1 2 kn VOV 2 1 2 1 = $\times 2 \times VOV 2 \Rightarrow VOV = 1 V RD$ ID = VG 0 VGS = Vt + VOV = 1 + 1 = 2 V ID RD VD Since VG = 0 V, VS = -VGS = -2 V RG which leads to VS - (-5) - 2 + 5 RS = = 6 k = IC 0.5 VD is required to be halfway between cutoff (+5 V) and saturation (0 - Vt = -1 V). ID = 2.2 (h) Refer to Fig. They also apply to p-channel devices with v DS replaced by v SD , k n by k p , and v OV with |v OV|. This is achieved by keeping v CE1, $2 \ge 0.3 V$. (8.48) and (8.49) and assuming α 1, so that iC1 iE1 and iC2 iE2, we get 11 - v od = IRC 1 + e-v id /VT 1 + ev id /VT choice is IC = 0.325 mA. 1 = π · Conduction angle = $\pi - 2\theta = 3.04$ rad = 8.3 V The diode conducts for iL, avg = 3.04 × 100 = 48.4% of the cycle $2\pi v O$, avg 1 = $2\pi \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3$ mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg $\pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3$ mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg $\pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3$ mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg $\pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3$ mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg $\pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3$ mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg $\pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3$ mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg $\pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3$ mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 mA 1 k 3.68 12 : 1 D4 = 4.15 V iD, avg \pi - \theta \sqrt{(10 2 \sin \phi - 0.7)} d\phi \theta \theta 8.3 = 8.3 Peak voltage across R = $102 - 2VD \sqrt{=} 102 - 1.4 = 12.74$ V vS 102V 1.4 V t $\theta = sin - 11.4 \sqrt{=} 5.68^{\circ} = 0.1$ rad 102 Fraction of cycle that D1 & D2 conduct is $\pi - 2\theta \times 100 = 46.8\% 2\pi \sqrt{v^{\circ}0} = 102 - VD = 13.44$ V Conduction starts at $\theta = sin - 10.7 \sqrt{=} 1022.84^{\circ} = 0.05$ rad and ends at $\pi - \theta$. For a high-frequency gain of 40 dB, R2 /R1 Vo - Vi 1 + $(\omega 1 / j\omega) R2 = 100 \Rightarrow R2 = 100 k R1$ (b) For $\omega 1 \omega \omega 2$ For f3dB = 2 kHz, Vo -(R2 / R1) Vi Q.E.D. (c) For $\omega \omega 2 \Rightarrow C = 79$ nF The magnitude of the transfer function reduces from 40 dB to unity (0 dB) in two decades. The result is vi (t) t (ms) v O (t) = v Ofinal - v Ofinal - v Ofinal)e^{-t/\tau} where vo (t), mV v Ofinal = $-IRF = -0.1 \times 10 - 3 \times 106 = -100$ $V v Oinitial = 0 \tau = CRF = 159 \times 10 - 12 \times 106 = 159 \mu s Thus, v O(t) = -100(1 - e - t/159), V t (ms) 10 20 30 Chapter 2-26 2.80 1 = 0.16 nF 2\pi \times 1 \times 103 \times 106 C = C From the Bode plot shown in previous column, the unity-gain frequency is 100 kHz. R2 R1 Vi Vo Let Z2 = R2 1 and Z1 = R1 sC Vo Z2 Y1 1/R1 = - = - = - 1 Vi Z1 Y2 + sC R2 Vo = - 1 Vi Z1 Y2 +$ Vi This function is of the STC low-pass type, having R2 a dc gain of - and a 3-dB frequency R1 1 CR2 Z2 /Z1 1 + Z2
/Z1 1 + A For Z1 = R, Z2 = 1/sC, and A = A0, Vo = - Vi = - (R2 /R1) = - 1 + sCR2 $\omega 0 = 2.81$ Equation (2.5) can be generalized as follows: = - 1/sCR 1 1 1 + A0 sA0 CR 1 1 1 1 CR(1 +) s + A0 (A0 + 1)CR A0 /[(A0 + 1)CR] 1 s + (A0 + 1)CR] 1 s + (A0 + 1)CR A0 / [(A0 + 1)CR A0 / [(A0 + 1)CR] 1 s + (A0 + 1)CR] 1 s + (A0 + 1)CR A0 / [(A0 + 1)CR A0 / [(A0 + 1)CR] 1 s + (A0 + 1)CR] 1 s + (A0 + 1)CR A0 / [(A0 + 1)CR A0 / [(A0 + 1)CR] 1 s + (A0 + 1)CR] 1 s + (A0 + 1)CR A0 / [(A0 + 1)CR A0 / [(A0 + 1)CR] 1 s + (A0 + 1)CR] 1 s + (A0 + 1)CR A0 / [(A0 + 1)CR A0 / [(A0 + 1)CR] 1 s + (A0 + 1)CR] 1 s + (A0 + 1)CR A0 / [(A0 + 1)CR A0 / [(A0 + 1)CR] 1 s + (A0 + 1)CR] 1 s + (A0 + 1)CR A0 / [(A0 + 1)CR A0 / [(A0 + 1)CR] 1 s + (A0 + 1)CR] 1 s + (A0 + 1)CR A0 / [(A0 + 1)CR A0 / [(A0 + 1)CR A0 / [(A0 + 1)CR] 1 s + (A0 + 1)CR] 1 s + (A0 + 1)CR A0 / [(A0 + 1)CR A0 / [(A0 + 1)CR A0 / [(A0 + 1)CR] 1 s + (A0 + 1)CR] 1 s + (A0 + 1)CR A0 / [(A0 + 1)CR] 1 s + (A0 + 1)CR] 1 s + (A0 + 1)CR A0 / [(A0 + 1)CR A0 / [RPn RP0 RPn Chapter 2-13 Rf 2.45 Rf RN vI3 vOP vP1 Rp1 RN RP1 vI1 Rp2 vO RP2 vP2 vI2 RP4 vPn Rpn vI4 RP0 RP0 RF + v P2 + \cdots + v Pn RP2 RPn Adapting the expression given in Problem 2.44 to the circuit above yields Rf Rf RP vO = -vI3 + 1 + vI1 RN RN RP1 RP RP + vI2 + vI4 RP2 RP4 where RP = RP0 RP1 ··· RPn when all inputs are present: where RP = RP0 RP1 RP2 RP3. The current ID in each of the eight transistors can be found by inspection. Thus all transistors can be found by inspection. Thus all transistors can be found by inspection. Thus all transistors are present: where RP = RP0 RP1 RP2 RP3. The current ID in each of the eight transistors can be found by inspection. = 0 V, and v A = -13 V. We conclude that increasing the gain of the first stage increases CMRR. IE = \Rightarrow VOV = 1 V VBB - VBE R1 R2 RE + β + 1 \Rightarrow VGS = VOV + Vt = 1 + 1 = 2 V For the nominal case, β = 100 and \Rightarrow VS = -2 V 4 - 0.7 = 1.01 1 mA 4080 3 + 101 For β = 50, RS = VS - VSS - 2 - (-5) = 6 k = ID 0.5 \Rightarrow RS = 6.2 k If we choose RD = RS = 6.2 k, then ID will change slightly: $1 \times 1 \times (VGS - 1)2$. The slope of each graph at v DS = 0 is found by differentiating Eq. (1) relative to v DS with v OV = VOV and then substituting v DS = 0. Since the drain voltage (+7 V) is higher than the gate voltage (+7 V) is higher than th and thus IC IE = 0.5 mA. Rout = ro + (Re rn)(1 + gm ro) ro + (Re rn)(gm ro) Rout = 1 + gm (Re rn) ro = 1 Aqn2i In = Aqn2i Dp V/VT - 1 e Lp ND Cj0 31.6 fF = Cj = VR 3 1 + 1 + V0 0.754 = 14.16 fF Cj0 VR m 1 + V0 1.95 Equation (1.73), Cj = 0.4 pF For VR = 1 V, Cj = 1 + Dn V/VT e - 1 Lp ND 0.4 pF For VR = 10 V, Cj = 1 + 10 0.75 1/3 = 0.16 pF For this case using Eq. (1.65): IS Aqn2i 1/3 = 0.3 pF + Aqn2i 1 0.75 Dp = $104 \times 10-8 \times 1.6 \times 10-19$ Lp ND 2 × 1.5 × 1010 10 10 × 10-4 × 1017 1.96 Equation (1.67): $\alpha = A 2 \text{ s } q = 3.6 \times 10-16 \text{ eV}/(25.9 \times 10) - 1 = 1.0 \times 10-3 \alpha \text{ Cj} = \sqrt{2} \text{ VO} + \text{VR} \Rightarrow \text{V} = 0.742 \text{ V}$ Substitute for α from Eq.

(1.67): NAND $\sqrt{A2}$ s q s N + ND $\times\sqrt{Cj} = \sqrt{As2V0} + VR 1.94$ Equation (1.72): q N N 1 s A D Cj0 = A 2 NA + ND V0 NA ND V0 = VT ln n2i 2 s q 10 × 10 = 0.754 V = A s × 17 16 = s A 2 s q = s A W 1 NA + ND NA ND 1 1 1 + NA ND (V0 + VR) (V0 + VR an equation for the loop containing the EBJ results in To obtain the value of RC, we note that at the nominal emitter current value of 1 mA, VC = -1 V, $5 - 0.7 IE = RB RE + \beta + 1 - 1 - (-5) = 4.04 k 0.99$ Specified to the nearest kilohm, Thus, RC = $4 k 4.3 4.3 RE + RB 51 (1) = IEmin (2) 4.3 RE + RC = = 1 RB RE + 101 RB 151 IC = \alpha IE = 0.99 mA$ Finally, for our design we need to determine the range obtained for collector current and collector voltage for β ranging from 50 to 150 with a nominal value of 100. (b) v I = +3 V, v - = +3 V $CMRR = 20 \log 4(x/100)$ where K is the nominal differential gain. 0 Triode * With the source and drain interchanged. 0.5 Vt = = 5 k I 0.1 For the circuits in (c) and (d) to remain in saturation, VD must not exceed VG by more than |Vt|. See figure above. VS1 = VS2 = -(VOV 1, 2 + Vtn) (a) With v G1 = v G2 = 0 V, (b) For the situation in (a), VDS of Q3 is zero, thus zero current flows in Q3. Of the two remaining poles, the one caused by CC2 has associated relatively low-valued resistances (RD and RL are much lower than RG), thus to minimize the total capacitance we place fP3 at 10 Hz and fP1 at 1 Hz. Thus, $10 = 12\pi$ CC2 (RD + RL) 12π CC2 (RD + RL) 12π × $3.53 \times 10-6 \times 4.5 \times 10-6 \times 4.5 \times 10-6 \times 4.5 \times 10^{-6}$ $103 \equiv (d)$ Since fP fZ, $\Rightarrow CC2 = 0.53 \mu$ F fL fP = 100 Hz Select CC2 = 1 μ F. 18.8 23.5 27.0 34.3 for VT = 25 mV at 17° C 3.17 I1 = IS e0.7/VT = 10-3 i2 = IS ev /0.025 \therefore 10,000IS = IS ev /0.025 \therefore 10,000IS = IS ev /0.025 Conduction starts at v I = A sin θ = 12 π rad θ = 4 At v = 0.230 V 17 sin θ = 12 π rad θ = 12 0.7 V, i = IS e0.7/0.025 = 1.45×1012 IS Chapter 3-6 3.19 I = IS eVD /VT 10-3 = IS e0.7/VT (1) For VD = 0.71 V, I = IS e0.7/VT (2) (b) VD = 0.650 V, ID = $10 \mu A \Rightarrow IS = 5.11 \times 10-17 A$; Combining (1) and (2) gives VD = 0.59 V I = 10-3 e(0.71 - 10) = 0.650 V, ID = $10 \mu A \Rightarrow IS = 5.11 \times 10-17 A$; Combining (1) and (2) gives VD = 0.59 V I = 10-3 e(0.71 - 10) = 0.650 V. 0.7/0.025 (d) VD = 0.700 V, ID = 100 mA \Rightarrow IS = 6.91 \times 10-14 A; = 1.49 mA 10% of ID gives VD = 0.64 V For VD = 0.8 V, I = IS e0.8/VT (3) Combining (1) and (3) gives I = 10-3 \times e(0.8 - 0.7)/0.025 3.21 The voltage across three diodes in series is 2.0 V; thus the voltage across each diode must be 0.667 V. Since both circuits use equal power supplies, the power dissipation of the differential pair will be twice that of the CS amplifier. For ± 10 -V supplies, the largest undistorted sine-wave output is of 9-V peak amplitude or 6.4 Vrms. 6.97 VCC 9 V ICmax = 1 × e(0.710-0.699)/0.025 = 1.55 mA 0.06 mA and ICmin = 1 × e R1 (0.710-0.721)/0.025 0.6 mA RC 3V VCE 3 V ICmin = 0.64 mA VCE will range from VCE min = $3 - 1.55 \times 2 = -0.1$ V which is impossible, implying that the transistor will saturate at this biasing arrangement is useless, since even the small and inevitable tolerances in RB1 and RB2 caused such huge variations in IC that in one extreme the transistor left the active mode of operation altogether! Initial design: $\beta = \infty$ RC = RE = 3V = 5 k 0.6 6.96 R1 + R2 = 9 = 150 k 0.06 R1 = 150 - 61.7 = 88.3 k Using 5% resistors from Appendix J, and R2 so as to obtain a VBB that is a VBB th slightly higher than 3.7 V, we write R1 = 82 k and R2 = 62 k RE = 5.1 k and RC = 5.1 k Chapter 6-35 VBB = VCC IE = 62 R2 = 3.875 - 0.7 = 0.58 mA 35.3 $5.1 + 91 \text{ VE} = 0.58 \times 5.1 = 3.18 \text{ VB} = 3.88 \text{ V}$ IC = α IE = $90 \times 0.58 = 0.57 \text{ mA}$ 91 VC = 6.1 V IR2 VB 3.88 = $= 0.063 \text{ mA} = R2 62 \text{ IB} = 0.58 \text{ IE} = 0.006 \text{ mA} \text{ and } \beta + 1.91 \text{ For this value}, VBB - VBE \text{ IE nominal } RE - VBE - VBE \text{ IE nominal } RE + 0.90 = 0.95 \text{ IE nominal } RE + 0.963 = 1.02 \text{ IE nominal } RE + 0.963$ $1 + \beta + 1$ VBB - VBE VCC = 5.73 3 1 + 101 \Rightarrow VBB = VBE + 0.352VCC (c) VCC = 5 V IR1 = 0.069 mA VBB = 0.7 + 0.352 \times 5 = 2.46 V 6.98 Refer to Fig. vn = 2.8125 vp As expected, since ND is increased by 100, the resistivity decreases by the same factor. P8.21. The current in the 12 k will be (3 - 0)/12 = 0.25 mA. vO 1 M + 2 = - vI R3 2.25 (a) Equation (2.5): $R_3 = -G = vO = vI - R_2/R_1$ R2 1+ 1+ A R1 and Gnominal = -R2 R1 Gain error G - Gnominal G = -1 = Gnominal Gnominal - 1 + R/R 2 1 2 1 1 + 1 + A A = 1 + 1 + 1 + 1 + R2 R1 R2 R1 Solving for A, we get R2 1 A = 1 + -1 R1 1 = (1 - Gnominal) - 1 (b) Gnominal = -R2 R1 Gain error G - Gnominal G = -1 = Gnom $-100 = -R3 = -(c) 1 M = 125 k (-10 + 2) vO 1 M = -2 V/V, R3 = - = \infty vI (-2 + 2) (a) Rin = R1 = 200$ vO $-R2 R4 R4 (b) = +1 + = -500 vI R1 R2 R3 A 1 + vO = -100 V/V vI (a) 2.27 R2 /R1 = 500, R2 = 100 k \Rightarrow R1 = 200 A 1 + 1 M vO + 2 vI R2 R1 Rin = 1 k = R1 If R2 = R1 = R4 = 100 k \Rightarrow R1 = 200 A 1 + 1 M vO + 2 vI R2 R1 Rin = 1 k = R1 If R2 = R1 = R4 = 100 k \Rightarrow R1 = 200 A 1 + 1 M vO + 2 vI R2 R1 Rin = 1 k = R1 If R2 = R1 = R4 = 100 k \Rightarrow R1 = 200 A 1 + 1 M vO + 2 vI R2 R1 Rin = 1 k = R1 If R2 = R1 = R4 = 100 k \Rightarrow R1 = 200 A 1 + 1 M vO + 2 vI R2 R1 Rin = 1 k = R1 If R2 = R1 = R4 = 100 k \Rightarrow R1 = 200 A 1 + 1 M vO + 2 vI R2 R1 Rin = 1 k = R1 If R2 = R1 = R4 = 100 k \Rightarrow R1 = 200 A 1 + 1 M vO + 2 vI R2 R1 Rin = 1 k = R1 If R2 = R1 = R4 = 100 k \Rightarrow R1 = 200 A 1 + 1 M vO + 2 vI R2 R1 Rin = 1 k = R1 If R2 = R1 = R4 = 100 k = 1$ $R_3 = 200$ Rin = R1 = 100 k 2.28 iI = So vI vI, vx = -iI R2 = -R2 R1 R1 vx R2 = -vI R1 R1 = 1 k R2 R2 = 100R1 = 100 k Again Gnominal = -100 and max = 10% 1 \therefore A = (1 - Gnominal) -1 1 = [1 - (-100)] -1 0.1 = 101 × 9 A = 909 V/V 100 k 500 - 2 R4 vx R2 iI iI vI R1 0V vO Chapter 2-7 Now, because of the virtual ground at the negative input terminal of the op amp, v O appears across the series combination of R4 and (R2 R3);
thus vx = vO = vO (R2 R3) + R4 R2 R3 R4 = 1 + R3 R4 vO R2 R3 + R2 R4 + R3 R4 = 1 + R3 R2 vO vO vx = vI vx vI R2 R4 R4 = - + 1 + R1 R3 R2 See Fig. re = 8.49 gm = VT 25 mV = 250 IE 0.1 mA = $\alpha \times \text{Total}$ resistance in collectors vo = vi Total resistance in emitters = 2μ Cox W ID L $\sqrt{2 \times 3 \times 0.1}$ = 0.77 mA/V Ad | = gm RD = $0.77 \times 10 = 7.7 \text{ V/V}$ RD RD | Acm | 2RSS RD $0.99 \times 25 \text{ k}$ 2re + 500 = 0.99× 250 + 500) 8.50 Refer to Fig. Replacing the 68 k-33 k divider network by its Thévenin Chapter 8-43 equivalent, we obtain VBB = $-5 V + IE3 = 33 \times 10 V 33 + 68 = 2.1 \text{ mA} = -1.73 V VO = -5 + 2.1 \times 2.4 = 0 V RBB = 68 \text{ k} 33 \text{ k} = 22.2 \text{ k}$ (b) Rin = 68 k 33 k = 22.2 k (b) Rin = 68 k 33 k = 22.2 k (b) Rin = 68 k 33 k = 22.2 k (c) Rin = 68 k 33 k = 22.VBB - (-5) - 0.7 RBB 4.7 + β + 1 - 1.73 + 5 - 0.7 = 0.52 mA 22.2 4.7 + 101 IC1 = α 1 × 0.52 = 0.99 × 0.52 mA The collector current IC1 and the 8.2-k resistor it feeds can be replaced by a Thévenin equivalent as shown in Fig. Using Eq. (1.50) and s = 11.7 × 8.854 × 10-14 F/cm, we have W = 2 × 10-5 cm = 0.2 µm. However, for v id even as large as 20 mV, the gain is only 5% below its ideal value of 100. This voltage is -5 + 0.3 = -4.7 V. Ad 1 CMRR = 20 log A (b) In Fig. This represents an increase in L by a 5 0.90 = .2.40 This is a weighted summer circuit: Rf Rf Rf vO = -vO + v1 + v2 + v3 R0 R1 R2 R3 We may write: $v 0 = 5V \times a0$, $v 2 = 5V \times a2$, $v 1 = 5V \times a1$, $v 3 = 5V \times a3$, Chapter 2-12 5 5 5 a0 + a1 + a2 + a3 80 40 20 10 2.42 R3 10 k a a1 a2 a3 0 v O = -Rf + + + 16 8 4 2 R2 10 k Rf 0 vO = - 2 a0 + 21 a1 + 22 a2 + 23 a3 16 R1 10 k v O = - Rf vI vO For -12 V ≤ v O ≤ 0, Rf 0 2 × 1 + 2 × 1 + 23 × 1 16 = Short-circuit R3 : vO = 1 vI 15Rf = 12 16 ⇒ Rf = 12.8 k R2 2.41 10 k R3 R2 10 k 10 k vI (a) vO R2 = 1 = 1 + vI R1 Set R2 = 0 and eliminate R1 vO R2 (b) = 2 = 1 + vI R1 R2 = 20; set R1 = 10 k, R2 = 20; set R1 = 10 k the output voltage, v O = -10 V, iL = -10 mA, i = 0.1 mA, and iO = -10.1 mA, again well under the 20-mA maximum allowed. (a) From Fig. (1) and (2) and substituting ID = I gives 1 W W = \times L CS L diff 2 W W = $2 \Rightarrow$ L diff L CS For the transistor to remain in saturation = 0.5 + 0.005 = 0.505 V W L |A| = 2μ n Cox 2 μ n Cox W ID L W/ ID RD L (1) $VDD \ge 2.105 V$ For a differential pair biased with a current I and utilizing drain resistances RD, the differential gain is Thus, the lowest value of VDD is 2.21 V. From symmetry, we see that IR $\le |Vtp| Q.E.D$ Chapter 5-16 (b) (i) R = 0, the condition above is satisfied and ID = I = 0.1 = 1 k p |VOV| 2 2 1 × 0.2 × |VOV| 2 operation, 1 2 ID = k p (VSG - |Vtp|)VSD - VSD 2 $1 0.1 = 0.2 (\text{VSG} - 1)(\text{VSG} - 3) - (\text{VSG} - 3)22 \Rightarrow |\text{VOV}| = 1 + 1 = 2 \text{ V2} - 2\text{VSG} - 4 = 0 \Rightarrow \text{VSG} \text{ VSD} = 2 \text{ V (iv)} \text{ R} = 10 \text{ k} (10 \text{ V IR} = 0.1 \times 10 = 1 \text{ V VSG which just satisfies the}$ condition for saturation-mode operation in (a) above. Published by Oxford University Press 198 Madison Avenue, New York, New York 10016 Oxford is a registered trademark of Oxford is a registered trademark of Oxford is a registered trademark of Press All rights reserved. Thus the only parameter that is significantly affected by the press All rights reserved. Thus the only parameter that is significantly affected by the press All rights reserved. Av o Rin + Rsig RL + Ro VOV = 0.25 V Gv = -gm (RD RL) gm = If RD is reduced to 15 k, Gv = -gm (RD RL) = $-1 \times (15 \ 15) = -7.5$ V/V 6.61 Rin = $\infty 1$ W 2 ID = μ n Cox VOV 2 $\pm 12320 = \times 400 \times 10 \times VOV 2 \Rightarrow VOV = 0.4$ V 2ID 2 $\times 0.32$ gm = = 1.6 mA/V VOV 0.4 Av o = -gm RD = $-1.6 \times 10 = -1.6 \times 10 = = -8 \text{ V/V} = -16 \times 10 + 10 \ 0.2 \text{ V}$ Peak value of v sig = 25 mV. P4.60. 100 140 Thus the rms value = $\sqrt{100 \text{ mV} 220 - 0.1} = 10 \text{ V/}\mu\text{s}$. v id (mV) 25810203040 iE1 /v id (V-1) 9.99 9.97 9.92 9.87 9.50 8.95 8.30 I This table belongs to Problem 8.30. 7.28 ro = VA 20 V = $\sqrt{100 \text{ mV} 220 - 0.1} = 10 \text{ V/}\mu\text{s}$. v id (mV) 25810203040 iE1 /v id (V-1) 9.99 9.97 9.92 9.87 9.50 8.95 8.30 I This table belongs to Problem 8.30. 7.28 ro = VA 20 V = $\sqrt{100 \text{ mV} 220 - 0.1} = 10 \text{ V/}\mu\text{s}$. v id (mV) 25810203040 iE1 /v id (V-1) 9.99 9.97 9.92 9.87 9.50 8.95 8.30 I This table belongs to Problem 8.30. 7.28 ro = VA 20 V = $\sqrt{100 \text{ mV} 220 - 0.1} = 10 \text{ V/}\mu\text{s}$. v id (mV) 25810203040 iE1 /v id (V-1) 9.99 9.97 9.92 9.87 9.50 8.95 8.30 I This table belongs to Problem 8.30. 7.28 ro = VA 20 V = \sqrt{100 \text{ mV} 220 - 0.1} = 10 \text{ V/}\mu\text{s}. = 200 k ID 0.1 mA A0 = gm ro = 0.4 × 200 = 80 V/V From Table J.1: µn Cox = 190 µA/V2 Now, ID = 1 W 2 µn Cox VOV 2 L 100 = The highest instantaneous voltage allowed at the drain is that which results in a voltage equal to (VOV) across the transistor. 1 we see that at dc, capacitor CS behaves as open circuit and the gain becomes DC gain = -9.5 Vo f (log scale) 10 k RD = -11 + RS + 4.5 gm 2 = -2 V/V Id I s RD 1 gm Is Vi RS 9.6 See figure on next page. f = 10 Av ~ -40 10 102 103 104 105 106 107 108 (Hz) 60 60 60 57 Thus Ro1 0.8 k f (Hz) 60 40 20 0 (dB) 57 Similarly, for node B, 20 kHz = $12\pi (Ro2 Ri3) \Rightarrow Ro2 Ri3 = 12\pi \times 20 \times 103 \times 1 \times 10 - 9 = 1000$ 7.96 k The designer should connect a capacitor of value Cp to node B where Cp can be found from \Rightarrow Cp = 1.70 Ti (s) = Vi (s) 1/sC 1 + R1 sC1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1
LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = Bandwidth = 105 - 102 = 99,900 Hz f0i = 1 1 = 159 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = 100 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = 100 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = 100 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = 100 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = 100 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = 100 kHz 2\pi C1 R1 + 1 LP with a 3-dB frequency Ro2 = 8.65 k 10 kHz = 100 kHz 2\pi C1 R1 + 100 kHz = 100 kHz 2\pi C1 R1 + 100 kHz = 100 kHz 2\pi C1 R used: $12\pi Cp$ (Ro2 Ri3) C2 R2 $12\pi \times 10 \times 103 \times 7.96 \times 103 = 2$ nF GmR2Vi Vo R3 Note that if she chooses to use node A, she would need to connect a capacitor 10 times larger! Vo R3 = -Gm R2 Vi R2 + R3 + 1/sC 2 1.69 The LP factor 1/(1 + jf/105) results in a Bode plot like that in Fig. Circuit (a) is useless as a differential amplifier! 2.71 Ideally, R4 R2 Ad = 1 + R3 R1 (1) Acm = 0 CMRR = ∞ For R2 = R3 = R4 = 100 k, and 2R1 = 10 k. Assume that Q2 also is operating in saturation, V5 = V4 - VGS2 = 2.5 - 1.84 = 0.66 V VGS2 = 0 - V2 = -V2 Since Q1 is conducting an equal ID and has the same VGS, and ID1 = 0.66 mA V2 = -2.5 + ID × 1 = V3 = V4 + VGS1 = 2.5 + 1.84 = 3.34 V $\Rightarrow ID = V2 + 2.5 We could, of course, have used the circuit symmetry, observed earlier, to write this final result. (b). Is = Vg 1 + ZS qm 8.426 \times 5(4.7 \ 10) 8.426 + 0.1 = 12 \pi CC1 (RG + Rsig) 12 \pi \times 0.01 \times 10 - 6 (8.426 + 0.1) \times 106 = 1.9 Hz Chapter 9-2 qm + 1/RS 2 \pi CS fP2 = = 5 \times 10 - 3 + 0.5 \times 10 - 3 = 87.5 Hz 2 \pi \times 10 \times 10 - 6 (20 \ dB/decade 26 \ dB/decade$ 0.04 = 2.96 mA VB and IB IC 2.96 $\beta = 74 = IB 0.04 4.27$ IC IE 2.5 V IE 0.5 mA RE VE Since the meter resistance is small, VC VB and the transfer characteristic in Fig. Exercise 2-6 10-3 s = 0.1 μ F 10 k From Eq. (2.27) the transfer characteristic in Fig. Exercise 2-6 10-3 s = 0.1 μ F 10 k From Eq. (2.27) the transfer characteristic in Fig. Exercise 2-6 10-3 s = 0.1 μ F 10 k From Eq. (2.27) the transfer characteristic in Fig. Exercise 2-6 10-3 s = 0.1 μ F 10 k From Eq. (2.27) the transfer characteristic in Fig. Exercise 2-6 10-3 s = 0.1 μ F 10 k From Eq. (2.27) the transfer characteristic in Fig. Exercise 2-6 10-3 s = 0.1 μ F 10 k From Eq. 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(2.27) the transfer characteristic in Fig. Exercise 2-6 10-3 s = 0.1 function of this integrator is: $C = 1 Vo(j\omega) = -Vi(j\omega) j\omega CR$ For $\omega = 10 rad/s$, the integrator transfer function has magnitude Vo $1 = V 1 \times 10 - 3 = 100 V/Vi \circ and PCR = 2 V$ and VCM max = $VBE1, 2 + VEmax 11 = 2 - (IRC) 2 VCM max = 0.574 + 0.1 = 0.674 V \Rightarrow IRC = 2 V$ The minimum value of VCM is dictated by the need to keep the current source operating properly, i.e. to keep 0.3 V across it, thus (c) IB = I $\leq 2 \times 101 \times 2 = 404 \mu \text{A VEmin} = -1.2 + 0.3 = -0.9 \text{V}$ Select and I = 0.4 mA VCM min = VEmin + VBE1,2 then = $-0.9 \times 101 \times 2 = 404 \mu \text{A VEmin} = -1.2 + 0.3 = -0.9 \text{V}$ Select and I = 0.4 mA VCM min = VEmin + VBE1,2 then = $-0.9 \times 101 \times 2 = 404 \mu \text{A VEmin} = -1.2 + 0.3 = -0.9 \text{V}$ Select and I = 0.4 mA VCM min = VEmin + VBE1,2 then = $-0.9 \times 101 \times 2 = 404 \mu \text{A VEmin} = -1.2 + 0.3 = -0.9 \text{V}$ Select and I = 0.4 mA VCM min = VEmin + VBE1,2 then = $-0.9 \times 101 \times 2 = 404 \mu \text{A VEmin} = -1.2 + 0.3 = -0.9 \text{V}$ Select and I = 0.4 mA VCM min = VEmin + VBE1,2 then = -0.9 \times 101 \times 2 = 404 \mu \text{A VEmin} = -1.2 + 0.3 = -0.9 \text{V} Select and I = 0.4 mA VCM min = VEmin + VBE1,2 then = -0.9 \times 101 \times 2 = 404 \mu \text{A VEmin} = -1.2 + 0.3 = -0.9 \text{V} Select and I = 0.4 mA VCM min = VEmin + VBE1,2 then = -0.9 \times 101 \times 2 = 404 \mu \text{A VEmin} = -1.2 + 0.3 = -0.9 \text{V} Select and I = 0.4 mA VCM min = VEmin + VBE1,2 then = -0.9 \times 101 \times 2 = 404 \mu \text{A VEmin} = -1.2 \times 101 \times 2 = 404 \mu \text{A VEmin} = -1.2 \times 101 \times 10^{-1} \text{C} mode range is $-0.326 \text{ V} \le \text{VICM} \le +0.674 \text{ V}$ (c) Refer to Fig. To determine VZ0, we use VZ0 + IZT rz 7.5 = VZ0 + 0.01 × 30 (b) \Rightarrow VZ0 = 7.2 V From Fig. P5.51(c): Assuming saturation-mode operation, we have ID = 2 = 1 k p |VOV|2 2 5.52 (a) Refer to Fig. However, it has the limitation that the load impedance must be floating. isc = RL If RL = 100 k: v s (t) Rs v o = 10 mV × For circuit b. 1 above. = iL 1 mA ·· Total small-signal resistance of the four diodes = 20 20 ·· For each diode, rd = = 5. Thus each of the two transistors in the cascode circuit will have gm = gma. Thus, Observe that Q1 is operating in the active mode, as implicitly assumed, and the current source has a voltage of 2.323 V across it, more than sufficient for its proper operation. Thus the signal across (re + Re) is 50 mV. Specifically, RG2 VG = VDD RG2 + RG1 22 = 9× = 4.95 V 22 + 18 It can be shown (after simple but somewhat tedious analysis) that the resulting ID will be ID = 0.986 mA, which is sufficiently close to the desired 1 mA. $gm = \mu n \cos \mu n \cos W n = \mu p \cos W n = \beta = 200 IC 0.5 mA = VT 25 mV = 20 mA/V = 20 mA/V$ IC = 1 mA = 1 mA = 40 mA/V 25 mV β v be = gm v be rn ie = ib + β ib = (β + 1)ib = (β + 1)ib = (β + 1) VT α VT 25 mV = 25 = re = IE IC 1 mA rn = v be rn v be v be = rn (β + 1) re Ex: 6.18 Ex: 6.16 IC 1 mA = 40 mA/V gm = VT 25 mV v ce = -gm RC Av = v be C gmvbe ib = -40 × 10 B = -40 × 10 = -40 × 10 = -40 × 10 = -40 × 10 = -40 × 10 = -40 × 10 = -40 × 10 = - $= 15 - 1 \times 10 = 5 \text{ V v C}$ (t) = VC + v c (t) = VC - IC RC) + Av v be (t) v be -gm v be re 1 = v be $-\text{gm v be rm}/\beta + 1 \text{ rm}$ $\beta + 1\beta \text{ v be} = v$ be $- = \text{rm rm rm ib} = = (15 - 10) - 400 \times 0.005 \text{ sin \omega t} = 5 - 2 \text{ sin \omega t iB}$ (t) = IB + ib (t) where 1 mA IC = $= 10 \text{ µA IB} = \beta 100$ and ib (t) = gm v be (t) $\beta \text{ Ex: } 6.19 40 \times 0.005 \text{ sin \omega t} = 10 \text{ µA IB} = \beta 100$ and ib (t) = gm v be (t) $\beta \text{ Ex: } 6.19 40 \times 0.005 \text{ sin \omega t} = 5 - 2 \text{ sin \omega t iB}$ (t) = IB + ib (t) where 1 mA IC = $= 10 \text{ µA IB} = \beta 100$ and ib (t) = gm v be (t) $\beta \text{ Ex: } 6.19 40 \times 0.005 \text{ sin \omega t} = 5 - 2 \text{ sin \omega t iB}$ (t) = IB + ib (t) where 1 mA IC = $= 10 \text{ µA IB} = \beta 100$ and ib (t) = gm v be (t) $\beta \text{ Ex: } 6.19 40 \times 0.005 \text{ sin \omega t} = 5 - 2 \text{ sin \omega t iB}$ (t) $= 10 \text{ µA IB} = \beta 100$ and ib (t) = gm v be (t) $\beta \text{ Ex: } 6.19 40 \times 0.005 \text{ sin \omega t} = 5 - 2 \text{ sin \omega t iB}$ (t) $= 10 \text{ µA IB} = \beta 100$ and ib
(t) $= 10 \text{ µA IB} = \beta 100$ and ib (t) $= 10 \text{ µA IB} = \beta 100$ and ib (t) $= 10 \text{ µA IB} = \beta 100$ and ib (t) $= 10 \text{ µA IB} = \beta 100$ and ib (t) $= 10 \text{ µA IB} = \beta 100$ and ib (t) $= 10 \text{ µA IB} = \beta 100$ and ib (t) $= 10 \text{ µA IB} = \beta 100$ and ib (t since the product since the since the product of the product since the product sinc $100 = 2.5 \text{ k gm} 40 \text{ ro} = \text{VA } 100 = 101 \ 100 \text{ k} = \text{IC } 0.99 \text{ (c)} \text{Rsig} = 2 \text{ k RB} = 10 \text{ k rn} = 2.5 \text{ k } 25 \text{ mV} = 26.9 \ 0.93 \text{ mA } \text{gm} = 40 \text{ mA/V} \ 0.99 \times 7.5 \times 103 = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ i} = 10 \text{ mV}, v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{ o} = 276.2 \text{ V/V} \ 26.9 \text{ For } v^{\hat{}} \text{$ 100) (10 2.5) + 2 - 0.5 × 40 × 3.846 = -77 V/V 8 k If ro is negelected, XY 10 k ZI 1 mA Vy = -80, for an error Vsig of 3.9%. Thus 4.60 Refer to the circuit in Fig. IDQ = 1 2 k n VOV 2 1 × 10 × 0.04 = 0.2 mA 2 VDD - VDS 5-1 RD = = 20 k IDQ 0.2 = Coordinates of point B: Equation (6.6): $\sqrt{2} k n RD VDD + 1 - 1 VGS B = Vt + k n RD \sqrt{2} × 10$ $\times 20 \times 5 + 1 - 1 = 0.5 + 10 \times 20 = 0.5 + 0.22 = 0.72$ V Equations (6.7) and (6.8): $\sqrt{2k}$ n RD VDD + 1 - 1 VDS B = 0.22 V k n RD VOV = -10 $\times 20 \times 0.2 = -40$ V/V The lowest instantaneous voltage allowed at the output is VDS B = 0.22 V. Obviously, this bias method is very intolerant of the inevitable variations in β . β = IC 0.394 = -40 V/V The lowest instantaneous voltage allowed at the output is VDS B = 0.22 V. Dviously, this bias method is very intolerant of the inevitable variations in β . β = IC 0.394 = -40 V/V The lowest instantaneous voltage allowed at the output is VDS B = 0.22 V. Dviously, this bias method is very intolerant of the inevitable variations in β . = 66 IB 0.006 α = IC 0.394 = 0.985 = IE 0.4 Since IC 1E 4.51 VCC 3 V 3.4 - VB = VB + 2.3 VB = 0.55 V For this value, VE = 0.55 - 0.7 = -0.15 V 0.1 mA RC 1 k R1 0 VB 1.2 V VC = -0.15 V 0.1 mA RC 1 k R1 0 VB 1.2 V VC = -0.15 V 0.1 mA RC 1 k R2 Figure 1 Chapter 4-16 4.52 From Fig. (b) Refer to Fig. 0.5 ID 0.01 = 1 VA 2 kn (1 – Vt) 2 \Rightarrow VA = 50 V (or larger to limit the mismatch in ID to 1%). However, the input resistance is only 25 k. \Rightarrow R = 5 k IL R 0.8 I 0.2 I 0.1R 1.1R 4 I 1.12 R 0.2 I 0.1R 1.1 point them out to me. Thus, we were justified in neglecting IR above. To obtain the coordinates of point M, we solve the load line and line L2 to find N: 6.22 ID = v GS = VGS For point M: iC = 8 + (8/100)v CE and iC = 10 - v CE \therefore iC M = 8.15 mA, 1 Vgs × 100 Q.E.D 4 VOV For Vgs = 10 mV, to keep the second-harmonic distortion to less than 1%, the minimum overdrive voltage required is $1 \ 0.01 \times 100 = 0.25 \ V \ OV = \times 41 = IC = iC = 10 - v \ CE = 5.24 \ mA \ v \ CE \ M = 1.85 \ V \ 11 \ 2k \ n \ VOV = \times 41 = IC = iC = 0.22 \ V \ 11 \ iD = k \ n \ v \ 20V = \times 10 \times 0.22 = 0.242 \ mA \ 22 \ Thus, id = 0.02 \ V \ OV = 0.2 \ V \ OV = 0.22 \ OV = 0.22 \ V \$ 0.242 - 0.2 = 0.042 mA For point N: iC = 2 + 0.02v CE and iC = 10 - v CE v CE N = 7.84 V, 1 k n (VGS - Vt) 2 + k n (VGS - Vt $\omega t 2$ iC N = 2.16 mA Thus the collector current varies as follows: For v gs = -0.02 V, v OV = 0.2 - 0.02 = 0.18 V 1 1 iD = k n v 2OV = × 10 × 0.182 = 0.038 mA 2.91 mA 8.15 mA 5.24 mA i 5.99 mA, peak to peak 2.16 mA 3.08 mA Thus, an estimate of gm can be obtained as follows: 0.042 + 0.038 = 2 mA/V gm = 0.04 Alternatively, using Eq. (6.33), we can write $gm = k n VOV = 10 \times 0.2 = 2 mA/V$ which is an identical result. = 4×106 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5, Vo = $10 \times 0.5 = 5$ V 2 Output distortion will be due to slew-rate limitation and will occur at the frequency for dv O which = SR dt max t W ω max $\times 5 = 10 \times 106$ ω max = 2×106 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5, Vo = $10 \times 0.5 = 5$ V 2 Output distortion will be due to slew-rate limitation and will occur at the frequency for dv O which = SR dt max t W ω max $\times 5 = 10 \times 106$ ω max = 2×106 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5, Vo = $10 \times 0.5 = 5$ V 2 Output distortion will be due to slew-rate limitation and will occur at the frequency for dv O which = SR dt max t W ω max $\times 5 = 10 \times 106$ ω max = 2×106 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5, Vo = $10 \times 0.5 = 5$ V 2 Output distortion will be due to slew-rate limitation and will occur at the frequency for dv O which = SR dt max t W ω max $\times 5 = 10 \times 106$ ω max = 2×106 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5, Vo = $10 \times 0.5 = 5$ V 2 Output distortion will be due to slew-rate limitation and will occur at the frequency for dv O which = SR dt max t W ω max $\times 5 = 10 \times 106$ ω max = 2×106 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow fmax = 637 kHz vi (V) 2.116 (a) Vi = 0.5 rad/s \Rightarrow 106 rad/s and fmax = 318.3 kHz vO (V) (b) The output will distort at the value of Vi that dv O results in = SR. 7.49. Thus the maximum allowable negative signal swing at the output is VDSQ - 0.22 = 1 - 0.22 = 0.78 V. (e) The lowest value of A0 is obtained with the first design when operated at ID = 100μ A. Chapter 8-15 vⁱ d \Rightarrow VCM max = VCC + 0.4 - 2 v^{id} Ad VT + Q.E.D. 2 (b) VCC = 2.5 V, (4) v^{id} = 10 mV, Ad = 50 V/V, VCM max = 2.5 + 0.4 - 0.005 - 50(25 + 5) × 10 - 3 1.4 V v^{od} = Ad × v^{id} = 50 × 10 = 500 mV = 0.5 V Using Eq. (2), we obtain IRC = 2Ad VT = 2 × 50 × 0.025 = 2.5 V To limit the power dissipation in the quiescent state to 1 mV, the bias current must be limited to I = Pmax 1 = 0.2 mA VCC + VEE 5 Using this value for I, we get RC = 2.5 = 12.5 k 0.2 (c) To obtain VCM max = 1 V, we use Eq. (4) to determine the allowable value of Ad, 8.40 (a) Consider transistor Q1, I vⁱ d v C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - \text{Ad} (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - \text{Ad} (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - \text{Ad} (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - \text{Ad} (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - \text{Ad} (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v
C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - \text{Ad} (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - \text{Ad} (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - \text{Ad} (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - \text{Ad} (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - \text{Ad} (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - \text{Ad} (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad 2 2 1 = $2.5 + 0.4 - 0.005 - Ad (25 + 5) \times 10^{-3}$ (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad (25 + 5) \times 10^{-3} (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d v C1min = (VCC - RC) - Ad (25 + 5) \times 10^{-3} (1) where Ad = gm RC = I/2 RC VT IRC 2VT Since vⁱ d B1 = VCM max + 2 to keep Q1 in the active mode, v B1 \leq 0.4 + v C1min Thus, VCM max + vⁱ d vⁱ d = 0.4 + VCC - Ad VT + 2 2 Thus, by reducing VCM max from 1.4 V to 1 V, we are able to increase the differential gain from 50 V/V to 63.2 V/V. v O_avg vo 200 vi vo 7 mV = 33.8 vi 200 + 7 V 200 VO IL rZ VO - IL (rZ 200) = IL IL mA = -6.8 $(Vs \sin \varphi - VD) d \varphi \theta 1 [-Vs \cos \varphi - VD \varphi] \varphi = \pi - \theta \varphi - \theta 2\pi 1 [Vs \cos \theta - Vs \cos (\pi - \theta) - VD (\pi - 2\theta)] = 2\pi But \cos \theta 1$, $\cos (\pi - \theta) - 1$, and $\pi - 2\theta \pi VD 2Vs - 2\pi 2 VD Vs - \pi 2 \sqrt{V} O_{x} = -\pi 2$ VBE3 + VBE1 = 1.187 V If IREF is increased to 1 mA, VBE1 = 0.7 IC3 0.02 mA 1 = 0.6 V VBE3 = 0.7 - 0.025 ln 0.02 Vx = 1.3 V Thus, 1 = 1.6 k gm Vx = 1.3 - 1.187 = 0.113 V (b) Replacing the BJT with its hybrid- π model results in the equivalent circuit in Fig. VA 125 V = 1.25 k IC 10 mA 4.42 The equivalent circuits shown in the figure correspond to the circuits in Fig. P8.46. Thus the fundamental will have a frequency of 98/7, or 14 kHz, and peak amplitude of $63 \times 7 = 441$ mV. With the selected capacitor values, we obtain fP2 1 = 0.64 Hz $2\pi \times 0.1 \times 10-6$ KZ = 0 (dc) fP3 1 = = 5.3 Hz $2\pi \times 1 \times 10-6$ (20 + 10) $\times 103$ Since fP2 fP1 and fP3, we have fL fP2 = 95.5 Hz 9.7 The amplifier in Fig. Thus there will be (2N - 1) discrete steps from 0 to VFS with the step size = (b) bN is the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change corresponding to a change in the LSB VFS 2N - 1 This is the analog change corresponding to a change corresponding $2 v_1 = R v_1 only$: $Ri = I v_1 + R1$ vo $R4 R I v_1 R R3 R2 = 5 V/V \Rightarrow R2 = 50 k = R4 R1 R1 = R3 = 10 k v_0 = v_0$ The two resistance ratios $\therefore R1 = R3 = 5 k$, R2 = R4 = 100 k R4 R2 Equation (2.15): $= 20 R3 R1 v_1 R4 R4 + R3$ (Refer to Fig. NMOS Sat. (d) Since current source I2 is implemented with a cascoded current source, the minimum voltage required across it for proper operation is 2VOV = 2 (0.2 V) = 0.4 V. The circuit together with its equivalent half-circuit are shown in the figure. Thus, the possible 1 M range of IOS is 0.2 µA to 0.4 µA. Rsig vo vsig R1 R2 vp Rin rp gmvp RC RL Chapter 6-45 For VE 4.3 = $2.15 \text{ k} = \text{IE} = 2 \text{ mA}, \text{RE} = \text{IE} 2 5 \text{ IR} 2 = 0.2 \text{ mA}, \text{R2} = 25 \text{ k} 0.2 2 \text{ IE} = 0.02 \text{ mA} \text{ IB} = \beta + 1 101 \text{ IR} 1 = \text{IR} 2 + \text{IB} = 0.2 + 0.02 = 0.22 \text{ mA} \text{ VCC} - \text{VB} 15 - 5 \text{ R1} = 47 \text{ k}, \text{ R2} = 24 \text{ k} \text{ For these values}, \text{VBB} - \text{VBE} \text{ IE} = \text{RB} \text{ RE} + \beta + 1 \text{ where } 24 \text{ R2} = 5.07 \text{ V} = 15 \times \text{VBB} = \text{VCC} \text{ R1} + \text{R2} 24 + 47 \text{ RB} = 0.2 \text{ mA} \text{ VCC} - \text{VB} 15 - 5 \text{ R1} = 45.5 \text{ k} = \text{IR} 1 0.22 \text{ Choosing } 5\% \text{ resistors}; \text{RE} = 2.2 \text{ k}, \text{R1} = 47 \text{ k}, \text{R2} = 24 \text{ k} \text{ For these values}, \text{VBB} - \text{VBE} \text{ IE} = \text{RB} \text{ RE} + \beta + 1 \text{ where } 24 \text{ R2} = 5.07 \text{ V} = 15 \times \text{VBB} = \text{VCC} \text{ R1} + \text{R2} 24 + 47 \text{ RB} = 0.2 \text{ mA} \text{ RC} + 100 \text{ mA} \text{ R} = 100 \text{ mA} \text{ R} + 100 \text{ mA} \text{ R} = 100 \text{ mA} \text{ R} + 100 \text{ mA} \text{ R} = 100 \text{ mA} \text{ mA} = 100 \text{ mA} = 100 \text{ mA} \text{ mA} = 100 \text{$ R1 R2 = 47 24 = 15.89 k 5.07 - 0.7 = 1.85 mA IE = 15.89 2.2 + 101 VB = IE RE + VBE = 1.85 × 2.2 + 0.7 = 4.8 V IC = α IE = 0.99 × 1.85 = 1.84 mA IC 1.84 gm = = 73.4 mA/V = VT 0.025 β 100 rn = = 1.36 k = gm 73.4 Rin = R1 R2 rn = 47 24 1.36 = 1.25 k Rin 1.25 vn = = 0.385 V/V v sig Rin + Rsig 1.25 + 2 For an overall gain of -40 V/V, 40 vo = -104 V/V = - vn 0.385 But vo = -gm (RC RL) vn - 104 = -73.4 (RC 2) which is slightly higher than the required gain, and we will obtain VC = $15 - 5.1 \times 1.84 = 5.6 \text{ V}$ which allows for only 1.2 V negative signal swing. Assuming that all transistors are operating in the active mode and that β 1, so that we can neglect all base currents, we see that the current I through Q1 will flow through the two-output mirror Q3, Q4, and Q2 are diode connected, then (6) If Q1 and Q3 are diode connected, the (6) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 are diode connected, the (7) If Q1 and Q3 the symmetry will be broken. $R2 = 100 \text{ k} R1 = 100 \text{ k} 9 R3 = 5 \text{ k} 2.93 \text{ IB1} = 2 \pm 0.1$, μA , VOS = 0 IB2 = 2 ± 0.1 , μA , VOS = 0 IB2 = 2 ± 0.1 , μA , R3 IB1 - IB2 R1 C1 R1 VO = -IB2 R3 1 + R1 C2 (1) R3 The maximum value of VO is obtained when IB1 = $2.1 \mu A$ and $IB2 = 1.9 \mu A$, $100 \text{ VOmax} = 2.1 \times 100 - 1.9 \times 51 + 100 \text{ VOmax} = 2.1 \times 100 - 1.9 \times 51 + 100 \text{ VOmax} = 2.1 \times 100 - 1.9 \times 51 + 100 \text{ VOmax} = 2.1 \times 100 \text{ VOmax} = 2.1 \times 100 - 1.9 \times 51 + 100 \text{ VOmax} = 2.1 \times 100 \text{ VOmax} = 2.1 \times 100 - 1.9 \times 51 + 100 \text{ VOmax} = 2.1 \times 10$ 100/9 = 210 - 95 = 115 mV The minimum value of VO is obtained when IB1 = 1.9 µA and IB2 = 2.1 µA, R2 = R3 = 100 k 1 + R2 = 100 R 1 + R2 = 100 k 1 + R2 = 100 k 1 + R2 = 100 k 1 = 10 µF C = 100 × 103 When IB1 = 1.9 µA and IB2 = 2.1 µA, R2 = R3 = 100 k 1 + R2 = 100 k 1 + a dc voltage of -1 V is applied, a dc current of 1 V/100 k = 0.01 mA will flow as shown in the figure below. (3.34) and (3.35): Vp 14.9 V
iDav = IL 1 + π , where IL = 2Vr 100 \sqrt{Vp} = 12 2 - 2 × 0.8, and Vr = 1 V; thus iDmax = I 1 + 2 π iD = VC ln + 0.7 V 1 mA For v I = 10 mV, v O = v I = 10 mV It is an ideal op amp, so i + = i - = 0. P6.80. The circuit will work properly as long as the op amp does not saturate (i.e., as long as VO ≤ -10 V). P5.52(a) with the 10- μ A current source replaced with a 400-k resistor. P6.111(a): v o1 10 10 Av o $\equiv = = = 0.99$ V/V 1 1 vi 10 + 10 + gm 10 1 Ro = 10 k = 0.1 10 = 99 gm (b) Refer to Fig. 2ID 2 × 0.3 = 3 mA/V = (b) $gm1 = gm2 = VOV 0.2 RD1 = RD2 = 10 k RL = 10 k Chapter 6-23 This figure belongs to Problem 6.62. The 6.4 From Eq. (6.18): | Av max | = B B Thus, -14 = -k n RD × 0.25 \Rightarrow k n RD = 56 To obtain the required VDS Q, we use Eq. (6.18): | Av max | = B B Thus, -14 = -k n RD × 0.25 \Rightarrow k n RD = 56 To obtain the required VDS Q, we use Eq. (6.18): | Av max | = B B Thus, -14 = -k n RD × 0.25 \Rightarrow k n RD = 56 To obtain the required VDS Q = -56VOV Q Thus, 12 VOV Q Thu$ (6.17), $VDD - VDS Q Av = -VOV Q/2 2 - VDS Q - 12 = -0.214/2 \Rightarrow VDS = 0.714 V Q 6.5 RD = 20 k k n = 200 µA/V2 VRD = 1.5 V VGS = 0.7 V Av = -10 V/V Av = -10 V/V$ $k n = k n \therefore W = 1.67 \text{ mA/V2}$ L remains in saturation is 1.61 V and the corresponding output voltage is 0.61 V. (b) The amplifier small-signal equivalent-circuit model is shown in Fig. P4.50. The current I will split equally between Q1 and Q2. (2) and (3), respectively, in Eq. (1) and equating Gv to 50.5 V IE3 IC4 10 k 30 k Supernode V + 0.2 V - 0.5 Q3 IB3 10 k V - 0.5 V I Q4 20 k V - 0.7 10 k IE4 (c) Chapter 4-27 VC4 = V - 0.5 = 1.54 V Thus, Next we determine all currents utilizing Eqs. (c) If both W and L are halved, k n will remain unchanged and rDS will vary in the original range of 2.5 k to 125. Q1 off Ex: 4.29 Refer to the circuit in Fig. = 0.0495 rad v O, avg Conduction ends at π - θ. 9.3. s s+ $1 \text{ CC2} (\text{RD} + \text{RL}) 1 2 \pi \text{CC2} (\text{RD} + \text{RL}) \text{ fP3} = 1 = 8.84 \text{ Hz} 2\pi \times 10 \times 10 - 6 \times 1.8 \times 103 \text{ AM} = -\text{RG} \times \text{gm} (\text{RD} \text{ RL}) \text{ RG} + \text{Rsig}$ where where RG = RG1 RG2 = 47 M 10 M RD = 10 k, gm = 5 mA/V, RD = 4.7 k and RL = 10 k. 6.57(b)] Exercise $6-1150 \times 20(88) 50 + 50 \text{ Rin} = \text{RB1} \text{ RB2}$ [(β + 1)(re + Re)] = Thus, = 40 V/V 10 = 182 100 [101(0.05 + Re)] VT = where we have substituted re = IE 25 = 50. \Rightarrow -12 V ≤ v Icm ≤ 12 V This circuit is that in Fig. 6.26. τ C 1 = CC 1 [Rsig + (RB rn)] = 1 × 10-6 [5 + (100 2.5)] × 103 = 7.44 ms RB $+1\beta = \text{gm} \, \text{rn} = 40 \times 2.5 = 100 \, \text{re} \, 1/\text{gm} = 25$ 100 $5 - 6 \times 103 \, 5 \, 0.025 + \tau \text{CE} = 1 \times 10 \, 101 \, \tau \text{CE} = 0.071 \, \text{ms} \, \tau \text{C} \, 2 = \text{CC} \, 2 \, (\text{RC} + \text{RL}) = 1 \times 10 - 6 \, (8 + 5) \times 103 = 13 \, \text{ms} \, \text{Ex}$: 9.4 gm = 2k n (W/L)ID = 2 × 0.16 × (10/1) × 0.1 = 0.566 \, \text{mA/V} \, \text{gm} \, \text{fT} = 2\pi(\text{Cgs} + \text{Cgd}) = 0.566 \times 10 - 3 \, 2\pi(24.72 + 1.72) \times 10 - 15 \, \text{fT} = 3.4 \, \text{GHz} Ex: 9.5 Cde = τF gm where τF = 20 ps gm = IC 1 mA = 40 mA/V VT 0.025 V Exercise 9-2 Thus, fH = Cde = 20 × 10-12 × 40 × 10-3 = 0.8 pF 1 2 \pi Cin (Rsig RG) 1 2 \pi × 4.26 × 10-12 (0.01 4.7) × 106 Cje 2 Cje 0 = 2 × 20 = 40 fF = 3.7 MHz C \pi = Cde + Cje = 0.8 + 0.04 = 0.84 pF 1 × 106 = 20 \Rightarrow Cin = 1.625 pF = 0.33 = 12 fF 2 0.5 gm fT = 0.33 = 12 fF 2 0.5 gm fT = 0.31 = 1.625 pF = 0.31 = 1.625 pF = 0.33 = 12 fF 2 0.5 gm fT = 0.31 = 1.625 pF = 0.31 = 1.625 pF = 0.33 = 12 fF 2 0.5 gm fT = 0.31 = 1.625 pF = 0.31 = 1.625 pF = 0.33 = 12 fF 2 0.5 gm fT = 0.31 = 1.625 pF = 0.31 = 1.625 pF = 0.31 = 1.625 pF = 0.33 = 12 fF 2 0.5 gm fT = 0.31 = 1.625 pF = 0.31 = 1.6 $2\pi(C\pi + C\mu) + 40 \times 10 - 3 = 7.47 \text{ GHz } 2\pi(0.84 + 0.012) \times 10 - 12 \text{ Ex: } 9.6 \text{ | hfe|} = 10 \text{ at } f = 50 \text{ MHz } \text{Thus, } fT = 10 \times 50 = 500 \text{ MHz } \text{gm } C\pi + C\mu = 2\pi fT = 40 \times 10 - 32\pi \times 500 \times 106 = 12.7 \text{ pF } \text{Cm} = 12.7 \text{ - } 2 = 10.7 \text{ pF } \text{Cm}$ found, we reduce RL by the same factor, thus RL = 1.5 k But, RL = ro RC RL 1.5 = 100 8 RL \Rightarrow RL = 1.9 k Cin = C π + C μ (1 + gm RL) = 7 + 1(1 + 40 × 1.5) = 68 pF 10.7 = Cde + 2 fH = \Rightarrow Cde = 8.7 pF Since Cde is proportional to gm and hence IC, at IC = 0.1 mA, Cde = 0.87 pF and C π = 0.87 + 2 = 2.87 pF 4 × 10-3 = 130.7 MHz 2 π (2.87 + 2) × 10-12 Ex: 9.8 AM = - = - RG gm RL RG + Rsig $4.7 \times 7.14 = -7.12$ V/V 4.7 + 0.01 1 2π Cin (0.1 4.7) × 106 But, Ex: 9.7 Cn = Cde + Cje fT = 1 2π Cin (Rsig RG) Cµ0 VCB m 1 + V0c Cµ = = Ex: 9.9 fH = = 1 2π Cin Rsig $12\pi \times 68 \times 10 - 12 \times 1.65 \times 103 = 1.42$ MHz Thus, by accepting a reduction in gain by a factor of 2, the bandwidth is increased by a factor of 1.42/0.754 = 1.9, approximately the same factor as the reduction in gain. 4.5(b) is shown below in Fig. increase), this voltage difference will be independent of temperature! 0.4 i (mA) 0.35 Load line 3.32 R $1 \text{ k}\Omega$ VDD i v 1V 0.30 0.660 0.664 v (V) 0.67 From this graph we get the operating point IS = 10-12 mA i = 0.338 mA, v = 0.6635 V Calculate some points Now we compare graphical results with the exponential model. See analysis on figure. This constraint is removed in circuit (b), but the input resistance is finite (2R1). (vo vgs)/R2 R2 R1 vsig vo gmvgs vgs RD ro Figure 2 - R2 /R1 1 + R2 /R1 1 + R2 /R1 1 + R2 /R1 vsig 1 + gm (RD ro R2)(1 - 1/gm R2) RB = R1 R2 = 15 27 = 9.643 k = IC = Q.E.D Substituting numerical values yields vo = v sig 2/0.5 - 1 + (2/0.5) 1 + 1.07(55 561 2000)(1 - 1/1.07 × 2000) = -45 1 + 52.6 0.99(5.357 - 0.7) = 1.85 \text{ mA} = 74 \text{ mA/V} = \text{VT } 0.025 \text{ V rm} = \beta 100 = = 1.35 \text{ k gm } 74 \text{ Replacing the BJT with its hybrid-model results in the} equivalent circuit shown at the bottom of the page: Rin = R1 R2 r = RB r = 9.643 1.35 = 1.18 k Rin v = 0.371 V/V = v sig Rin + Rsig 1.18 + 2 = -3.65 V/V vo = -gm (RC RL) v Note that the gain is nearly equal to -R2/R1 = -4, which is the gain of an op amp connected in the inverting configuration. vi VG1 = VDD - VSG1 = VDD - |Vtp = v sig Rin + Rsig 1.18 + 2 = -3.65 V/V vo = -gm (RC RL) v = -3.65 V/V vo = -gm (RC RL) v = -3.65 V/V vo = -gm (RC RL) v = -3.65 V/V vo = -gm (RC RL) v = -3.65 V/V vo = -gm (RC RL) v = -3.65 V/V vo = -gm (RC RL) v = -3.65 V/V vo = -gm (RC RL) v = -3.65 V/V vo = -gm (RC RL) v = -3.65 V/V vo = -gm (RC RL) v = -3.65 V/V vo = -gm
(RC RL) v = -3.65 V/V vo = -gm (RC RL) v = -3.65 V/V vo = -3.65 V/V |-|VOV| = 1.8 - 0.4 - 0.2 = 1.2 V 5 mV 0 t VG2 = VS2 - VSG2 = 1.6 - 0.4 - 0.2 = 1.0 V v1 VG3 = VS3 - VSG3 50 mV = 1.4 - 0.4 - 0.2 = 0.8 V 0 t v2 - 1 V All transistors carry the same ID = 0.2 mA and operate at the same value of <math>|VOV| = 0.2 V. However, Q3, which has the same VGS as Q1 but has 10 times the width, will have a drain current 10 times larger than Q1 . P7.86. 7.40 with its T model while neglecting ro results in the circuit shown below. Figure 2 Chapter 7-9 7.22 Refer to Fig. $Gv = Gv \circ 6.78$ IC = 2 mA re = Rsig 10,000 = 12.5 + β + 1 101 VT VT 25 = = 12.5 IE IC 2 For RL = 250, RL = 250 , RL Gv = Gv o RL + Rout 250 = 1 × = 0.69 V/V 250 + 111.5 (a) Rin = (β + 1) (re + RL) = 101 × 101 $(12.5 + 500) = 51.76 \text{ k} \text{Rin} 51.76 \text{ vb} = v \text{ sig Rin} + \text{Rsig } 51.76 + 10 \text{ 6.79} \text{ Rout} = re + v \text{ sig v} \text{ sig v} = 0.84 \times \text{Rsig } \beta + 1 \text{ RL} + re \text{ Subtracting Eq. (1) from Eq. (2), we have } 5000 \beta + 1 \beta + 1 = 50 0.5 = 0.84 \times 0.5 + 0.0125 100 = 0.82 \text{ V/V Substituting in Eq. (1) yields (b) } 5000 \beta + 1 10,000 250 = re + \beta + 1 150 = re + v \text{ sig v} \text{ sig v} = 0.84 \times 0.5 + 0.0125 100 = 0.84 \times 0.5 + 0.012$ $50 \Rightarrow re = 50$ RL Gv = Rsig RL + re + β + 1 1000 = 0.8 V/V = 10,000 1000 + 50 + 50 150 = re + Rsig ai B i re vsig RL Rin vbe vo 6.80 (a) Refer to Fig. From the table we see that gain of 50 is obtained for IC between 0.2 and 0.5 mA and also for IC above 1.25 mA. 8.13(a), 1 W 2 for all NMOS VOV Since ID = μ n Cox 2 L transistors, $W = = L 1 L 2 L 3 L 4 2ID 2(100 \mu A) = = 12.5 2 \mu n Cox VOV 400 \mu A/V2 (0.2 V)$ $W W W = = L 5 L 6 L 7 L 8 = 2ID 2(100 \mu A) = = 50 2 \mu p Cox VOV 100 \mu A/V2 (0.2 V)$ $W W W = = L 5 L 6 L 7 L 8 = 2ID 2(100 \mu A) = = 50 2 \mu p Cox VOV 100 \mu A/V2 (0.2 V)$ $W W W = = L 5 L 6 L 7 L 8 = 2ID 2(100 \mu A) = = 50 2 \mu p Cox VOV 100 \mu A/V2 (0.2 V)$ $W W W = = L 5 L 6 L 7 L 8 = 2ID 2(100 \mu A) = = 50 2 \mu p Cox VOV 100 \mu A/V2 (0.2 V)$ $W W W = = L 5 L 6 L 7 L 8 = 2ID 2(100 \mu A) = = 50 2 \mu p Cox VOV 100 \mu A/V2 (0.2 V)$ $W W W = = L 5 L 6 L 7 L 8 = 2ID 2(100 \mu A) = = 50 2 \mu p Cox VOV 100 \mu A/V2 (0.2 V)$ $VOV = (v GS - Vt) = 0.5 V 1 W W = k n VOV \Rightarrow 5.15 gDS = 1 k L L L = 0.18 \mu m$, so $W = 0.93 \mu m Ex$: 5.2 Cox = ox 34.5 pF/m = 8.6 fF/µm2 = tox 4 nm µn = 450 cm2 /V · s k n = µn Cox = 387 µA/V2 ID = 1 W 2 W k V = 0.3 mA, = 20 2 n L OV L \therefore V OV = 0.28 V VDS, min = VOV = 0.28 V VDS, min = VOV = 0.28 V VDS, min = VOV = 0.28 V VDS = 1 V > VOV = 0.5 V = 0.5 V = 0.28 V VDS. Saturation: I D = 1 W 2 k V (1 + λ VDS) 2 n L OV 1 16 × 200 × × 0.52 (1 + 0.025 × 1) 2 0.8 = 0.51 mA VA 40 = = 80 k ro = ID 0.5 ID = where ID is the value of ID without channel-length modulation taken into account. 0.5 = 0.05 mA \therefore id = 10 and i = 2id = 0.1 mA. Lp ND Dn Ln NA Dp \therefore IS ~ = Aqn2i Dp Dn + Lp ND Ln NA = $10-4 \times 1.6 \times 10-19 \times (1.5 \times 1010) 2 / |x| \setminus 105 \times 10-4 \times +16102 | 18 | -418 / 10 \times 10 \times 10 = 1.46 \times 10-14 \text{ AI} = IS (eV / VT - 1) - 3)$ IS eV /VT = $1.45 \times 10-14 \text{ e} 0.605/(25.9 \times 10 = 0.2 \text{ mA} 2s \text{ q Ex}: 1.36 \text{ W} = 2 \times 1.04 \times 10-12 \text{ } 1.6 \times 10-1911 + \text{NA ND 1 1018} = 3.2 \text{ pF Equation} (1.71), Cj0 Cj = VR 1 + VO 3.2 \times 10-12 = 2$ 1 + 0.814 + 1 (V0 - VF) (0.814 - 0.605) 1016 = 1.66 × 10 - 5 cm = 0.166 µm Ex: 1.37 W = Ex: 1.38 Equation (1.72), q N N 1 s A D Cj0 = A 2 NA + ND V0 1.04 × 10 - 12 × 1.6 × 10 - 19 = 10 - 4 2 1018 × 1016 1 0.814 1018 + 1016 = 1.72 pF 2s q 2 × 1.04 × 10 - 12 1.6 × 10 - 19 1 1 + NA ND 1 1018 + (V0 + VR) 1 1016 Dp Dn + Lp ND Ln NA D (0.814 + 2) Ex: 1.39 Cd = d dQ = $(\tau T I) dV dV d [\tau T \times IS (eV /V T - 1)] dV d (eV /V T - 1) = \tau T IS dV 1 V /V T e = \tau T IS VT \tau T = × IS eV /V T VT \tau T ~ I = VT = Exercise 1-8 Ex: 1.40 Equation (1.75), <math>\tau p = ND = 1016 / cm3$, Equation (1.75), $\tau p = ND = 1016 / cm3$, Equation (1.75), $\tau T = VT = Exercise 1-8 Ex: 1.40 Equation (1.75), \tau p = ND = 1016 / cm3$, Equation (1.75), $\tau T = VT = Exercise 1-8 Ex: 1.40 Equation (1.75), \tau p = ND = 1016 / cm3$, Equation (1.75), $\tau T = VT = Exercise 1-8 Ex: 1.40 Equation (1.75), \tau p = ND = 1016 / cm3$. $\tau p = 25 \text{ ns}$ $25 \times 10 - 9 \therefore$ Cd = 0.1 × 10 - 3 25.9 × 10 - 3 = 96.5 pF Chapter 1-1 (e) P = I 2 R = I = P/R I = 0.1 mA × 10 k = 1 V 1.1 (a) I = V = IR = 31.6 mA × 1 k = 31.6 V IV V = = 0.01 A = 10 mA (d) I = R 100 mW/1 k = 31.6 mA × 10 k = 1 V 1.1 (a) I = V = IR = 31.6 mA × 10 consistent set of units. P4.55(b). Thus VGS4 = VGS3 = VGS1 = 2.5 V Thus, VSGP + VGSN = $3\sqrt{(3 + 1)}$ VOVN + $1 = 3 \Rightarrow$ VOVN = 0.732 V VOVP = 1.268 V V2 = 5 - VGS4 = 2.5 V This is equal to the voltage at the gate of Q3; thus Q3 is indeed operating in saturation, as assumed. At v I = -2.5 V the diode begins to conduct and its current reaches 1 mA at vI = -1.3 V (corresponding to v O = -2.3 V). P5.52(f). The required value of IC is found by substituting for ro and 1/gm from Eqs. Thus, 4.41 iC (mA) Temperature coefficient of VE R2 = -11×-2.2 R1 = -11×-2.2 R = -6.95 V As a check on our assumption of constant IE, let us find the value of IE at 75° C: I1 (75° C) = VBE (75° C) R1 0.68 - 2.2 × 10 - 3 × 50 6.8 Slope of iC -v CE line corresponding to v BE = 710 mV is 0.2 mA 1.3 - 1.1 = 0.02 mA/V Slope = 15 - 5 10 V Near saturation, VCE = 0.3 V, thus iC = 1.1 - 0.02 × (5 - 0.3) = 1.006 1 mA iC will be 1.2 mA at, = 0.084 mA IE ($75 \circ C$) = I - I1 ($75 \circ C$) = I - I1 ($75 \circ C$) = 1.1 - 0.084 = 1.016 mA which is reasonably close to the assumed value of 1 mA. VC1 = V2 - VD2 = 6.2 - 0.7 = 5.5 V VE2 = V2 solutions are free of error. For L = $0.5 \mu m$ and $\mu n = 450 \text{ cm} 2$ /V·s, Cgd = WLov Cox = $20 \times 0.05 \times 4.3$ we have = $4.3 \text{ fF VOV} = 0.2 \text{ V} \Rightarrow \text{fT} = \text{Csb0
Csb} = |\text{VBB}| 1 + \text{V0} = 20 = 9.4 \text{ fF } 2.5 1 + 0.7 \text{ gm fT} = 2\pi(\text{Cgs} + \text{Cgd}) = 1.3 \times 10 - 3 = 3.1 \text{ GHz} 2\pi(61.6 + 4.3) \times 10 - 15 (1) 3 \times 450 \times 108 \times 0.2 4\pi \times 10^{-15} (1) 3 \times 450 \times 108 \times 0.2 4\pi \times 10^{-15} (1) 3 \times 450 \times 108 \times 0.2 4\pi \times 10^{-15} (1) 3 \times 450 \times 108 \times 0.2 4\pi \times 10^{-15} (1) 3 \times 450 \times 108 \times 0.2 4\pi \times 10^{-15} (1) 3 \times 450 \times 108 \times 0.2 4\pi \times 10^{-15} (1) 3 \times 450 \times 108 \times 0.2 4\pi \times 10^{-15} (1) 3 \times 10^{-15} (1) 3 \times 450 \times 108 \times 0.2 4\pi \times 10^{-15} (1) 3 \times 10^{-15} (1) 3 \times 450 \times 108 \times 0.2 4\pi \times 10^{-15} (1) 3 \times 10^{-15} (1) 3 \times 450 \times 108 \times 0.2 4\pi \times 10^{-15} (1) 3 \times 10^$ $0.52 = 5.73 \text{ GHz VOV} = 0.4 \text{ V} \Rightarrow \text{fT} = 3 \times 450 \times 108 \times 0.4 \text{ 4}\pi \times 0.52 = 11.46 \text{ GHz } 9.15 \text{ fT} = \text{gm } 2\pi(\text{Cgs} + \text{Cgd}) \text{ For Cgs} (2) \text{ Chapter } 9-8 9.17 \text{ fT} = \text{The transconductance gm is given by}$ W ID gm = 2µn Cox L (3) where IC 0.5 mA = 20 mA/V VT 0.025 V gm = Substituting from (2) and (3) into (1), we get W ID 2µn Cox L fT = 2 2 $\pi \times$ WLCox 3 1.5 µn ID = Q.E.D. πL 2Cox WL gm 2 π (C $\pi + C\mu$) C $\pi = 8 pF C\mu = 1 pF$ Thus, We observe that for a given device, fT is proportional to ID; thus to obtain faster operation the MOSFET is operated at a higher ID. To reduce the gain to half this value, we use 1 Rs = 2 gm \Rightarrow Rs = 2 gm 8.19 Refer to Fig. 0.5 mA (c) For RB = 1 k, we assume saturation-mode operation: VB = VE + 0.2 5 - (VE + 0.2) IC = 4.8 - VE 1 VE IE = = VE 1 These values can be substituted into (b) 3 V 3.6 k ~ 0.5 mA V3 3 0.5 3.6 1.2 V ~ 0 IB IE = IB + IC VE 0.7 V to obtain 4.7 k VE = 4.3 - VE + 4.8 - VE I 4 0.7 (3) $0.5 \text{ mA } 4.7 \Rightarrow$ VE = 3 V VB = 3.7 V 3 V C hapter 4-19 3 V a (d) 3 V (c) 3 1.45 6.2 0.25 mA IE 0.5 mA 3.6 k V8 0.75 V ~ 0 mA V7 3 0.5 3.6 1.2 V 43 k 6.2 k 110 k IB 0 V6 V5 0.7 V 0 V9 3 0.25 10 0.5 V 0.75 V 4.7 k IE 0.7 (-3) 4.7 0.5 mA 3 V 10 k 0.25 mA 3 V 3 V (e) 6 480 (-3) 4.7 k VE = 4.3 - VE + 4.8 - VE I 4 0.7 (3) 0.5 mA 4.7 \Rightarrow VE = 3 V VB = 3.7 V 3 V C hapter 4-19 3 V a (d) 3 V (c) 3 1.45 6.2 0.25 mA IE 0.5 mA 3.6 k V8 0.75 V ~ 0 mA V7 3 0.5 3.6 1.2 V 43 k 6.2 k 110 k IB 0 V6 V5 0.7 V 0 V9 3 0.25 10 0.5 V 0.75 V 4.7 k IE 0.7 (-3) 4.7 0.5 mA 3 V 10 k 0.25 mA 3 V 3 V (e) 6 480 (-3) 4.7 k VE = 4.3 - VE + 4.8 - VE I 4 0.7 (-3) 4.7 v 0 mA V 7 3 0.5 mA 3 V 10 k 0.25 mA 3 V 3 V (e) 6 480 (-3) 4.7 v 0 mA V 7 3 0.5 mA 3 V 10 k 0.25 mA 3 V 3 V (e) 6 480 (-3) 4.7 v 0 mA V 7 3 0.5 mA 3 V 10 k 0.25 mA 3 V 3 V (e) 6 480 (-3) 4.7 v 0 mA V 7 3 0.5 mA 3 V 10 k 0.25 mA 3 V 3 V (e) 6 480 (-3) 4.7 v 0 mA V 7 3 0.5 mA 3 V 10 k 0.25 mA 3 V 3 V (e) 6 480 (-3) 4.7 v 0 mA V 7 3 0.5 mA 3 V 10 k 0.25 mA 3 V 3 V (e) 6 480 (-3) 4.7 v 0 mA V 7 3 0.5 mA 3 V 10 k 0.25 mA 3 V 10 k 0.25 mA 3 V 3 V (e) 6 480 (-3) 4.7 v 0 mA V 7 3 0.5 mA 3 V 10 k 0.25 mA 3 V 3 V (e) 6 480 (-3) 4.7 v 0 mA V 7 3 0.5 mA 3 V 10 k 0.25 mA 3 V 10 k 0.25 mA 3 V 3 V (e) 6 480 (-3) 4.7 v 0 mA V 7 3 0.5 mA 3 V 10 k 0.25 mA 3 V 10 0.0125 mA I 3 1.45 IE 0.25 mA 6.2 6.2 k 180 k V11 0.75 0.7 1.45 V V10 3 0.0125 300 0.75 V 0 V12 3 10 0.25 10 k 0.5 V 300 k 0.25 mA 3 V 4.56 (a) 3 V IC a 0.5 0.495 mA 3.6 k VB 0.005 43 0.215 V V2 3 0.495 3.6 1.218 V 43 k IB 0.5 101 0.005 mA V1 0.215 0.7 0.915 V 0.5 mA 3 V (a) See solution and answer on the figure, which corresponds to Fig. Thus 1 W 2 VOVN I3 = μ n Cox 2 L I3 = (1) (2) Equating Eqs. 200 β = = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 10 = 9.95 mA VC = IC RC = 9.95 \times 0.1 k = 0.995 \times 0.1 (which is greater than the required minimum of 10 mV). Thus, RC vo Q1 vi Q2 ID1 = ID2 = 0.5 mA 1 W 2 VOV ID1,2 = $\mu \text{ Cox } 2 \text{ L } 1 \text{ 2} \times 2.5 \times \text{VOV } 2 \Rightarrow \text{VOV } = 0.632 \text{ V } 0.5 = \text{re1 Rin2}$ re2 v e1,2 re2 1 = = vi re1 + re2 2 αRC vo = v e1,2 re2 VCM = VGS + 1 mA × RSS = Vt + VOV + 1 × RSS = $0.7 + 0.632 \text{ V } 12 \times 2.5 \times \text{VOV } 2 \Rightarrow \text{VOV } = 1.58 \text{ mA/V} = 1.58 \text{ mA$ VOV 0.632 Thus, (b) gm = 1 α RC α RC vo = x = vi 2 re2 2re Ad = gm RD which is identical to the expression found in (a) above. The emitter current becomes 0.23 mA at IE = VB - 0.7 - (-3) = VB + 2.3 1 VC = VE + VCEsat = VB - 0.5 IC = 3 - (VB - 0.5) = 3.5 - VB 1 IB = IE - IC = 2 VB - 1.2 IC 3.5 - VB = = 2 IB 2 VB - 1.2 = 2 IB 2 VB - 1.2 = 2 IB 2 VB - 1.2 IC 3.5 - VB = = 2 IB 2 V $VB = +1.18 VVB = -3 + 0.23 \times 1 + 0.7 = -2.07 V 4.50$ Refer to the circuit in Fig. The circuit can - be analyzed by looking at v + O and v O separately. The voltage across the current source becomes W 2 1 µn Cox VOV 2 L 5 1 2 × VOV 0.1 = × 0.4 × 2 0.4 = VOV = 0.2 V (a) VCS = 2.5 - VDS - IRS VGS = Vt + VOV = 0.5 + 0.2 = 0.7 ID = (1) To keep a cross the current source becomes W 2 1 µn Cox VOV 2 L 5 1 2 × VOV 0.1 = × 0.4 × 2 0.4 = VOV = 0.2 V (a) VCS = 2.5 - VDS - IRS VGS = Vt + VOV = 0.5 + 0.2 = 0.7 ID = (1) To keep a cross the current source becomes W 2 1 µn Cox VOV 2 L 5 1 2 × VOV 0.1 = × 0.4 × 2 0.4 = VOV = 0.2 V (a) VCS = 2.5 - VDS - IRS VGS = Vt + VOV = 0.5 + 0.2 = 0.7 ID = (1) To keep a cross the current source becomes W 2 1 µn Cox VOV 2 L 5 1 2 × VOV 0.1 = × 0.4 × 2 0.4 = VOV = 0.2 V (a) VCS = 2.5 - VDS - IRS VGS = Vt + VOV = 0.5 + 0.2 = 0.7 ID = (1) To keep a cross the current source becomes W 2 1 µn Cox VOV 2 L 5 1 2 × VOV 0.1 = × 0.4 × 2 0.4 = VOV = 0.2 V (a) VCS = 2.5 - VDS - IRS VGS = Vt + VOV = 0.5 + 0.2 = 0.7 ID = (1) To keep a cross the current source becomes W 2 1 µn Cox VOV 2 L 5 1 2 × VOV 0.1 = × 0.4 × 2 0.4 = VOV = 0.2 V (a) VCS = 2.5 - VDS - IRS VGS = Vt + VOV = 0.5 + 0.2 = 0.7 ID = (1) To keep a cross the current source becomes W 2 1 µn Cox VOV 2 L 5 1 2 × VOV 0.1 = × 0.4 × 2 0.4 = VOV = 0.2 V (a) VCS = 2.5 - VDS - IRS VGS = Vt + VOV = 0.5 + 0.2 = 0.7 ID = (1) To keep a cross the current source becomes W 2 1 µn Cox VOV 2 L 5 1 2 × VOV 0.1 = × 0.4 × 2 0.4 = VOV = 0.2 V (a) VCS = 2.5 - VDS - IRS VGS = Vt + VOV = 0.5 + 0.2 V (a) VCS = 2.5 - VDS - IRS VGS = Vt + VOV = 0.5 + 0.2 V (a) VCS = 2.5 - VDS - IRS VGS = Vt + VOV = 0.5 + 0.2 V (a) VCS = 2.5 - VDS - IRS VGS = Vt + VOV = 0.5 + 0.2 V (a) VCS = 2.5 + 0.2 V (a) V VCS at least at 0.5 V, the maximum RS can be found from VS = $0 - VGS = -0.7 VRS = VS - (-1) - 0.7 + 1 = 3 k = ID 0.1 RD = 0.7 1 - VD 1 - 0.3 = = 7 k = ID 0.1 0.1 0.5 = 2.5 - 1 - 0.1 \times RSmax = 10 kV1 = 2.5 - 0.5 = 2 V (b) VCS = 1 - VDS - IRS 1 V which is identical to Eq. (1). (1) W = W1 = 10 \mu m$ \Rightarrow VSG = 1.05 V (2) W = W2 = 20 µm \Rightarrow VSG = 0.82 V (3) W = W3 = 40 µm \Rightarrow VSG = 0.82 V (4) W = W1 + W2 = 30 µm \Rightarrow VSG = 0.86 V (5) W = W1 + W3 = 50 µm \Rightarrow VSG = 0.80 V 7.6 Refer to the circuit of Fig. vO (V) Figure 3 10 t (s) 6.28 2.79 Each pulse provides a constant current of 1V through the capacitor and thus deposits a R 1V charge of \times 10 µs on the capacitor, resulting R in a change of -1 V in v O (t). If in the CC-CE amplifier of Example 7.7, Rsig = 400 k, Gv becomes Gv = 255 \times 0.99 \times -160 255 + 400 = -61.7 V/V Ex: 7.30 Ex: 7.28 2ID 2 × 0.2 = 2 mA/V gm = = VOV 0.2 gmb = χ gm = 0.2 × 2 = 0.4 mA/V ro1 = ro3 = VA 5 = 25 k = ID 0.2 RL = ro1 ro3 Rsig Q1 vsig Ex: 7.29 Q2 vo 1 = 25 25 2.5 k gmb = 2.083 k RL 2.083 vo = 0.81 V/V = = 1
1 vi RL + 2.083 vo = 0.81 V/V = = 1 1 vi RL + 2.083 vo = 0. $(\beta 1 + 1)[re1 + (\beta 2 + 1)(re2 + RE)]$ re1 + Rsig /($\beta 1 + 1$) Rout = RE re2 + $\beta 2 + 1$ vo = vsig RE re1 + Rsig /($\beta 1 + 1$) RE + re2 + $\beta 2 + 1$ For IE2 = 5 mA, $\beta 1 = \beta 2 = 100$, RE = 1 k, and Rsig = 100 k, we obtain 25 mV = 5 5 mA 5 5 = = 0.05 mA $\beta 2 + 1 101$ re2 = gm1 = 2k n ID $\sqrt{2} = 2 \times 8 \times 1 = 4$ mA/V 1 = 0.25 k gm1 gm2 = 40 mA/V 100 = 2.5 k 40 Rin = ∞ vsig vsig vi = = ib = 1 1 0.25 + 2.5 + rn 2 + rn 2 gm1 gm1 vsig = 2.75 100 × 4 vsig vo = $-\beta$ ib RL = -2.75 rn 2 = IE1 25 mV = 500 0.05 mA Rin = 101 × (0.5 + 101 × 1.005) = 10.3 M 0.5 + (100/101) 1 + 0.005 + 101 = 0.98 V/V Ex: 7.31 Refer to Fig. Replacing the MOSFET with its T model results in the circuit shown in the figure. 20 200 k or 20 log 83.3 = 38.4 dB Ap = vo RL 100 v s v o /100 = $0.69 \times 1.2 \times 104$ v s /1.2 M vo = 8280 A/A or Power gain = v 20 /100 v 2s /1.2 M 78.4 dB = 5713 W/W or 10 log 5713 = 37.6 dB vo 100 10 k × 1000 × = vs 10 k + 100 k 100 × = vs 10 k + 100 k 100 × = 8.26 V/V = 110 1100 The signa loses about 90% of its strength when connected to the amplifier input (because Ri = Rs /10). The diode starts conduction at Ex: 3.18 v S = VD = 0.7 V $\sqrt{122}$ sin θ = 0 $180 - \theta$. 2ID 2I = VOV VOV 2I $0.25 \Rightarrow$ I = 0.25 mA 2 = For identical transistors, Ro = (gm ro)ro = 2VA2 2VA VA = VOV I VOV I 2VA2 200 = $0.25 \times 0.25 \Rightarrow$ VA = 2.5 V VA = VA L L = IRo = 2|VA| |VA| × |VOV | I 2.5 VA = 0.25 m VA 5 To obtain W/L, we use 1 W 2 VOV ID = I = µn Cox 2 L W 1 × 100 V I 2VA2 200 = $0.25 \times 0.25 \Rightarrow$ VA = $0.25 \times 0.25 \times 0.25 \Rightarrow$ 0.252 250 = × 400 × 2 L W = 20 ⇒ L To obtain maximum negative signal swing at the output, we select VG so that the controlled-source gm vgs appears across its control voltage vgs, we can replace it by a resistance 1/gm, as indicated. Therefore: v = 1 - 2|VA| RSS Chapter 8-46 and the output resistance will be rof. $v = 0.7 + 2.3 \times 0.025 \log 1 V - 0.7 RV - 0.6 Using v D = 0.6 V$, $\Rightarrow iD1 = 0.6882 V 1 - 0.6882 = 0.6235 mA 4 i = 0.5 k Stop as we are getting the same result. P1.19. 3 below. Chapter 4-17 If with RB = 100 k, we need the voltages to remain at$ the values obtained with RB = 20 k, the transistor must have a β value determined as follows. v be1 = 2.5 sin(ω t), mV and v be2 = -2.5 sin(\omegat), mV and v be2 = -2.5 sin(ω t), mV an $0.25 \text{ gm} = I \text{ I v C1} = 5 - \times 10 - \times 10 \times 2.5 \times 10 - 3 \sin(\omega t) 2 0.05 = 5 - 5I - 0.5I \sin(\omega t) (a) \text{ Ad} = \text{gm RC} = 10 \times 5 = 50 \text{ V/V}$ To ensure operation in the active mode at all times with v CB = 0 V, we use where we have neglected the effect of ro since ro RC. 9.10(a), we determine $\tau C1$ as $\tau C1 = CC1$ [(RB rn) + Rsig] To make the contribution of CC1 to the determination of fL equal to 10%, we use 1 = $0.1 \times 2\pi FL \tau C1 \Rightarrow \tau C1 = re = Io RG 1 2\pi CC1 (RG + Rsig) P1 = RD 1 = 15.92 \times 10-3 \Rightarrow CC1 = 0.38 \mu F Select CC1 = 0.5 \mu F. P2.2. v + = vI \times vO = Rm Gm v2 - v1$ Rmi vO 1 k 1 = vI 1 k + 1 M 1001 v2 1 v O = Av + = Av I 1001 vO A = 1001 vI Gmv2 4 1 A = 4004 V/V = 1001 × 2.5 Refer to Fig. v = 0.7 V 1 - 0.7 = 0.6 mA 1 i = 0.5 k Chapter 3-10 2. gm1 = 21 2ID 2 × 0.1 = = 1 mA/V |VOV| |VO Ro = (gm2 ro2)(ro1 rn2) For |VA| = 5 V and $\beta = 50$ we obtain 5/0.025 1 Av = - = -4000 V/V 2 (0.025/5) + (1/50) 7.74 (a) Refer to circuit in Fig. This is especially pronounced for v id > 20 mV. P5.56(d) with the 10- μ A current source replaced with a 400-k resistor. It follows that the first frequency (10 kHz) is less than fb. Rsig 20 k Ro 100 vsig vi Rin 100 k Av ovi RL vo 2 k Av o 100 Chapter 6-20 This figure belongs to Problem 6.55. = $100 \ \mu m 2 = 100 \times 10 - 3 \ w 0 = VT$ at 300 K = $25.9 \ w V = W$ W, where junction area × $0.328 \times 10 - 4$ Using Eq. (1.46), built-in voltage V0 is obtained: NA ND = $25.9 \times 10 - 3 \times V0 = VT$ ln n2i $1017 \times 1016 \ln 2 1.5 \times 1010 \text{ Holes } QJ = 100 \times 10 - 8 \times 1.6 \times 10 - 19 1.85 \text{ From Table 1.3}, \text{ NA ND NA + ND}$ xp xn Electrons 11 + NA ND Since NA ND, we have W V0 = 2 s 1 V0 q ND qND 2 · W 2 s V0, $1017 \cdot 1016 1017 +
1016 1017 + 1016 1017 + 1016 1017 + 1016 1017 + 1016 1017 + 1016 1017 + 1016 1017 + 1016 1017 + 1016 1017 + 1016 1017 + 1016 1017 + 1016 1017 + 1016 1017 + 1016 1017 + 1016 1007 + 1007 + 1$ \times 0.2 \times 10-4 2 \times 1.04 \times 10 -12 = 0.31 V NA ND QJ = Aq W \sim = AqND W NA + ND since NA ND, we have QJ = 3.2 fC. 1.45 In Example 1.3, when the first and the second stages are interchanged, the circuit looks like the figure above, and v i1 100 k = 0.5 V/V = vs 100 k + 100 k Av 1 = v i2 1 M = 100 \times v i1 1 M + 1 k = 99.9 V/V v i3 10 k = 10 \times v $i2\ 10\ k + 1\ k\ vL\ 100\ = 0.909\ V/V\ = 1\times\ v\ i3\ 100\ + 10$ Total gain = Av = vL = Av\ 1\times\ Av\ 2\times\ Av\ 3\ v\ i1\ = 99.9\times9.09\times9.09\ \times 0.909\ = 825.5\ V/V The voltage gain from source to load is vL vL v i1 v i1 = x = Av \cdot vs\ v\ i1\ vS\ vS\ = 825.5\times0.5\ = 412.7\ V/V The overall voltage has reduced appreciably. P8.48. 7.68 VDD 1.8 V VG1 Q1 ro1\ 1.6 V\ 1\ v^2\ 1\ = -\times20\ \times\ vi $= -10 \times 5 = -50 \text{ mV } 2$ Thus, v1 is a 50-mV peak sine wave that is 180° out of phase with vi . 1.24(a) with the 3-dB frequency To (s) = f0 = 102 Hz. which is an HP, with = -Gm (R2 R3) s s + 1 C2 (R2 + R3) Chapter 1-25 3-dB frequency To (s) = f0 = 12 Hz. which is an HP, with = -Gm (R2 R3) s s + 1 C2 (R2 + R3) Chapter 1-25 3-dB frequency = 1 2 \pi C 2 (R2 + R3) Ri ≥ Rs f0 = 11 + × - 909.1 × s 2 \pi × 159 × 103 s s + (2 \pi × 14.5) 20 dB/decade 159 kHz (1) 1 1 + RL R0 1 1 $\geq 2\pi$ CL f3dB - Ro RL Ro \leq (a) To satisfy constraint (1), namely, x Vs Vi $\geq 1 - 100$ 1 2π f3dB CL - (4) 1 RL (c) To satisfy constraint (c), we first determine the dc gain as we substitute in Eq. (1) to obtain x Ri $\geq 1 - \text{Rs} + \text{Ri 100}$ (2) dc gain = Ri Gm (Ro RL) Rs + Ri For the dc gain to be greater than a specified value A0, Thus 1 Rs + Ri \leq x Ri 1 - 100 Ri Gm (Ro RL) \geq A0 Rs + Ri The first factor on the left-hand side is (from constraint (2)) greater or equal to (1 - x/100). 3 V 3 V IE IE 6.2 k 6.2 k 180 k V11 VBB V10 3 V V12 IC 10 k 3 V (e) (e) See figure above. so, 0.4 V \leq vO \leq 1.35 V. 4.22 and let VBB = 1.7 V. Diode has 0.7 V drop at 1 mA current VO = 1.5 V when RL = 1.5 k ID = IS $eV/VT 1 \times 10-3 = IS e0.7/0.025 \Rightarrow IS = 6.91 \times 10-16 A 1.5 = 0.75 V$. Since VC1, 2 = 0.4 V, VEmax = 0.4 - 0.3 = 0.1 V and 8.27 Refer to Fig. Thus, the maximum amplitude of input sine wave is (1.61 - 1.5) = 0.11 V. Thus, gm = I 10 $\mu A = = 0.4 \text{ mA/V VT} 25 \text{ mV rn} = \beta 100 = = 250 \text{ k gm} 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V VT} 25 \text{ mV rn} = \beta 100 = = 250 \text{ k gm} 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V VT} 25 \text{ mV rn} = \beta 100 = = 250 \text{ k gm} 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M I } 10 \ \mu A = = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M } A = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M } A = 0.4 \text{ mA/V ro} = 10 \text{ V } A = = 1 \text{ M } A = 0.4 \text{ mA/V ro} = 10 \text{ V } A = 10 \text{ mA/V ro} = 10 \text{ mA/V ro} = 10 \text{ M } A = 10 \text{ mA/V ro} = 10 \text{ M } A = 10 \text{ mA/V ro} = 10 \text{ mA/V$ + ie1 re1 $\alpha VT \alpha VT$ + ie 2(1 - α)IREF IREF VT VT vx = α ie + IREF IREF = 2(1 - α)ie (1) A0 = gm ro = VA 10 V = 400 V/V = VI 0.025 V Chapter 7-10 For I = 100 μ A = 4 mA/V 25 mV 100 = 25 k rn = 4 mA/V gm = Rin = rn = β 100 = 5 k gm 20 mA/V Av o = -A0 = -gm ro = -20 \times 200 = -4000 V/V 10 V = VI 0.025 V Chapter 7-10 For I = 100 μ A = 4 mA/V 25 mV 100 = 25 k rn = 4 mA/V gm = Rin = rn = β 100 = 5 k gm 20 mA/V Av o = -A0 = -gm ro = -20 \times 200 = -4000 V/V 10 V = VI 0.025 V Chapter 7-10 For I = 100 μ A = 4 mA/V gm = Rin = rn = β 100 = 5 k gm 20 mA/V Av o = -A0 = -gm ro = -20 \times 200 = -4000 V/V 10 V = VI 0.025 V Chapter 7-10 For I = 100 μ A = 4 mA/V gm = Rin = rn = β 100 = 5 k gm 20 mA/V Av o = -A0 = -gm ro = -20 \times 200 = -4000 V/V 10 V = VI 0.025 V Chapter 7-10 For I = 100 μ A = 4 mA/V gm = Rin = rn = β 100 = 5 k gm 20 mA/V Av o = -A0 = -gm ro = -20 \times 200 = -4000 V/V 10 V = VI 0.025 V Chapter 7-10 For I = 100 μ A = 4 mA/V gm = Rin = rn = β 100 = 5 k gm 20 mA/V Av o = -A0 = -gm ro = -20 \times 200 = -4000 V/V 10 V = VI 0.025 V Chapter 7-10 For I = 100 \muA = 4 mA/V gm = Rin = rn = β 100 = 5 k gm 20 mA/V Av o = -A0 = -gm ro = -20 \times 200 = -4000 V/V 10 V = VI 0.025 V Chapter 7-10 For I = 100 \muA = 4 mA/V gm = Rin = rn = β 100 = 5 k gm 20 mA/V Av o = -A0 = -gm ro = -20 \times 200 = -4000 V/V 10 V = -200 \muA = 0 mA/V av 0 = -400 V/V = -200 \muA = 0 mA/V av 0 = -400 V/V = -200 \muA = -400 V/V = -200 h = -200 \muA = -400 V/V = -400 V 100 k ro = $100 \mu \text{A}$ Ro = ro = 200 k A0 = $4 \text{ mA/V} \times 100 \text{ k} = 400 \text{ V/V}$ To raise Rin by a factor of 5 by changing I, the value of I must be lowered by the same factor to I = 0.1 mA. A supply voltage VCC = 10 V will certainly be sufficient. Thus the waveform looks as follows: v 1V T 0 Lowest value = 0 V ... Figure 3 Thus, Figure 2 Rin = 20 k Rib = 20 k (β + 1) (Re + 2) From Fig. $0.1 \times 10-3 = -t 159 \times 10-12 = -0.63 \times 106 t$, V At the end of the pulse, $t = 10 \mu s$, resulting in v O (10 μs) = $-0.63 \times 106 \times 10 \times 10-6 = -6.3$ V See Fig. E3.2. 2.5 k 5 V (d) V0V 10 V v¹ = = 10 mA Ex: 3.3 ⁱD = R 1 k 1 dc component of v O = v⁰ O \pi 1 10 = v¹ = \pi \pi = 3.18 V 05 2.5 2 mA I 2.5 k 5 V (e) I 3V Ex: 3.4 0 V3V 2V (a) $0 1V 5 V I 2.5 k I 1 k 50 2 mA 2.5 (f) 3 mA 1 5 V V0V 1 k 0 3 V (b) 0 2 V 5 V 1 V 2.5 k I0A V5V I Ex: 3.5 Vavg = 10 \pi 10 10 k 50 + R = \pi = 1 mA \pi$ R = 3.133 k 51 1 4 mA I V1V Exercise 3-2 R 10 k Ex: 3.6 I2 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 × 25 × 10 - 3 × log 0.1 I2 II I2 V2 = V1 + 10 K Ex: 3.6 I2 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 × 25 × 10 - 3 × log 0.1 I2 II I2 V2 = V1 + 10 K Ex: 3.6 I2 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 × 25 × 10 - 3 × log 0.1 I2 II I2 V2 = V1 + 10 K Ex: 3.6 I2 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 × 25 × 10 - 3 × log 0.1 I2 II I2 V2 = V1 + 10 K Ex: 3.6 I2 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 × 25 × 10 - 3 × log 0.1 I2 II I2 V2 = V1 + 10 K Ex: 3.6 I2 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 × 25 × 10 - 3 × log 0.1 I2 II I2 V2 = V1 + 10 K Ex: 3.6 I2 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 × 25 × 10 - 3 × log 0.1 I2 II I2 V2 = V1 + 10 K Ex: 3.6 I2 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 × 25 × 10 - 3 × log 0.1 I2 II I2 V2 = V1 + 10 K Ex: 3.6 I2 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 V T log II At room temperature VT = 25 mV VCC 5 V 10 V2 - V1 = 2.3 V T log II At room temperature VT $2.3 \times VT \log I1 V2 - V1 = 2.3 \times VT \log Ex: 3.7 i = IS ev /VT (1) 1 (mA) = IS e (2) 0.7/VT Dividing (1) by (2), we obtain (v - 0.7)/VT \Rightarrow v = 0.7 + 0.025 ln(i) where i is in mA. Finally, from the loop containing v O, R2, RG, and R2: R2 v O = -2i1 1 + 2 R2 - 2i1 R2 RG R2 = -4i1 R2 1 + RG (1) Chapter 2-20 This figure belongs to Problem 2.66. For a$ 0.5-V step size, analog signals in the range ± 3.5 V can be represented. For VB = 5 V and 50- μ A current through RB2, we have = -17.1 V/V Ex: 6.39 To reduce v gs to half its value, the unbypassed Rs is given by Rs = 1 gm Rin = RB1 RB2 rn From the solution to Exercise 6.37 above, gm = 2 mA/V. P8.17 will be v od 1 = gm1 ro3 ro1 Ad = v id gm3 For Rs = 0, Since both sides of the amplifier are matched, this expression can be written in a more general way as 1 ro3,4 ro1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger
that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (b) Neglecting ro1,2 and ro3,4 (much larger that 1/gm3,4), gm1,2 Ad gm3,4 (much larger that 1/gm3,4), g the conduction angle of D2, $(\pi - 2\theta)$, where $3 = 30 \circ \theta = \sin - 16$ Thus vO = vI + 1 V 3.5 A B X 0 0 1 1 0 1 0 1 0 0 0 1 Y $\pi - 2\theta = 180 \circ - 60 = 120 \circ 0 1 1 1$ The average value of iB does not change. P5.51(d): Both transistors are operating in saturation at equal |VOV|. Because the voltages at their gates are zero and at their sources are -(Vt + VOV), each of Q3 and Q4 will be operating at an overdrive voltage equal to VOV. The results are given in the following table. Analysis of the circuit proceeds as follows: V2 = -0.7 V Chapter 4-24 IE1 = V2 - (-5) -0.7 + 5 = = $0.524 \text{ mA 8.2 8.2 IC1} = \alpha IE1 = 0.99 \times 0.524 = 0.52 \text{ mA}$ (b) For v I = +2 V, Q1 will be conducting and Q2 will be cut off, and the circuit reduces to that in Fig. dn(x) dx W n0 = 10 / (µm) 5 3 3 Dn = 35 cm2 / s = 35 × (104) 2 (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 8 5 A / µm 2 = 56 µA / µm NA NA = W ND NA + ND For In = 1 mA = Jn × A 1 mA 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 × 10 8 5 A / µm 2 = 56 µA / µm NA NA = W ND NA + ND For In = 1 mA = Jn × A 1 mA 10 / (µm) 5 3 3 Dn = 35 cm2 / s = 35 × (104) 2 (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 × 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 × 10 / (µm) 5 3 3 Dn = 35 cm2 / s = 35 × (104) 2 (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 × 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 × 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 / (µm) 2 / s - 6 = 56 × 10 × 35 × 10 / (µm) 2 / s - 6 = 56 × 10 / (µm) 2 / s - 6 = 56 × 10 / (µm) 2 / s - 6 = 56 × 10 / (µm) 2 / s - 6 = 56 × 10 / (µm) 2 / (µm) 2 / s - 6 = 56 × 10 / (µm) 2 / (µm) number of terminals required by a quad op amp is 14: each op amp requires two input terminals and one output terminals for the four op amps). VE = 0.43 - 0.1 VE + 4.8 - VE = 2.5 VVC = 2.7 VIC VB = 3.2 V5 - 3.2 = 0.18 mA IB = 105 - 2.7 = 2.3 mA IC = 12.8 IB 0.18 3 V (a) 0.5 mA 3.6 kV23 0.5 3.6 1.2 V 43 k IB 0 0V V1 0.7 V which is lower than the value of β , verifying saturation-mode operation. From the table of 5% resistors in Appendix J we select RE = 4.7 k VB = VE + 0.7 = 2.86 V RC = 3.91 k For these values, (b) For RB = 10 k, IE = 4.3 = 3.91 m 10 1+ 101 VE = 3.91 v VB = 3.91 vmA 4.7 Assuming active-mode operation, we obtain IC IE = 0.49 mA IC = α IE = $0.99 \times 3.91 = 3.87$ mA VBC = $0 - VC = -(-3 + 0.49 \times 3.9) = -1.1$ V VC = 5 - 3.87 = +1.13 V Chapter 4-18 Since VC < VB - 0.4, the transistor is operating in saturation, contrary to our original assumption. 5.39 Refer to the circuits in Fig. P5.52(h). Since ro2 = ro4 = -0.49 ∞ , the resistance at this node is equal to the input resistance of Q5 which is Rn5, $rn5 = \beta$ gm5 Chapter 8-41 where gm5 = IC5 0.5 = 20 mA/V VT 0.025 ic3 5 k thus rn 5 ib3 Q3 100 = = 5 k 20 v b5 = -Gm rn 5 v id = -8 × 5 = -40 V/V The voltage gain of the second stage is A2 = v c5 = -gm5 RC v b5 where RC5 is the total resistance in the collector of Q5. PMOS Sat. (d) (i) vO = 0 V vO vO 5V 5V t t Vp + = 5 V, Vp - = 0 V, f = 1 kHz 2.5 V Vp + = 5 V, Vp - = -2.5 V, f = 1 kHz 2.5 V Vp + = 5 V, V = -2.5 V Vp + = 5 V, V = -2.5 V Vp + = 5 V, V = -2.5 V Vp + = 5 V, V = -2.5 V Vp + = 5 V, V = -2.5 V Vp + = 5 V, V = -2.5 V Vp + = 5 V Vp + = 5 V, V = -2.5 V Vp + = 5 V Vp + = 5 V Vp + = 5 V, V = -2.5 V Vp + = 5 V Vp + = 5 V Vp + = 5 V, V = -2.5 V Vp + = 5 V Vp= 11.2 IB 0.43 Since 11.2 is lower than the transistor is operating in saturation, as assumed. RC = 2.74 1 Vo (jω) = - Vi (jω) jωCR Vo = 1 $\angle \phi$ = +90° V ωCR i For C = 1 nF and R = 10 k, CR = 1 × 10-9 × 10 × 104 = 10-4 s 1 = 104 rad/s. Q1 Q5 Q6 Q7 Q8 112.5 5,7,8 W W W = = 25 L 5 L 7 L 8 1 W |VOV |2 ID6 = $200 = \mu p \cos 2 L 6$ W 1 200 = $\times 100 \times \times 0.04 2 L 6$ W = 100 L 6 Thus The results are summarized in the following table: A0 = A1 A2 = $-36 \times -36 = 1296$ V/V The upper limit of VICM is determined by the need to keep Q5 in saturation, thus VICM max = VDD - |VOV 5| - |VSG1| = 1.5 - 1.5 +
1.5 + 1.5 0.25 - 1 = +0.25 V The lower limit of VICM is determined by the need to keep Q1 and Q2 in saturation, thus VICM min = VG3 - |Vt| = -VSS + |VGS3| - |Vt| = -VSS + VOV 6 \le v O \le VDD - |VOV 7| Transistor Q1 W/L Q2 Q3 Q4 Q5 Q6 Q7 Q8 12.5 12.5 50 50 25 100 25 25 that is, -1.25 V $\le v O$ \leq +1.25 V Ideally, the dc voltage at the output is zero. Q2 VG2 (gm2ro2) ro1 1.4 V VG3 Q3 Ro = (gm3ro3) (gm2ro2) ro1 I 0.2 mA 1 v³ = - × 20 × 5 = -50 mV 2 Thus, v3 is a 50-mV peak sine wave, 180° out of phase relative to vi. VD = 0.025 ln 10-12 ID = 1 - 0.6638 = 0.3362 mA 1K 0.3362 = 0.6635 V 4. 100 = 2ID 2 × 10 = 80 µA/V = (a) gm = -20 × 10 = 80 µA/V = -20 × 10 = 80 µA/V = (a) gm = -20 × 10 µA/V = (a) gm = -20 × 10 µ VOV 0.25 VA 2ID 0.2 mA = 0.8 mA/V = VOV 0.25 V 7.36 A0 = |Av o| = 100 7.35 L = 0.36 μ m, VOV = 0.25 V, ID = 10 μ A ro = gm = 5 V/ μ m, we have L = 10 VA = 0.5 μ m = VA 20 1 W 2 k V 2 n L OV W 1 × 0.22 50 = × 200 × 2 L W $\Rightarrow = 12.5$ L ID = (b) If ID is increased to 100 µA (i.e., $\sqrt{\text{by a factor of 10}}$, VOV increases by a factor of 10 = 3.16 to 7.37 Refer to Fig. 3 V I = 0.133 mA I 2 k V = 0V 3.42 1 V D1 V 10 10 5 k 0.7 V V 2 V D2 Cutoff V = 1 + 0.7 = 1.7 V 3 - 1.7 = 0.65 mA I = 2 10 5 10 10 2.5 V I 20 k (a) Chapter 3-13 5 k V 5 k 0 mA 1.5 V 2.5 V Maximum allowable voltage signal change when the current change is limited to $\pm 10\%$ is found as follows: The current varies from 0.9 to 1.1 iD2 = eV /VT iD1 (b) For 0.9, V = 25 ln (0.9) = -2.63 mV 2.5 - 0.7 (a) I = $= 0.072 \text{ mA } 5 + 20 \text{ V} = 0.072 \times 20 = 1.44 \text{ V}$ For 1.1, V = 25 ln (1.1) = +2.38 mV For $\pm 10\%$ current change the voltage signal change is limited to $\pm 10\%$ is found as follows: The current varies from 0.9 to 1.1 iD2 = eV /VT iD1 (b) For 0.9, V = 25 ln (0.9) = -2.63 mV 2.5 - 0.7 (a) I = $= 0.072 \text{ mA } 5 + 20 \text{ V} = 0.072 \times 20 = 1.44 \text{ V}$ For 1.1, V = 25 ln (1.1) = +2.38 mV For $\pm 10\%$ current change the voltage signal change is limited to $\pm 10\%$ is found as follows: The current varies from 0.9 to 1.1 iD2 = eV /VT iD1 (b) For 0.9, V = 25 ln (0.9) = -2.63 mV 2.5 - 0.7 (a) I = $= 0.072 \text{ mA } 5 + 20 \text{ V} = 0.072 \times 20 = 1.44 \text{ V}$ For 1.1, V = 25 ln (1.1) = +2.38 mV For $\pm 10\%$ current change the voltage signal change is limited to $\pm 10\%$ current change the voltage signal change is limited to $\pm 10\%$ current change the voltage signal change is limited to $\pm 10\%$ current change the voltage signal change is limited to $\pm 10\%$ current change the voltage signal change is limited to $\pm 10\%$ current change is limited to $\pm 10\%$ current change the voltage signal change is limited to $\pm 10\%$ current change is lin the current change is limited to $\pm 10\%$ +2.38 mV (b) The diode will be cut off, thus I = 0 3.45 The dc current I flows through the diode VT and giving rise to the diode vT and giving rise to the diode resistance rd = I the small-signal equivalent circuit is represented by V = 1.5 - 2.5 = -1 V 3.43 Rs vI iD v I peak $- 0.7 \le 40 \text{ mA R} \sqrt{1202} - 0.7 \text{ R} \ge = 4.23 \text{ k} 40 \sqrt{\text{Reverse voltage}} = 1202 = 169.7 \text{ V}$. P6.48. vO VDD 1.0 200 V/V or 10 log AP = 23.8 dB Supply power = $2 \times 3 \text{ V} \times 20 \text{ mA} = 120 \text{ mW} \sqrt{v2}$ (2.2/2)2 = 24.2 mW Output power = orms = RL 100 24.2 = 0.1 mW (negligible) 242 Amplifier dissipation Supply power = 120 - 24.2 = 95.8 mW Amplifier dissipation Supply power = 120 - 24.2 = 95.8 mW Amplifier dissipation Supply power = $2 \times 3 \text{ V} \times 20 \text{ mA} = 120 \text{ mW} \sqrt{v2}$ (2.2/2)2 = 24.2 mW Output power = 120 - 24.2 = 95.8 mW Amplifier dissipation Supply power = $2 \times 3 \text{ V} \times 20 \text{ mA} = 120 \text{ mW} \sqrt{v2}$ (2.2/2)2 = 24.2 mW Output power = $2 \times 3 \text{ V} \times 20 \text{ mA} = 120 \text{ mW} \sqrt{v2}$ (2.2/2)2 = 24.2 mW Output power = 120 - 24.2 = 95.8 mW Amplifier dissipation Supply power = $2 \times 3 \text{ V} \times 20 \text{ mA} = 120 \text{ mW} \sqrt{v2}$ (2.2/2)2 = 24.2 mW Output power = $24.2 \times 100 = 20.2\%$ 120 RL RL + Ro 1.40 v o = Av o v i For ± 15 -V supplies, the largest undistorted sine-wave output is of 14-V peak amplitude or 9.9 Vrms. Eq. (2.58) is tr 2.2 × time constant = $\omega t A0 = 106 V/V$ or 120 dB Thus, tr 0.35 μ s The gain falls off at the rate of 20 dB/decade. Using a factor of safety of 1.5, then each of the four diodes must have PIV = $1.5 \times 25.7 = 38.6 \text{ V}$ 3.80 Refer to Fig. P7.75(a). (Otherwise the symmetry would be violated.) Thus each branch will carry a Vx = 1.05 k Ix 1.19 Refer to Fig. However, λ is divided in half; thus for v DS = 2 V, iD becomes 0.408 mA; for v DS = 2 V, iD becomes 0.412 mA; and for v DS = 10 V, iD becomes 0.44 mA. Had I1 and I2 been equal, then we would have had = 0.1 + for the given value of v BE. Thus the two 9 resistances can be made equal by connecting a R1 = $100 \text{ k} = 1.01 \text{ k} 9911 = 2\pi \times 105 = 1.58 \mu\text{F} 11 = 2\pi \times 100 \text{F} 11 =$ capacitor placed in series with the 1-k resistor results in 1 k 1 M VOS I VO VOS v - = v + = VOS VA = 2VOS = 6 mV I = VOS 6 mV = = 6 nA 1 M 1 M VO = VA + 1 M × I + = 2 VOS + 1 M × VA 1 k v + = v - = VOS VOS 2 VOS + 1 M 1 k No dc current flows through R1, C branch \therefore VO = VA + VOS = 2003 VOS = 3 VOS = 2003 × I M × I + = 2 VOS + 1 M × I + = 2 V $3 \text{ mV} = 3 \times 3 \text{ mV} \sim = 6V = 9 \text{ mV}$ For capacitively coupled input, 1 M I0 VA 2.95 1 M 1 M 1 k (1000/99) k VO VOS 100 = 1 + v + = v - = VOS I = 0 VO (a) VO = 200 \times 10 - 9 \times 1 \times 106 = 0.2 V VA = VOS VO = VA + 1 M \times R2 \Rightarrow R1 = 10.1 k R1 (b) Largest output offset is VOS = VOS + 1000VOS 1 k VO = 2 mV \times 100 + 0.2 V = 400 mV = 0.4 V Chapter 2-33 (c) For bias current compensation, we connect a resistor R3 in series with the positive input terminal of the op amp, with R3 = R1 R2, R3 = 10 k 1 M 10 k IOS = 0.4 V = 0.4 µA. vo 200 = $1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67
\text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v is $v = 1.67 \text{ V/V} = 10 \times \text{v}$ in 1 k + 200 v ii 1 v ii 1 v v in 1 k + 200 v ii 1 v v ii 1 v i V/V. Thus = ro2 + RL 1 + gm2 ro2 9 + 143.6 = 10.2 k 1 + 1.55 × 9 Rd 1 = ro1 Rin2 = 9 10.2 = 4.8 k A1 = -gm1 Rd 1 = -1.55 × 4.8 = -7.41 V/V Avc = -gm Ro -gm [(gm ro)ro] 7.67 Refer to Fig. For a dc voltage β + 1 101 drop across RB of 1 V, we obtain IB = The overall voltage gain can be found from Gv = $-\alpha v^{\circ} o = 40 v^{\circ}$ sig = 40 × 10 mV = 0.44 V/V Avc = -gm Ro -gm [(gm ro)ro] 7.67 Refer to Fig. For a dc voltage β + 1 101 drop across RB of 1 V, we obtain IB = The overall voltage gain can be found from Gv = $-\alpha v^{\circ} o = 40 v^{\circ}$ sig = 40 × 10 mV = 0.44 V/V Avc = -gm Ro -gm [(gm ro)ro] 7.67 Refer to Fig. For a dc voltage β + 1 101 drop across RB of 1 V, we obtain IB = The overall voltage gain can be found from Gv = $-\alpha v^{\circ} o = 40 v^{\circ}$ sig = 40 × 10 mV = 0.44 V/V Avc = -gm Ro -gm [(gm ro)ro] 7.67 Refer to Fig. For a dc voltage β + 1 101 drop across RB of 1 V, we obtain IB = The overall voltage gain can be found from Gv = $-\alpha v^{\circ} o = 40 v^{\circ} sig$ V 1V = 100 k 0.01 mA The result is a base voltage of -1 V and an emitter voltage of -1.7 V. 1.16(a). To calculate the output levels, we shall consider the discharge and its voltage is given by Maximum reverse voltage = -Vp + VD3 = -14.4 + 0.7 = -13.7 V v O(t) = 11.3 e-t/CR The same applies to the other three diodes. We utilize the results of (a) above as follows: At node 1 we have a resistance R to ground and, looking left, a resistance R. ID1 = IS1 eVD /VT (1) VD /VT (2) ID2 = IS2 e Summing (1) and (2) gives ID1 + ID2 = (IS1 + 10.2) (IS IS2) eVD /VT But ID1 + ID2 = I Thus I = (IS1 + IS2) eVD /VT (3) From Eq. (3) we obtain I VD = VT ln IS1 + IS2 Also, Eq. (3) can be written as IS2 I = IS1 eVD /VT 1 + IS1 (4) Chapter 3-7 ID1 = 10I S eVD1 /VT Now using (1) and (4) gives ID1 = I IS1 = I + (IS2 /IS1) IS1 + IS2 Taking the ratio of the two equations above, we have 7 1 V /V T 1 (VD2 -VD1 //VT ID2 = = e e ID1 3 10 10 70 = V = 0.025 ln = 78.7 mV 3 We similarly obtain ID2 = I IS2 = I 1 + (IS1 / IS2) IS1 + IS2 3.23 Connecting an identical diode in parallel would reduce the current in each diode by a factor of 2. Also, the maximum value of iL is approximately equal to its average value during the short interval t. P2.44: (a) Using superposition, we first set v P1 = v P2, . Smith. To obtain a gain of -16 V/V, we write re = 20 This figure belongs to Problem 6.65. Thus 6.92 (b) Vt = 2 V and k n = 1.25 mA/V2 ID = 0.73 mA VG = VD = 10 - 10 \times 0.73 = 2.7 V 1 \times 1.25(10 - 10ID - 2)2 \Rightarrow ID2 - 1.616ID + 0.64 = 0 ID = 5V ID = 0.92 mA or 0.695 mA RD ID 0 RG VD VG VGS The first root can be shown to be physically meaningless, thus ID = $0.695 \text{ mA VG} = VD = 10 - 10 \times 0.695 = 3.05 \text{ V} 6.94 \text{ VDD} 5 \text{ V} 1 \times 10(\text{VGS} - \text{Vt}) 2 \Rightarrow \text{VGS} = 1.2 \text{ V} 5 - 1.2 = 19 \text{ k} \text{ RD} = 0.2 \text{ ID} =$ the transistor leaves the saturation region of operation when v D < VOV, we select VD = VOV + 2 VGS = VDD - ID RD = 10 - 10 (a) Vt = 1 V and k n = 0.5 mA/V2 1 ID = k n (VGS - Vt) 2 2 VD = 2.5 V Since IG ID, we can write VDD - VD 5 - 2.5 = 2.5 k = RD = ID 1 VGS = Vt + VOV = 0.8 + 0.5 = 1.3 V Chapter 6-34 Thus the voltage drop across RG2 is 1.3 V and that across RG1 is (2.5 - 1.3) = 1.2 V. 8.41. P5.53(b), we can use the solution of part (a) above to write ID2 = 0.66 mA and VGS2 = 1.84 V Thus, 5.53 (a) Refer to the circuit in Fig. All transistors are operating at ID = IREF = 100 μ A and equal VOV, found from 1 W 2 VOV ID = μ n Cox 2 L For the current source in Fig. vO vO 0 V (h) 0 t t Neither D1 nor D2 conducts, so there is no output. Our work is considerably simplified by observing that this circuit is similar to that in Fig. 1.2 (a) $P = I 2 R = (20 \times 10 - 3) 2 \times 1 \times 103 = 0.4 W - 3 2$ (b) $P = I R = (40 \times 10) \times 1 \times 10 1.4$ See figure on next page, which shows that there are 17 possible resistance values: 5.7, 6.7, 8, 8.6, 10, 13.3, 14.3, 17.1, 20, 23.3, 28, 30, 40, 46.7, 50, 60, and 70 k. Thus 100 k v O = $-100(v^2 - v^1) 100 \text{ k} = 1 \sin(2\pi \times 1000t), V 2.38$ Using the circuit of Fig. Thus each of Q3 and Q4 will have an rDS given by un Cox Since (d) (i) Rs = 1 gm1, 2 VOV 3 = VOV 1, 2 rDS3, 4 = 0.5 gm1, 2 W L VOV 1 gm1, 2 (W/L)3, 4 Rs = rDS3 + rDS4 then 2 (W/L)1, 2 gm1, 2 W L VOV 3 = VOV 1, 2 rDS3, 4 = 0.5 gm1, 2 W L VOV 1 gm1, 2 (W/L)3, 4 Rs = rDS3 + rDS4 then 2 (W/L)1, 2 gm1, 2 W L VOV 3 = VOV 1, 2 rDS3, 4 = 0.5 gm1, 2 W L VOV 1 gm1, 2 (W/L)3, 4 Rs = rDS3 + rDS4 then 2 (W/L)1, 2 gm1, 2 W L VOV 3 = VOV 1, 2 rDS3, 4 = 0.5 gm1, 2 W L VOV 3 = VOV 1, 2 rDS3, 4 = 0.5 gm1, 2 W L VOV 1 gm1, 2 (W/L)3, 4 Rs = rDS3 + rDS4 then 2 (W/L)1, 2 gm1, 2 W L VOV 3 = VOV 1, 2 rDS3, 4 = 0.5 gm1, 2 W L VOV 1 gm1, 2 (W/L)3, 4 Rs = rDS3 + rDS4 then 2 (W/L)1, 2 gm1, 2 W L VOV 3 = VOV 1, 2 rDS3, 4 = 0.5 gm1, 2 W L VOV 1 gm1, 2 (W/L)3, 4 Rs = rDS3 + rDS4 then 2 (W/L)1, 2 gm1, 2 W L VOV 3 = VOV 1, 2 rDS3, 4 = 0.5 gm1, 2 W L VOV 1 gm1, 2 (W/L)3, 4 Rs = rDS3 + rDS4 then 2 (W/L)1, 2 gm1, 2 W L VOV 3 = VOV 1, 2 rDS3, 4 = 0.5 gm1, 2 W L VOV 1 gm1, 2 (W/L)3, 4 Rs = rDS3 + rDS4 then 2 (W/L)1, 2 gm1, 2 W L VOV 3 = VOV 1, 2 rDS3, 4 = 0.5 gm1, 2 W L VOV 1 gm1, 2 (W/L)3, 4 Rs = rDS3 + rDS4 then 2 (W/L)1, 2 gm1, 2 W L VOV 1 gm1, 2 W L VOV (W/L)3,4 Rs = (3) (b) With v G1 = v id /2 and v G2 = -v id /2 where v id is a small signal, Ad = v od v id 2 RD 1 1 + Rs + gm1 gm2 Using (3), we obtain Ad = 1 gm1,2 = RD 1 (W/L)3,4 8.21 Refer to Fig. If v sig = 0.2 V and we wish to keep v gs = 50 mV, 3 then we need to connect a resistance Rs = in gm the source lead. Therefore, we must use the exact expression for |A|, that is, $A0 1 + (10/fb) 2 = 20 \times 103 (1) A0 1 + (100/fb) 2 = 51 + (10/fb) 2 = 51$ $A0 \times fb = 25 \times 103 \times 25 \times 103 = 625$ MHz 2.103 Gnominal = $-50 \Rightarrow 10,000$ 2500 -2 = 24 fb fb 0.1 MHz = 10 kHz 10 (d) A0 = 100 V/V fb = Dividing Eq. (1) by Eq. (2), we have (c) A0 = 1800 V/V ft = A0 fb = $1800 \times 10 = 18$ MHz Substituting the given data, we obtain ft = A0 fb = $20 \times 105 \times 1 = 2$ MHz fb = A0 |A| = 1 + (f/fb) 2 10 = 1 Hz 10 R2 $= 50 \text{ R1} \text{ A0} = 104 7500 = 17.68 \text{ kHz} 24 \text{ ft} = 106 \text{ Hz} \text{ Now, substituting in Eq. (1) yields } A0 = 20 \times 103 1 + 10 17.68 \text{ f3dB of closed-loop amplifier} = 2 = 22,976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \times 103 \times 17.68 \times 103 = 406.2 \text{ MHz} = 106 \text{ Hz} \text{ Now, substituting in Eq. (1) yields } A0 = 20 \times 103 1 + 10 17.68 \text{ f3dB of closed-loop amplifier} = 2 = 22,976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \times 103 \times 17.68 \times 103 = 406.2 \text{ MHz} = 106 \text{ Hz} \text{ Now, substituting in Eq. (1) yields } A0 = 20 \times 103 1 + 10 17.68 \text{ f3dB of closed-loop amplifier} = 2 = 22,976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \times 103 \times 17.68 \times 103 = 406.2 \text{ MHz} = 106 \text{ Hz} \text{ Now, substituting in Eq. (1) yields } A0 = 20 \times 103 1 + 10 17.68 \text{ f3dB of closed-loop amplifier} = 2 = 22,976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0 fb = 22.976 \text{ V/V} and the unity-gain frequency is ft = A0$ 50 = 49.75 V/V For f = 0.1 f3dB, $|G| = \sqrt{1.01}$ For f3dB = 5 MHz, ft = 10 MHz 50 For f = 10 f3dB, $|G| = \sqrt{4.975}$ V/V 1 + 100 which is a 20-dB reduction. Rin RL Av o Gv = Rin + Rsig RL + Ro To limit this change to 5% of the value with RL = 2 k, we require 2 1 2 - = 0.05 2 + Ro 1 + Ro 2 + Ro 2 100 × 100 × 100 + 20 2 + 0.1 = 79.4 V/V vo io = further verification that this is a high-pass network and T(s) is a high-pass transfer function, see that as $s \rightarrow \infty$, T (s) = R2 /(R1 + R2). Ex: 1.10 Voltage gain = 20 log 100 = 60 dB Power
gain = 20 log 100 = 60 dB Power gain = 20 log 100 dB Power gain $= P1 + P3 + P5 + \cdots 24V 214V 1 = \sqrt{+\sqrt{R}R 2\pi 32\pi 24V 1 + \sqrt{+} + \cdots R52\pi 8111V2 \times 2 \times 1 + + + + \cdots = R\pi 92549 Ex: 1.11 Pdc} = 15 \times 8 = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 - 18 = 102 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 - 18 = 102 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 - 18 = 102 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 - 18 = 102 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 - 18 = 102 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 18 \text{ mW} 1 \text{ Pdissipated} = 120 \text{ mW} \sqrt{(6/2)2 PL} = 10 \text{ mW} \sqrt{$ that the infinite series in the parentheses has a sum that approaches $\pi 2/8$; thus P becomes V 2/R as found from direct calculation. (2)-(6) into Eq. (1) gives 0.48 - 0.1V + 0.183 - 0.033V = 0.1V - 0.05 + 0.05V + 0.1V - 0.07 IC 2.07 = 3.2 = IB 0.657 = V = 2.044 V which is lower than the value of β , verifying saturation-mode operation. Note that IZ = 0.5 mA, thus VZ = VZK VZ0 = 7.2 V I = (c) To obtain VO = 7.5 V, we must arrange for IZ = 10 mA (the current at which the zener is specified). With v icm applied to both input terminals, we can replace each of Q1 and Q2 with an equivalent circuit composed of a controlled current, v icm /2RSS in parallel with a very large output resistance (Ro1 and Ro2 which are equal). From Example 2.2 we have R2 vO = - vI R1 $(1 - x)R4 (1 - x)R4 + 1 + R2 R3 + xR4 \therefore R1$, $R2 \ge 20 k Rf$ Here = 2, if R1 = 20 k, $Rf = 40 k R1 Rf 1 = \Rightarrow R2 = 2Rf = 80 k R2 2$ The minimum gain magnitude is obtained when x = 1, 2.35 R2 vO = - = -1 vI R1 v1 Thus, R2 = 100 k. Thus the output follows the input. P4.25(a). At the end of the pulse, $t = 10 \mu s$, $v O(10 \mu s) = -100(1 - e - 10/159) = -6.1 V It C Beyond t = 10 \mu s$, the capacitor discharges through RF. $-28 V \le v O \le 28 V$, or 56 V P-P (d) The phase relation between input and output remains unchanged. $-I 2 \times 10 k = -I3 \times 100 = Vx R R/2 2 1 R/2 3 R/2 4$. $I = I2 \times 10 k 100 = 0.1 \times 100 I R II R I2 R I3 I4 = 10 mA$ Now IL = I2 + I3 = 10.1 mA and Vx = $-I2 \times 10 \text{ k} = -0.1 \times 10 \text{ k} = -1 \text{ V}$ (b) Vx = RL IL + VO = 10.1 RL + VO RL = Figure 1 (b) Vx - VO - 1 - (-13) = = 1.19 \text{ k} 10.1 \text{ mA} 10.1 (c) 100 \leq \text{RL} \leq 1 \text{ k} \text{ I R I 1 R 2 R I1} I OV 2I R/2 4I R/2 R I2 2I 3 8I R/2 4 IL stays fixed at 10.1 mA. However, 4 the currents in their ro 's are far from being equal! There are some inconsistencies that result from the approximations made to obtain the results shown in Fig. The pole (or 3-dB) frequency is Rin = R1 = 10 k dc gain = 40 dB = 100 \therefore 100 = R2 \Rightarrow R2 = 100R1 = 1 M R1 ω P = 1 (A0 + 1)CR The ideal integrator has ω P = 0. 5.9 Vtp = -0.7 V (a) |VSG| = |Vtp| + |VOV| = 0.7 + 0.4 = 1.1 V \Rightarrow VG = -1.1 V (b) For the p-channel transistor to operate in saturation, the drain voltage must not exceed the gate voltage by more than |Vtp|. (1) Chapter 7-21 (a) For Rout = 5 ro, Eq. (1) gives Re = 0.495 k 500. dt max 2 $\omega \times 10V$ imax = SR t Vimax = SR t Vimax = 10 $\times 106 = 0.795$ V $2\pi \times 200 \times 103 \times 10$ (c) Vi = 50 mV Vo = 500 mV = 0.5 V 2.114 Slope of the triangle wave = Thus $10 V = SR T/2 10 \times 2 = 20 V/\mu ST \Rightarrow T = 1 \mu s \text{ or } f = \Rightarrow f = 1 = 1 MHz T For a sine wave <math>vO = V^{\circ} o \sin(2\pi \times 1 \times 106 \times 1 2.115 \text{ v} O = 3.18 V 2\pi \times 106 \times 1 2.115 \text{ v} O = 10 \sin \omega t \Rightarrow = 10\omega \cos \omega t \Rightarrow Slew rate begins at the frequency for which <math>\omega \times 0.5 = SR$ dt max $\Rightarrow V^{\circ} o = SR$ dt dv O dt dv O dt max 10 × 106 = 3.18 MHz $2\pi \times 0.5$ However, the small-signal 3-dB frequency is f3dB = ft 1 + R2 R1 = $20 \times 106 = 2$ MHz 10 Thus the useful frequency range is limited to 2 MHz. (d) For f = 50 kHz, the slew-rate limitation occurs at the value of Vi given by $\omega i \times 108 = 3.18$ V = $10 \times 106 = 2$ MHz 10 Thus the useful frequency range is limited to 2 MHz. (d) For f = 50 kHz, the slew-rate limitation occurs at the value of Vi given by $\omega i \times 108 = 3.18$ V = $10 \times 106 = 2$ MHz $100 \times 106 = 2$ MHz $10 \times 106 \times 106 = 2$ MHz input voltage, however, would ideally result in an output of 31.8 V, which exceeds VOmax. Its peak value will be 60 mA. P7.74(c). (3) Substituting from Eqs. Since VCE = VCC - IC RC IC RC VT VA = 100 V Chapter 6-14 These figures belong to Problem 6.39. Therefore we express Vo /Vi in the alternate form Vo Y1 = Vi Y1 + Y2 1 + sC1 Vo R1 = 11 Vi + s(C1 + C2) R1 R2 1.73 The HP STC circuit whose response determines the frequency response of the amplifier in the low-frequency response of the amplifier in the low-frequency response determines the frequency response of the amplifier in the low-frequency response determines the frequency response of the amplifier in the low-frequency response determines the frequency response determines the frequency response of the amplifier in the low-frequency response determines the frequency response of the amplifier in the low-frequency response determines the frequency response det to the HP STC network, and thus its value is 1 C1 R1 1 1 is + + (C1 + C2) R1 R2 s + 1 + 10 100 2 = -0.04 dB Similarly, at the drop in gain f = 1 kHz is caused by the LP STC network, (b) which is lower than β , verifying that O2 is operating in saturation. When y I = 2 sin 104 t, the output will be a sine wave of the same frequency but phase-shifted by $-270\circ$ (or $+90\circ$), and its magnitude will be 2 V × integrator gain at $\omega = 104$ rad/s. Each transconductance amplifier has the following equivalent circuit: 10 + 1 = 1.1 mA Ais ii $= 1 \times 101.51$ vi Rs 1 k Ri 2 k vs vi Gmvi Ro RL Ro 10 k Gm 20 mA/V vo The parallel connection of the two amplifiers at the output and the connection of RL means that the total resistance at the output is RL = 1 k 10 k. The bulk of the dc offset at the output, that due to IB, can be reduced to zero by making the dc resistances seen by the two input terminals equal. Thus 7.80 re1 = re2 = re3 = 2.5 V VT IREF Analysis of the circuit proceeds as follows. Specifying the resistor values to the nearest kilohm results in RE = $4 \text{ k} \text{RB} = 50 \text{ k} \text{VCmax} = -5 + 0.98 \times 4 = -1.1 \text{ V} 4.59 \text{ Figure 1 on next page shows the circuit with } \beta = \infty$; the required voltage values are indicated. Thus, CMRR increases to about 80 dB. VO = 1.43 V (c) VO = 1.29 = 8.6 \text{ mA } 0.15 1.29 = 0.645 \text{ V} 2 \text{ As VSupply changes from 5 V to } 6.786 \text{ V} (a change of +35.4%) the output voltage changes from 1.39 V to 1.43 V (a change of +2.88%). (b) we have 9 V I = 11 - 7.2 = 19.3 mA 0.167 + 0.03 Thus I R VO = VZ0 + Irz VO VZ 0.5 mA IL RL = 7.2 + 0.0193 × 30 = 7.78 V To determine the smallest allowable value of RL
while VS = 9 V, refer to Fig. 8.113 Refer to Fig. 8 2Vx Vx = 2 k 1 k Between node 1 and ground, RTh = (1 k 1.2 k) = 0.545 k VTh = 10 × 1.2 = 5.45 V 1 + 1.2 Find the Thévenin equivalent of the circuit to the right of node 2. Correspondingly, IC will be = To obtain IC = 1 mA, we write 1 mA IC IB = = = 0.01 mA \beta 100 Thus, RB = VCC - VBE 3 - 0.7 = 230 k IB 0.01 Since \beta ranges from 50 to 150 and IB is fixed at 0.01 mA, the collector current IC will range from $0.01 \times 50 = 0.5$ mA to $0.01 \times 150 = 1.5$ mA. Thus, 8.97 Gm = gm1, 2 ro2 2(I/2) 0.2 = 1 mA/V = = 50 k I/2 0.1 1000 = 50 |Acm| = (1 - Am)Gmcm(Rom Ro2) = 25 k I/2 0.1 1000 = 50 |Acm| = 0.05 V/V But from Eq. (8.153), we obtain Ro = ro2 ro4 = $50 \text{ k} I/2 0.1 \times 100 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Rom Ro2}) = 25 \text{ k} I/2 0.1 1000 = 50 |\text{Acm}| = (1 - \text{Am})\text{Gmcm}(\text{Am}) = (1 - \text{Am}) = (1 - \text$ Since Rom Ro2 and Gmcm = 1/2RSS, we have Ad = Gm Ro = $1 \times 25 = 25 V/V$ | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S = 25 V/V | Acm | = (1 - Am) 5 |VA| = 278S =Ro2) ro3 = ro2 = ro4 = 50 k where Rim = 1 k 50 k = 0.98 k Gmcm = 1 1 = 0.011 mA/V 2RSS 2 × 45 Chapter 8-35 Using the fact that Ro2 Rom, we obtain IB = Acm $-(1 - 0.98) \times 0.011 \times 45 0.125 \text{ mA I}/2 = 1.25 \mu \beta + 1.100 = -0.01 V/V$ Ad CMRR = A The lower limit on VICM is determined by the lowest voltage allowed at the collector of Q5 mA I /2 = 1.25 \mu \beta + 1.100 = -0.01 V/V Ad CMRR = A The lower limit on VICM is determined by the lowest voltage allowed at the collector of Q5 mA I /2 = 1.25 \mu \beta + 1.100 = -0.01 V/V Ad CMRR = A The lower limit on VICM is determined by the lowest voltage allowed at the collector of Q5 mA I /2 = 1.25 \mu \beta + 1.100 = -0.01 V/V Ad CMRR = A The lower limit on VICM is determined by the lowest voltage allowed at the collector of Q5 mA I /2 = 1.25 \mu \beta + 1.100 = -0.01 V/V Ad CMRR = A The lower limit on VICM is determined by the lowest voltage allowed at the collector of Q5 mA I /2 = 1.25 \mu \beta + 1.100 = -0.01 V/V Ad CMRR = A The lower limit on VICM is determined by the lowest voltage allowed at the collector of Q5 mA I /2 = 1.25 \mu \beta + 1.100 = -0.01 V/V Ad CMRR = A The lower limit on VICM is determined by the lowest voltage allowed at the collector of Q5 mA I /2 = 1.25 \mu \beta + 1.100 = -0.01 V/V Ad CMRR = A The lower limit on VICM is determined by the lowest voltage allowed at the collector of Q5 mA I /2 = 1.25 \mu \beta + 1.100 = -0.01 V/V Ad CMRR = A The lower limit on VICM is determined by the lowest voltage allowed at the collector of Q5 mA I /2 = 1.25 \mu \beta + 1.100 = -0.01 V/V Ad CMRR = A The lower limit on VICM is determined by the lowest voltage allowed at the collector of Q5 mA I /2 = 1.25 \mu \beta + 1.100 = -0.01 V/V Ad CMRR = A The lower limit on VICM is determined by the lowest voltage allowed at the collector of Q5 mA I /2 = 1.25 \mu \beta + 1.100 = -0.01 V/V while Q5 is in the active mode. Thus fT at IC = 0.25 mA is fT = 9.19 rx = 100 The expressions for A0 and fT can be used to obtain their values of L. We require ID = 100 µA and ID = ±0.01. Ro io Rin vi Avovi io Norton vo equivalent of output circuit vi Avovi Ro Gmvi Rin (a) (b) Figure 1 Rsig vsig vi Figure 2 Rin Gmvi Ro RL vo Ro vo Chapter 6-21 6.58 Refer to Fig. VC = 1 RS + re (β + 1) If I RS RC · 2 (β + 1) I RS RC · 2 (β + model and graphical results is = 0.6637 - 0.6635 = 0.0002 V = 0.2 mV 3.33 i (mA) 500 2.0 Diode characteristic 1V $1.0 \ 0.8 \ 0.6 \ 0.4 \ 0.2 \ 0$ iv Load line $0.4 \ 0.6 \ 0.8 \ 1.0 \ v$ (V) From this sketch one can see that the operating point must lie between v = 0.65 V to v = 0.7 V i For i = 0.3 mA, v = VT ln IS $3 = 0.025 \times \ln 10 - 121 - 0.7 = 0.6$ mA 0.5 k b) Diode has 0.7 V drop at 1 mA current. t 0.6 mA 0.1 mA 0.5 mA 0.4 mA 0 t iB (A) IB ib 1 A 6 A 5 A 4 A 0 t 6.18 Av = - But Av = IC /VT For a transistor biased at IC = 0.5 mA, we have 0.5 gm = 20 mA/V 0.025 6.19 For this circuit: VCC = 10 V, $\beta = 100$, RC = 1 k, VA = 100 V, IB = $50 \mu \text{ A}$ (dc

bias), At v CE = 0, iC = β iB \therefore IC = 50 × 100 = 5 mA (dc bias) Given the base bias current of 50 mA, the dc or bias point of the collector current IC, and voltage VCE can be found from the intersection of the load Chapter 6-8 line and the transistor line L1 of iB = 50 μ A. Triode Chapter 5-10 IR \leq |Vt | Since VDG > 0, the MOSFET is in saturation. It consists of the series connection of 4 parallel diodes. Thus the overall voltage gain becomes 303.5 2.3 + 0.025 100 = 3378 V/V 152 + 100 Thus, although the output resistance of the original amplifier is loaded in 100resistance is much lower than that obtained with the modified design. Ad = gm RD 8.65 VOV 2 ID I = gm gm VOV RD = 2 RD VOV = I/2I = 1 k n (W/L) k (W/L) 2 n 0.1 = 0.224 V 0.2 × 10 RD RD VOV = 0.04 \Rightarrow VOS = RD 2 RD = For I = 160 μ A, we have $\sqrt{gm} = 4 \times 0.16 = 0.8$ mA/V Ad = 0.8 $\times 10 = 8$ V/V = 0.16 = 0.2 V 0.8 0.2 $\times 0.02 = 2$ mV VOS = 2 For I = 360 μ A, we have $\sqrt{\text{gm}} = 4 \times 0.36 = 1.2 \text{ m}/\text{V}$ VOV = $0.224 \times 0.04 = 4.5 \text{ m}/\text{V}$ 2 (W/L) = $0.04 \Rightarrow \text{VOS} = (W/L)$ (W/L) $0.224 \times 0.04 = 4.5 \text{ m}/\text{V}$ = $0.04 \Rightarrow \text{VOS} = 1.2 \text{ m}/\text{V}$ = $0.04 \Rightarrow 0.04 \Rightarrow 1.2 \text{ m}/\text{V}$ = $0.04 \Rightarrow 0.04 \Rightarrow 1.2 \text{ m}/\text{V}$ = $0.04 \Rightarrow 0.04 \Rightarrow 0.04 \Rightarrow 1.2 \text{ m}/\text{V}$ = $0.04 \Rightarrow 0.04 \Rightarrow 0.04 \Rightarrow 1.2 \text{ m}/\text{V}$ = $0.04 \Rightarrow 0.04 \Rightarrow 0.04$ both the gain and the offset voltage increase, and by the same factor (1.5). Ex: 3.16 For a zener diode VZ = VZ0 + IZ rZ 10 = $VZ0 + 0.01 \times 50$ VZ0 = 9.5×10^{-5} V For IZ = 20 mA, R IL VO VZ = 9.5×10^{-5} V For IZ = 10^{-5} V For IZ = $10^$ CMRR = 20 log A 2.72 (a) Comment: In circuit (a), the first stage amplifies the differential signal and the common-mode signal equalized by adding a 5-k resistor in series with the negative input lead of the op amp. 1.22: io R v2 gmv2 Vi Vo Vi C R v1 = v2 = 1 V v1 = 1.01 V v2 = 0.99 V For (a) Vo = Vi ·· vo = 100 × 5 × 0.02 = 10 V g22 I1 g12 I2 g21V1 V1 1/g11 I2 V2 Ro I1 V1 1/g11 I2 V2 Ro II V1 I/g11 I2 V2 Ro II V1 I/g1 AvoV1 V2 which is of the form shown for the low-pass function in Table 1.2 with K = 1 and $\omega 0 = 1/RC$. Q.E.D. E 6.44 Refer to Fig. Observe that combining MOSFETs or BJTs. The lowest voltage at the output while Q3 remains in saturation is VOmin = VG3 - Vt3 7.75 (a) Refer to the circuit in Fig. (1) and (3) simultaneously, we obtain which meet our specifications. Sat. The circled numbers indicate the order of the analysis steps. From Exercise 1.1, ni at DC gain = Gm (RL 80) = $10 \times (RL 50) T = 350 K = 4.15 \times 1011 / cm3 nn = ND = 1017 / cm3 To obtain a dc gain of at least 40 dB (i.e., 100), 10(RL 50) \ge 10 \times (RL 50) T = 350 K = 4.15 \times 1011 / cm3 nn = ND = 1017 / cm3 To obtain a dc gain of at least 40 dB (i.e., 100), 10(RL 50) \ge 10 \times (RL 50) T = 350 K = 4.15 \times 1011 / cm3 nn = ND = 1017 / cm3 To obtain a dc gain of at least 40 dB (i.e., 100), 10(RL 50) \ge 10 \times (RL 50) T = 350 K = 4.15 \times 1011 / cm3 nn = ND = 1017 / cm3 To obtain a dc gain of at least 40 dB (i.e., 100), 10(RL 50) \ge 10 \times (RL 50) T = 350 K = 4.15 \times 1011 / cm3 nn = ND = 1017 / cm3 To obtain a dc gain of at least 40 dB (i.e., 100), 10(RL 50) \ge 10 \times (RL 50) T = 350 K = 4.15 \times 1011 / cm3 nn = ND = 1017 / cm3 To obtain a dc gain of at least 40 dB (i.e., 100), 10(RL 50) \ge 10 \times (RL 50) T = 350 K = 4.15 \times 1011 / cm3 nn = ND = 1017 / cm3 To obtain a dc gain of at least 40 dB (i.e., 100), 10(RL 50) \ge 10 \times (RL 50) T = 350 K = 4.15 \times 1011 / cm3 nn = ND = 1017 / cm3 To obtain a dc gain of at least 40 dB (i.e., 100), 10(RL 50) \ge 10 \times (RL 50) T = 350 K = 4.15 \times 1011 / cm3 nn = ND = 1017 / cm3 To obtain a dc gain of at least 40 dB (i.e., 100), 10(RL 50) \ge 10 \times 1000 H (i.e., 100) = 10 \times (RL 50) = 10 \times 1000 H (i.e., 100) = 10 \times (RL 50) = 10 \times 1000 H (i.e., 100) =$ $100 \text{ ni2 pn} \sim = \text{ND} \Rightarrow \text{RL} \ge 12.5 \text{ k} = \omega 0 = (4.15 \times 1011) 2 1017 = 1.72 \times 106 / \text{cm3 1 CL} (\text{RL Ro}) 1 = \text{CL} (12.5 50) \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 100 \times 103$, the highest value allowed for CL is CL = V2 1 = 159.2 pF $2\pi \times 10 \times 103$, the highest value allowed for CL is CL = V2 1 = 159.2 pF $2\pi \times 104 \times 103$, the highest value allowed for CL is CL = V2 1 = 159.2 pF $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 1004 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 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\omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For } \omega 0$ to be a least $2\pi \times 104 \times 103 \text{ For }$ /cm3 106 \therefore NA = pp = ni2 np Exercise 1-6 = (1.5 × 1010) 2 1.5 × 104 = 1.5 × 10 / cm 16 Dn = µp VT = 480 × 25.9 × 10-3 ~ = 35 cm2 / s 3 Dp = µp VT = 480 × 25.9 × 10-3 ~ = 35 cm2 / s 3 Dp = µp VT = 480 × 25.9 × 10-3 ~ = 35 cm2 / s 3 Dp = µp VT = 480 × 25.9 × 10-3 ~ = 12.4 cm2 / s Ex: 1.28 (a) ν n-drift = -µn E Here negative sign indicates that electrons move in a direction opposite to E. 2, we can write 3 V IC 1 mA I = 1.01 mA VC = 1.5 × 10 / cm 16 Dn = µn VT = 480 × 25.9 × 10-3 ~ = 35 cm2 / s Ex: 1.28 (a) ν n-drift = -µn E Here negative sign indicates that electrons move in a direction opposite to E. 2, we can write 3 V IC 1 mA I = 1.01 mA VC = 1.5 × 10 / cm 16 Dn = µn VT = 480 × 25.9 × 10-3 ~ = 35 cm2 / s Ex: 1.28 (a) ν n-drift = -µn E Here negative sign indicates that electrons move in a direction opposite to E. 2, we can write 3 V IC 1 mA I = 1.01 mA VC = 1.5 × 10 / cm 16 Dn = µn VT = 480 × 25.9
× 10-3 ~ = 35 cm2 / s Ex: 1.28 (a) ν n-drift = -µn E Here negative sign indicates that electrons move in a direction opposite to E. 2, we can write 3 V IC 1 mA I = 1.01 mA VC = 1.5 × 10 / cm 16 Dn = µn VT = 480 × 25.9 × 10-3 ~ = 35 cm2 / s Ex: 1.28 (a) ν n-drift = -µn E Here negative sign indicates that electrons move in a direction opposite to E. 2, we can write 3 V IC 1 mA I = 1.01 mA VC = 1.5 × 10 / cm 16 Dn = µn VT = 480 × 25.9 × 10-3 ~ = 35 cm2 / s Ex: 1.28 (a) ν = 1.5 × 10 / cm 16 Dn = µn VT = 480 × 25.9 × 10-3 ~ = 1.5 × 10 / cm 16 Dn = 1. V = IB RB + VBE 0.7 V IB2 IB IC β 1 = 1 + β IC 2IB RB1 I = IC + IB = IC + RC 2IB IC = 1 mA IB 1.5 = 0.01 \times RB + 0.7 RB2 RB = 80 k Figure 2 6.104 Refer to the circuit in Fig. 0.5 M 30 mV rms 10 k vi1 ~ 1 M 10vi1 vi2 (d) For Ri = 40 k and Ro = 500, the required value Av o can be found from 400 V/V = 10 k 100vi2 10 k vi3 1vi3 vo 100 $v i 3 10 k = 100 \times = 90.9 v i 2 10 k + 1 k \Rightarrow v i 3 = 100 mV \times 90.9 = 9.09 V 1 40 \times Av o \times 40 + 101 + 0.5 100 vo = 1 \times = 0.833 v i 3 100 + 20 \Rightarrow Av o = 750 V/V$ (e) Ri = 100 k(1 × 105) $\Rightarrow v o = 9.09 \times 0.833 = 7.6 V$ Ro = 100 (1 × 10) 2 400 = 20 1 k Po = 1000 100 × Av o × 100 + 10 1000 + 100 v 2 orms 7.62 = 0.57 W = RL 100 which exceeds the required 0.5 W. Thus, Thus, VE = -0.76 V IC β +1 101 = IC = 0.2 × IE = α β 100 = 0.202 mA Substituting for IS e (4) v BE /VT in Eqs. v GS1 = 0.283 V, Q1 is still operating in saturation, as implicitly assumed. Figure 1 RL vo (b) Figure 1 Av ovi Chapter 6-22 To determine Av o, we open-circuit RL and use the circuit in Fig. The diode will be conducting 1 mA and exhibiting a drop of 0.7 at v O = 2.3 V. Thus VGS = 3 = 1.5 V 2 V2 = 1.5 V Chapter 5-17 VOV = VGS - Vt = 1.0 V 1 W 2 VOV I1 = ID = µn Cox 2 L = 5.56 Refer to the circuit in Fig. C1 B1, B2 ii vp1 ro1 Rin gm1vp1 C2 rp1 io rp2 vp2 ro2 gm2vp2 Ro Chapter 7-8 7.21 Refer to Fig. P4.31. v be $\alpha = v$ be ic = α ire = gm v be Q.E.D 6.42 The large-signal model of Fig. In circuit (c), no current flows in the 20-k resistor connected between the negative input terminal and ground (because of the virtual ground at the inverting input terminal). C= The resulting low-pass filter will have a 3-dB frequency of 1 1 = f3dB = 2πCRF 2π × 159 × 10-12 × 106 = 1 kHz When a 10-μs, 1-V pulse (see Fig. Observing that the controlled-source gm vπ appears across its control voltage vπ, we can replace it by a resistance 1/gm, as indicated. Thus R 100 Chapter 3-32 iDav = 4.8 + 0.113 = 4.913 A Finally, to obtain the peak diode current, we use iDmax = iCmax + iLmax dv I 11.3 = C + dt R 11.3 12 + = C × T / 4 R = 100 × 10 - 6 × 12 × 4 11.3 + -3 1 × 10 100 = 4.8 + 0.113 = 4.913 A which is equal to the average value. \therefore vO = 0 V v A = -12 V = 2.76 A PIV of the diodes Ex: 3.25 $\sqrt{}$ = VS - VDO = 12 2 - 0.8 = 16.2 V To provide a safety margin, select a diode capable of a peak current of 3.5 to 4A and having a PIV rating of 20 V. 5 V 4 5.5 V Q1 on VCEsat 0.2 V 10 k 4.8 V 10 V 5 10 5.5 0.45 mA 10 1 3 Q2 off 5 V 4.8 mA 1 k 2 Chapter 4-1 4.1 1. i2 R2 10 k i1 For the circuit shown above we have: Rf Rf v1 + v2 vO = - R1 R2 vO RL 1 k Let us choose Rf to be 10 k, then Rf R1 = Rf = 10 k and R2 = 2 k 5 Ex: 2.8 v 1 is a virtual ground, thus $v_1 = 0$ V ii = 1 V - v1 1 - 0 = = 1 mA R1 1 k Assuming an ideal op amp, the current flowing into the negative input terminal of the op amp is zero. P2.30 (redrawn above) provides a constant current flowing into the negative input terminal of the op amp is zero. smaller devices. The result is that v - = vI, vO = 2v - = 2vI, and vA = vO + 0.7. Thus (a) vI = +1V, vO = +2V, and vA = +2.7V. Ro = 20 k = vs Ri 10 k Gm = 60 mA/V vi = vs r i + i2 i x = vx/Ri + gm vx | | | 1 i = vi/Ri | i x = vx + gm Ri | i 2 = gm vi | 1 v | x | | = 1 i 1/R x i + gm vi = vx Ri = Rin 1 + gm Ri vi i1 Ri gmvi 10 = 33.3v 2 3 To reduce the gain seen by v 2 from 33.3 to 20, we connect a resistance Rp in parallel with RL, 10 Rp = $2 \text{ k } 3 \Rightarrow \text{Rp} = 5 \text{ k We next consider the path for v 1}$. When all transistors have equal β and ro, and, since they conduct equal currents, they have equal β and ro, and, since the path for v 1. When all transistors have equal β and ro, and, since the path for v 1. When all transistors have equal β and ro, and, since the path for v 1. When all transistors have equal β and ro, and, since the path for v 1. ro (ro rn) (c) Refer to the circuit in Fig. Thus $10 = 12 \times 500 \times VOV = 0.2 V 2 VGS = 0.8 + 0.2 = 1 V V4 = 1 V$ (e) Refer to Fig. Rin = RG1 RG2 = 300 k 200 k = 120 k 2ID 2 × 0.5 gm = = 3.33 mA/V = VOV 0.3 VA 50 = 100 k = ro = ID 0.5 Rin gm (ro RD RL) Gv = -Rin + Rsig 120 × 3.33 × (100 5 5) = -120 + 120 = -4.1 V/V (c) VG = 2 V, $v^{GS} = 2 + v^{gS}$, (a) DC bias: $|VOV| = 0.3 V \Rightarrow VSG = |Vtp| + |VOV| = 1 V$ Since VG = 0 V, VS = VSG = +1 V, and 2.5 - 1 = 0.3 mA ID = RS $1.5 = 5 k \Rightarrow RS = 0.3$ (b) Gv = -gm RD where VD = 2.5 V gm = $v^{2}DS = 2.5 - |Av|v^{2}gS 2ID 2 \times 0.3 = 2 mA/V VOV 0.3$ Thus, where $-10 = -2RD \Rightarrow RD = 5 k |Av| = gm$ (ro RD RL) = 8.1 V/V This figure belongs to Problem 6.108. 5 V IE 4.61 (a) 5 V 20 k VE IC 10 k IB 1 k VE + 0.2 VE - 0.7 VE - 0.2 IB 10 k IC 1 k VE + 0.7 V VE IE 1 k (a) -5 V (b) Assuming saturation-mode operation, the terminal voltages are interrelated as shown in the figure, which corresponds to Fig. Z All diodes and zener are OFF Z 3.86 3.87 (a) 10 k VI vO 1 k vI vO D1 D2 (b) 10 k Diodes have 0.7 V drop at 1 mA current vO vI \therefore For diode D1 iD = e(v O - 0.7)/VT (c) v O = 0.7 + VT ln 10 k vI vO iD 1 mA vI = v O + iD × 1 k v I for the different values of v O. Choose from these three amplifier types: A Ri 1 M B Ri 10 k C Ri 10 k Av 10 V/ V Av 100 V/ V Av 10 V/V Ro 10 k Ro 1 k Ro 20 1.49 From the equivalent circuit of the output side of a voltage amplifier [Fig. For a 2-V, 100- μ s 10 2V input pulse, a current of = 0.02 mA 100 k flows into R and C, causing v O to decrease linearly from its initial value of 0 V according to 2.77 |T| = vO = - = I t C - 0.02 \times 10-3 t = -0.02 \times 10-3 O becomes $1 \Rightarrow CR = 1.59 \mu s CR$ For Rin = 10 k, R = 10 k, and $2.78 2\pi \times 100 \times 103 = 1.59 \times 10 - 6 = 159 \text{ pF} 104$ To limit the dc gain to 40 dB (i.e., 100 V/V), we connect a resistance RF across C (as in Fig. 25 mV = 100 0.25 mA The 0.1-V differential input signal appears across (2re + 2Re), thus 8.36 (a) re = ie = 100 mV = 0.1 mA 200 + 2 \times 400 v $be = 0.1 \times 100 = 10 \text{ mV}$ (b) The total emitter current in one transistor is I + ie = 0.35 mA and in the other transistor 2 I - ie = 0.15 mA. P8.110. To obtain saturation-mode operation with VCE = 0.2 V and β forced = 10, we use VCE = 0.3 V IC = β forced \times IB VCC - VCE 10 - 0.3 = 0.97 mA IC = RC 10 = 10 \times 0.1 = 1 \text{ mA} = 0.7 + 0.01 \times 10 = 0.8 \text{ V} IB = $0.97 \text{ IC} = 0.0194 \text{ mA} \beta 50 \text{ VBB} = \text{VB} + \text{IB} \text{ RB} = 0.7 + 0.0194 \times 10 = 0.894 \text{ V}$ (c) For operation deep in saturation with β forced = 10, we have VCE 0.2 V 10 - 0.2 = 0.98 mA = 10 IC = 0.98 mA = 10 IC = 0.98 mA = 10 IC = 0.098 mA =0.2 = 9.8 k 1 Ex: 4.22 Refer to the circuit in Fig. P7.75(b). corresponding peak input signal is $v^2g = 0.78 \text{ } 0.78 \text{ } V = = 19.5 \text{ mV} | \text{Av} | 40 \text{ To obtain the coordinates of point B}, we first use Eq. (6.6) to determine VGS B as <math>\sqrt{2 \text{ k n RD VDD} + 1 - 1 \text{ VGS B}} = \text{Vt} + \text{k n RD } \sqrt{2 \times 10 \times 20 \times 5 + 1 - 1} = 0.5 + 10 \times 20 = 0.5 + 0.22 = 0.72 \text{ V}$ The vertical coordinate of point B is VDS B - Vt = VOV B = 0.22 V VDD - VOV B VOV B / 2 - VOV B = 0.25 V B = 0.25 V B = 0.25 V B = 0.25 V B = 0.22 V VDD - VOV B VOV B / 2 = 0.25 V B = 0.25 V B = 0.25 V B = 0.25 V AD - VOV B = 0.25 V B = 0.25 V AD - VOV B = 0.25 V AD - VOV B = 0.25 V AD - VOV B = 0.25 V B = 0.25 V AD - VOV B = 0.2VDD - VDS B RD = ID B 5 - 0.5 = 7.2 k = 0.625 If the transistor is replaced with another having twice the value of k n, then ID B will be twice as large and the required value of k n,
then ID B will be twice as large and the required value of k n, then ID B will be twice as large and the required value of k n, then ID B will be twice as large and the required value of k n, then = I k 1 - k (1) Thus, \Rightarrow RD = 4 k For Q1 and Q2, VICM max = VD1,2 + Vtn 1 W µn Cox V2 2 L 1,2 OV W 1 0.2 = × 0.4 × 0.152 2 L 1,2 W \Rightarrow = 44.4 L 1,2 ID1,2 = $\sqrt{$ Imax = 2 kVOV Q.E.D. (3) Equations (2) and (3) can be used to evaluate Imax v id max (-0.9) - 0.55 R = 0.1 = 12.5 k The lower limit on VCM is determined by the need to keep Q3 operating in saturation. For the Widlar current source, use R = 2 k. P4.25(d). Thus, AM = - = -15.8 V/V fP1 = 9.3 Refer to Fig. 5. Since the required IE = 1 mA, the base current 1 IE = 0.01 mA. The additional current source, use R = 2 k. P4.25(d). power supplies (not shown). Observe that as A0 $\rightarrow \infty$, $\omega P \rightarrow 0$. To determine the systematic input offset voltage resulting from the error in the current mirror. 1). 2.20(a). To obtain the short-circuit current gain k, we replace the BJT with its T model and short circuit the collector to Chapter 7-20 io kisig Thus, Rout = $500 + (10\ 25) \times 2001$ ai i = 14.8 M ro Thus the CB amplifier has a current gain of nearly unity and a very high output resistance: a near-ideal current buffer! re E A more exact value of k can be obtained using Eq. (1); k = 0.975. 7.38, Ex: 7.22 Rop = (gm3 ro3) (ro4 $r\pi 3$) and VDD 1.8 V Ron = (gm2 ro2) (ro1 rm2) I1 2I vi Q1 VG2 Q2 vo I2 I The maximum values of these resistances are obtained when ro rm and are given by Ron = (gm2 ro2) rm 3 max Since gm rm = β , Ron = β 2 ro2 max Rop = β 3 ro3 max Exercise 7-6 Since Av = -gm1 Ron Rop , |Av max| = gm1 β 2 ro2 β 3 $ro3 3.6 1 2 \times 387 \times VOV 2 0.36 \Rightarrow VOV = 0.227 V 100 = VGS = 0.227 + 0.5 = 0.727 V Ex: 7.24$ For the npn transistors, $gm1 = gm2 |IC| 0.2 mA = = 8 mA/V = |VT| 25 mV VOmin = VGS - Vt3 = VGS4 + VGS1 - Vt3 \beta 100 = 12.5 k = gm 8 mA/V Thus$, rm1 = rm2 = ro1 = ro2 = |VA| 5V = 2.5 k = |IC| 0.2 mA = Vt + 2 VOV VOmin = 2VGS - Vt = 0.5 $+ 2 \times 0.227 = 0.95$ V From Fig. 1 below, where $\beta = \infty$ and R is open circuited. Ws will have to increase by factor of 0.54 3 the same factor. Referring to the figure below: $= 4 \times 0.022 \times 30 = 1.33 \times 10 - 3$ V/V CMRR = 4252.5 or 72.6 dB 8.51 Refer to Fig. Writing a loop equation for the base-emitter circuit results in IB Rsig + VBE + IE RE = 3 IE Rsig + VBE + IE RE = $3\beta + 10.5 \times 2.5 + 0.7 + 0.5$ RE = $3101 \Rightarrow$ RE = $4.6 \text{ kVC} = \text{VCC} - \text{IC RC} = 15 - 1 \times 6.8 = 8.2 \text{ V}$ (b) See figure below. From Fig. i = $-\text{isig}\beta 100 = 2.5 \text{ k} = \text{gm } 40 \text{ RE} = 4.3 \text{ k} 1/\text{ro } 111 + \text{re ro } \text{Rsig}$ Thus, Rout = $100 + (4.3 2.5) \times 4001 = 6.4 \text{ M}$ At the collector node, we can write io $\equiv \text{kisig} = \text{i1} - \alpha$ i For Thus, VC = 10 V kisig = isig $1/ro + (\alpha/re) 1 1 1 + + re ro Rsig 5 - 0.7 1 mA 4.3 (1) 10 V = 1.6 \mu A 6.4 M I = A very small change indeed! Now ro re and for the case Rsig re , we obtain <math>\alpha/re = \alpha 1/re$ For our case, $\beta \alpha = \beta + 1 \beta 100 k = \alpha = = 0.99 \beta + 1 101 k$ The output resistance Rout is given by Rout = ro + (Rsig rn)(1 + gm ro) where VA 50 V ro = = 500 k IC 0.1 mA IC $mA = gm = 4 mA/V VT 0.025 V gm ro = 4 \times 500 = 2000 \beta 100 rn = 25 k = gm 47.56 Refer to Fig. 1$, which indicates the given values. +1.0 + 1.0 0 + 2.0 Sat. Thus From the circuit we see that vi ie = re + Re Thus, re + Re Rin = $1-\alpha$ But $11-\alpha = \beta + 1$ Thus, Rin = $(\beta + 1)(re + Re)$ re = VT 25 mV = 75 = IE 0.33 mA Replacing the BJT with its T model results in the following amplifier equivalent circuit. vo2 aie RC ie re vi RE v o1 = vi RE + re 100 k 100 k vi RC RE + re vo2 α RC = - vi = 4762 A/A 2 Rin = 0.95 Rin + Rsig Rin = 0.95 Rin + 100 v o2 3.3 = 0.904 V/V = - vi 3.6 + 0.05 \Rightarrow Rin = 1.9 M (b) With RL = 2 k, If v o1 is connected to ground, RE will in effect be short-circuited at signal frequencies, and v o2 /v i will become v o2 α RC 3.3 = -66 V/V = - = - vi re 0.05 v o = Av o v i 2 2 + Ro With RL = 1 k, v o = Av o v i 1 1 + Ro Thus the change in v o is 1 2 v o = Av o v i - 2 + Ro 1 + Ro 6.54 See figures below and on next page. Since v 1 must see a gain factor of only 10, which is half that seen by v 2, we have to reduce the fraction of v 1 that appears at the input of its transconductance amplifier. t Chapter 1-11 Note that there are two possible representations of zero: 0000 and 1000. Therefore, to achieve iD desired ro (which is 5 times larger), we should increase L (L = $5 \times 1 = 5 \mu m$). VDS = VDD - RD ID Thus, = $1.8 - 12.5 \times 0.08 = 0.8 \text{ V gm}$ RD = 25 Design 2: Substituting for gm = k n VOV r, we have RD = $17.5 \text{ k k n VOV RD} = 25 - 10 = -0.4 \times 10 \times 10 \times 10^{-10}$ $0.2 \times \text{RD}$ Exercise 6-2 where k n = 1 mA/V2, thus vt vt + i = + gm v t ro ro it = VOV RD = 25 (1) Next, consider the bias equation \therefore Req = vt 1 = ro it gm VGS = VDD - RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VOV 2 2 2 we obtain 1 2 RD (2) 0.7 + VOV = 5 VD - RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VOV 2 2 2 we obtain 1 2 RD (2) 0.7 + VOV = 5 VD - RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VOV 2 2 2 we obtain 1 2 RD (2) 0.7 + VOV = 5 VD - RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD - RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD - RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD - RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD - RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD - RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD - RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD - RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD + RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD + RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD + RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD + RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD + RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n VOV = × 1 × VOV = VD + RD ID Substituting Vt = 0.7 V, VDD = 5 V, and VDD 1 1 1 2 2 2 k n V + RD = 0.7 V, and VDD 1 1 1 2 2 2 k n V + RD = 0.7 V, and VDD 1 1 1 1 2 2 2 k n V + RD = 0.7 V, and VDD 1 1 1 1 2 2 2 k n V + RD = 0.7 V, and VDD 1 1 1 1 2 2 2 k n V + RD = 0.7 V, and VDD 1 1 1 1 2 2 2 k n V + RD = 0.7 V, and VDD 1 1 1 1 2 2 2 k - VOV 2 Equations (1) and (2) can be solved to obtain ID = iD RD vDS vgs vGS VOV = 0.319 V and VGS RD = 78.5 k The dc current ID can be now found as 1.2 k n VOV = 50.9 μ A 2 To determine the required value of RG we use Eq. (6.48), again noting that RL is absent: ID = RG 1 + gm RD 0.5 M = VDD = 5 V VGS = 2 V Vt = 1 V λ =0 k n = $20 \mu A/V2 \text{ RG } 1 + 25 \text{ RD} = 10 \text{ k} \Rightarrow \text{RG} = 13 \text{ M}$
Finally, the maximum allowable input signal v¹ i can be found as follows: Vt 0.7 V = $27 \text{ mV v}^{1} = |Av| + 1.25 + 1 \text{ W} = 20 \text{ L}$ (a) VGS = $2 \text{ V} \Rightarrow \text{VOV} = 1 \text{ VDS}$ Ex: 6.5 1 W 2 k V = $200 \mu \text{ A}^{2} \text{ n}$ L OV = $10 \text{ k} \Rightarrow \text{RG} = 13 \text{ M}$ Finally, the maximum allowable input signal v¹ i can be found as follows: Vt 0.7 V = $27 \text{ mV v}^{1} = |Av| + 1.25 + 1 \text{ W} = 20 \text{ L}$ (a) VGS = $2 \text{ V} \Rightarrow \text{VOV} = 1 \text{ VDS}$ Ex: 6.5 1 W 2 k V = $200 \mu \text{ A}^{2} \text{ n}$ L OV = $10 \text{ k} \Rightarrow \text{RG} = 13 \text{ M}$ Finally, the maximum allowable input signal v¹ i can be found as follows: Vt 0.7 V = $27 \text{ mV v}^{1} \text{ i} = |Av| + 1.25 + 1 \text{ W} = 20 \text{ L}$ (a) VGS = $2 \text{ V} \Rightarrow \text{VOV} = 1 \text{ VDS}$ Ex: 6.5 1 W 2 k V = $200 \mu \text{ A}^{2} \text{ n}$ L OV = 10 V M = 120 L (b) gm = k n (c) Av = it \text{ Reg } D 0 vt (d) v gs = $0.2 \text{ sin } \omega \text{ V V}$ v ds = $-0.8 \text{ sin } \omega \text{ V V}$ v ds = $-0.8 \text{ sin } \omega \text{ V}$ V v ds = $-0.8 \text{ sin } \omega$ (e) Using Eq. (6.28), we obtain G i S v ds = -gm RD = -4 V/V v qs v DS = VDS + v ds $\Rightarrow 2.2 \text{ V} \leq v \text{ DS} \leq 3.8 \text{ V}$ i 1 qm W VOV = $400 \mu \text{A/V} = 0.4 \text{ m}$ (VGS - Vt)2 2 1 + k n (VGS - V 3.3(a). Rin = vi vi = ib $(1 - \alpha)$ ie Chapter 6-17 6.50 Refer to Fig. For Q1, ID = 1 W1 µn Cox (VGS1 - Vt) 2 L1 90 = W1 1 × 90 × (0.8 - 0.5) 2 L1 R = W1 = 22.2 × 0.5 = 11.1 µm ID = 180 µA R = and VD = 1 V 1 VD = = 5.6 k ID 0.18 Transistor is operating in saturation with |VOV| = 1.8 - VD - |Vt| = 1.8 - 1 - 0.5 = 0.3 V: ID = 1 W1 k |VOV |2 2 pL 180 = \Rightarrow W 1 × 100 × × 0.32 2 L W = 40 L W = 40 × 0.18 = 7.2 µm 5.46 Refer to Fig. Lp ND Ln NA Dp Dn and have approximately Lp Ln = 7.3 × 10-15 A similar values, if NA ND, then the term Dp can be neglected as compared to . v I becomes a horizontal line. (d) Q2 IC2 (b) IE2 = 5 - 0.74 - 0.7 8.2 3.3 + 101 = 1.05 mA IC2 1.04 mA The collector current IC2 and the 5.6-k resistance it feeds can be replaced by a Thévenin equivalent as shown in Fig. P8.104. 1, RG2 VDS = VGS 1 + RG1 3 = $0.95 \times 1 + 2.375 V_2 \Rightarrow |v^o| = 22 \text{ mV} |v^i| = 86.5 \text{ (c)}$ To determine Rin, refer to Fig. 1.23(a) with the 3-dB frequency f0 = 105 Hz. The + R1 Rc 1+ A 1+ R2 Vo = - Vi R1 Gain with resistance R1a R2 To make R1a R1 + VI R1 = Rc R2 Vo = -, we have to make Vi R1 + r1 + A - G Rc = R1 1+G 2.24 (a) |G| = where we have neglected the small effect of R1a on the denominator. 3 $RRL \leq 2 k R + RL 1.15$ For $RL = 10 k R \leq 2.5 k$ The resulting circuit needs only one additional resistance of 2 k in parallel with RL so that $v s \leq 1 V$. Also, ID = 0.5 mA. $VOV = 0.25 \times 3.16 = 0.79 V VSG2 = |Vtp| + |VOV| = 0.5 + 0.3 = 0.8 V \sqrt{and gm}$ increases by a factor of 10 = 3.16 to VG = 2.5 - VSG2 = 2.5 - 0.8 = 1.7 V Chapter 7-13 1 W V2 µn Cox 2 L 1 OV 1 $W 1 100 = x 200 \times x 0.32 2 L 1$ $W \Rightarrow = 11.1 L 1$ $1 W |VOV 2| 2 ID2 = \mu p Cox 2 L 2$ $W 1 100 = x 100 \times x 0.32 2 L 2$ $W \Rightarrow = 22.2 L 2 ID1 = Av = -gm1$ (rol ro2) $gm1 2ID 2 \times 0.1 = = 0.67 mA/V = VOV 0.3$ rol $= ro2 = |VA| L 20 \times 0.5 = 100 k = ID 0.1 Av = -0.67 \times (100 100) = -33.5 V/V 7.39$ Refer to Fig. This compensates for the factor 3 in the process transconductance parameter, resulting in k p = k n, and the two transistors are matched. (W/L)2 (W/L)1 7.17 Ais = 4 = Since L1 = L2, then W2 = 4 W1 Figure 1 Rin = ro1 1 1 gm1 gm1 For Figure 1 shows the current conveyor circuit with Y connected to a voltage V, X fed with a current source I, and Z connected to a voltage VZ that keeps Q5 operating in the active mode. We next draw a circle around the two transistors to define a "supernode." A node equation for the supernode." A node equation for the supernode. "A node equation for the supernode." A node equation for the supernode." A node equation for the supernode." A node equation for the supernode. "A node equation for the supernode." A node equation for the supernode. "A node equation for the supernode." A node e re 1 1+ Re re Thus, including Re reduces fL by the factor Re 1+. $5-0 \le 0.2$ mA R R ≥ 25 k From Fig. Observe that at the output node the total signal current is 4id where 1 ro1 is gm1 id = gm2 1 ii + ro1 gm1 = v id 2 I v id 2 |VOV| This figure belongs to Problem 8.115. S e d r a , Series Editor H EDITION A l l e n and H 8,605 2,657 44MB Read more SEDRA/SMITH INSTRUCTOR'S SOLUTIONS MANUA FOR Microelectronic Circuits INTERNATIONAL SEVENTH EDITION Adel S. Since Q1 and Q2 are now operating at equal VDS, we estimate IO = IREF = 180 μ A. (Equivalent Chapter 6-40 To remain in saturation, v^DS ≥ v^GS - Vt 2.5 - 8.1v^gs ≥ 2 + v^gs - 0.7 This is satisfied with equality at 2.5 - 1.3 = 0.132 V v²gs = 9.1 The corresponding value of v²sig = v^2 gs 120 The corresponding value of v²sig = $4.1 \times 0.264 = 1.08$ V Figure 1 VD = 2.5 V is higher than VG - Vt = 1.3 V by 1.2 V.) 1 2 ID = k n VOV 2 1 0.5 = k n × 0.33 2 \Rightarrow k n = 11.1 mA/V2 (d) To be able to double v^{sig} without leaving saturation, we must reduce v^{gs} to half of what would be its new value; that is, we must keep v^{gs} unchanged. v O = 10 V 10 V = 10 mA iL = 1 k Current supplied by the source is 0. Since VC = -4 V is lower than VB = -2.7 V, the transistor is operating in the active mode. (a) V1 = VDS = VGS = 1 V (b) V2 = +1 - VDS = 1 - 1 = 0 V (c) V3 = VSD = VSG = 1 V (d) V4 = +1.25 - VSG = 1.25 - 1 = 0.25 V 5.38 Case a, assume, sat, Now place a resistor R in series with the drain. 2.11: The value of R can be selected (arbitrarily but conveniently) as R = 10 k. If we add a resistor in series with the capacitor to limit the high-frequency gain of the differentiator to 100, the circuit would be: R C R1 Vi is 10-3 s, we have: CR = 10-3 s \Rightarrow For $\omega = 103$ rad/s, the differentiator transfer function has magnitude Vo = $103 \times 10-2 = 10$ V/V V i Since the desired integration time constant Vo At high frequencies the capacitor C acts like a short circuit. VDD 1.2 V Q3 Q4 Q6 Q1 Q2 vo IREF 200 A Q8 Q5 Q7 Chapter 8-40 1 W |VOV |2 kp 2 L 3,4 1 W 200 = $\times 100 \times \times 0.152$ 2 L 3,4 W \Rightarrow = 178 L 3,4 Thus ID3,4 = 0.65 V \leq VICM ≤ 1.05 V Note that the input dc voltage in part (a) should have specified a VICM greater than 0.65 V. Rsig vo vsig rp vp gmvp This figure belongs to Problem 6.119. 2 we see that re (10 2) ve = ie + ie 10 re +
ie re vb = ve + ie re vb = ve + ie re = ie (10 2) 1 + 10 re ii = (1 - α)ie + ie 10 ie re + ie = β + 1 10 We can now obtain Rin from re (10 2) 1 + 10 = re 1 + (β + 1)(10 2) 1 + 10 = re 1 + (β + 1)(10 2) × (1 + 0.00145) + 101 × 0.00145 1 + 101 × 0. + 1.4645 = 148.3 k 1 + 0.14645 vb Rin 148.3 = = 0.937 v sig Rin + Rsig 148.3 + 10 re ie 1 + (10 2) + ie re 10 1.00145 × (10 2) + 0.0145 = 0.991 V/V v sig = = 20 101 × 2.0145 = 18.21 \text{ k which is greatly reduced because of the absence of bootstrapping} R2 High-frequency gain (s $\rightarrow \infty$) = - R1 ω 1 = 1 C1 R1 and (a) For $\omega \omega$ 1, For a high-frequency input resistance of 1 k, we select R1 = 1 k. 1 2 k n VOV 2 1 2 0.5 = × 4VOV 2 \Rightarrow VOV = 0.5 V The voltage gain ID = Exercise 6-10 Thus, VGS = Vt + VOV = 1 + 0.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = VS + VGS = 3.5 + 1.5 = 1.5 V We now can obtain the dc voltage required at the gate, VG = 1.5 V We now can obtain the dc voltage required at the gate, VG = 1.5 V We now can obtain the dc voltage required at the gate, VG = 1.5 V We now can obtain the dc voltage required at the gate, VG = 1.5 V We now can obtain the dc voltage required at the gate, VG = 1.5 V We now can obtain the dc voltage required at the gate dc volta 5 V Using a current of 2 μ A in the voltage divider, we have 5V = 2.5 M RG2 = 2 μ A The voltage drop across RG1 is 10 V, thus RG1 = 10 V = 5 M 2 μ A This completes the bias design. 2.83 R 20 k i i vI The average value of the output is zero. To determine Rin , we simplify the circuit as shown in Fig. Chapter 7-2 This figure belongs to Problem 7.5. To find VSG, we use the following for the diode-connected transistor(s): 1 W ID = $\mu p \cos(VSG - |Vtp|) 2 2 L VDD Q1 Q2 I1 Q3 I2 I3 IREF$ and substitute ID = IREF = 100 μA . The resulting VBE will be 0.699 V and 0.721 V, respectively. P5.26 and let VD1 = 2 V and VD2 = 2.5 V. 1 0.025 vs = vs × 2 0.025 + 103 I = 15 ev /VT iD2 = e(V2 + 102 I) = 100 \mu A. -V1)/VT = ev /VT iD1 For +5 mV change we obtain iD2 = e5/25 = 1.221 iD1 % change 1.221 - 1 iD2 - iD1 × 100 = × 100 = iD1 1 = -18.1% vo For v o = 3.46 As shown in Problem 3.45, VT 0.025 vo = = vi VT + RS I 0.025 + 104 I Here RS = 10 k (1) The current changes are limited $\pm 10\%$. This manual has greatly benefited from the careful work of the accuracy checkers listed below. 9.3(b). At v I = 3.5 V, the diode begins to conduct. Now, to allow for 0.8-V negative signal swing, we must have VD = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 2 mA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 12 MA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 12 MA/V (b) gm = = VOV 0.4 VA 40 = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 12 MA/V (b) gm = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 12 MA/V (b) gm = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 12 MA/V (b) gm = = 0 V and 5-0 = 12.5 k 0.4 2ID 2 × 0.4 = 12 MA/V (b) gm = 12.5 k 0.4 2ID 2 × 0.4 = 12 MA/V (b) gm = 12.5 k 0.4 2ID 2 × 0.4 = 12 MA/V (b) gm = 12.5 k 0.4 2ID 2 × 0.4 = 12 MA/V (b) gm = 12.5 k 0.4 2ID 2 × 0.4 = 12 MA/V (b) gm = 12.5 k 0.4 2ID 2 × 0.4 100 k ro = ID 0.4 (c) If terminal Z is connected to ground, the circuit becomes a CS amplifier, vy RG = $\times -\text{gm}$ (ro RD RL) Gv = $-v \text{ sig RG} + \text{Rsig RD} = 10 \times 2 \times (100 \ 12.5 \ 10) 10 + 1 = -9.6 \ V/V = - \text{Chapter } 6-42 \ (d)$ If terminal Y is grounded, the circuit becomes a CD or source-follower amplifier: vz (RS ro) = 1 vx (RS ro) + gm (9.5 \ 100) = 0.946 \ V/V $= 1 (9.5 \ 100) + 2$ Looking into terminal Z, we see Ro : 1 Ro = RS ro gm 1 = 9.5 100 = 473 2 (e) If X is grounded, the circuit becomes a CG amplifier. |VOV| = 1.5 - 0.8 - 0.5 = 0.2 V Thus, 1 W 0.2 = $\times 0.1 \times \times 0.22$ 2 L 6.3 W W = = 100 L 3 L 6 Transistor W/L I D (mA) |V GS|(V) Each of Q4 and Q5 is conducting a dc current of (I /2) while Q7 is conducting a dc current IREF = I. To start with, we minimize L by using the smallest feature size, 5.3 With v DS small, compared to VOV, Eq. (5.13a) applies: $L = 0.18 \mu m rDS 1$ = W ($\mu n Cox$) (VOV) L rDS = 1 k n (W/L) v OV (a) VOV is doubled $\rightarrow rDS$ is halved. Thus, the differential half circuit will be as shown in the figure, and v od RD = Rs 1 v id + gm 2 1 ro3 RD = gm3 Ad = and the differential gain of the amplifier in Fig. This is the price paid for doubling Rid. For v I < 0, the diode is cut off, zero current flows through R, and v O = 0. The slope at v OV = VOV is d (iD /k n) = VOV d v OV v OV = VOV keplacing k n by k p and v OV by |v OV| adapts this graph to PMOS transistors. See the circuit below: VS 15 V R VO - 8.74 0.04 VS = 13.5 V 170 mV 1.5 V 20 mA VO IZmin 5 mA IZ RL Chapter 3-24 R < 15 - VZ0 20 + 5 where we have used the minimum value of VS, the maximum value of VS, the maximum value of VS, the maximum value of VS and the minimum value of VS and the min Rsig 5 k vsig rp 25 k vp gmvp gm 4 mA/V ro 1 M vo RL 100 k Chapter 7-11 7.27 A0 = 2VA 2VA L = VOV VOV VA = 5 × 0.3 = 1.5 V ro = 2×5×L 0.2 \Rightarrow L = 0.4 µm 20 = A0 = gm ro = 1 × 15 = 15 V/V 1 W 2 µn Cox VOV 2 L W 1 × 0.22 100 = × 387 × 2 L W \Rightarrow = 13 \Rightarrow W = 3.9 µm L ID = 2ID 2I = gm = VOV VOV 2I 0.2 \Rightarrow I = 0.2 mA 1 W 2 VOV ID = un Cox 2 L 2= $0.2 = VA 1.5 V = 15 k = ID 0.1 mA 7.31 \text{ gm} = W 1 \times 0.4 \times 0.04 2 L 2ID 2 \times 0.1 = 0.4 mA/V = VOV 0.5 W = 25 \Rightarrow L From Table I.1 (Appendix I), we find that for the 0.5-um process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O2 vid 2 vo 4vid 2id 0V O7 O8 This figure belongs to Problem 8.116, part (c), Thus, 4.3 = 8.6 k 0.5 m Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O2 vid 2 vo 4vid 2id 0V O7 O8 This figure belongs to Problem 8.116, part (c), Thus, 4.3 = 8.6 k 0.5 m Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O2 vid 2 vo 4vid 2id 0V O7 O8 This figure belongs to Problem 8.116, part (c), Thus, 4.3 = 8.6 k 0.5 m Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O2 vid 2 vo 4vid 2id 0V O7 O8 This figure belongs
to Problem 8.116, part (c), Thus, 4.3 = 8.6 k 0.5 m Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O2 vid 2 vo 4vid 2id 0V O7 O8 This figure belongs to Problem 8.116, part (c), Thus, 4.3 = 8.6 k 0.5 m Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O2 vid 2 vo 4vid 2id 0V O7 O8 This figure belongs to Problem 8.116, part (c), Thus, 4.3 = 8.6 k 0.5 m Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O2 vid 2 vo 4vid 2id 0V O7 O8 This figure belongs to Problem 8.116, part (c), Thus, 4.3 = 8.6 k 0.5 m Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O2 vid 2 vo 4vid 2id 0V O7 O8 This figure belongs to Problem 8.116, part (c), Thus, 4.3 = 8.6 k 0.5 m Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O2 vid 2 vo 4vid 2id 0V O7 O8 This figure belongs to Problem 8.116, part (c), Thus, 4.3 = 8.6 k 0.5 m Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O7 O8 This figure belongs to Problem 8.116, part (c), Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O7 O8 This figure belongs to Problem 8.116, part (c), Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1 id O6 2id id O7 O8 This figure belongs to Problem 8.116, part (c), Process |VA| = 20 V/um, O5 O3 id O4 id vid 2 O1$ Rin gm (RC RL) Gv = Rin + Rsig RE = Ex: 6.44 Refer to Fig. That is, IO = VO 1V = $0.01IO \Rightarrow ro2 = 0.01 \times 100 \ \mu A \Rightarrow L = 100 V = 5 \ \mu m \ 20 V / \mu m$ To keep VOV of the matched transistors the same W of the transistor should as that in Example 7.1, L remain the same. 4.30(b). Thus the maximum value of vo is 3.3 - 0.224 = 3.076 V. $\Rightarrow \omega H = 0.64\omega P 1$ The approximate value using Eq. (9.77) is $2 \omega P 1 \omega H 1 = \sqrt{\omega P 2 1 2}$ Ex: $9.16 | AM | = gm RL = 1.25 \times 10 = 12.5$ V/V = $0.71\omega P 1 GB = |AM | fH$ For k = 2, the exact value of ωH is obtained from $\omega H 2 \omega H 2 1 + 2 = 1 + \omega P 1 2\omega P 1 = 12.5 \times 135.5 = 1.69$ GHz = $1 + 5 \omega H 4 \omega P 1 2 + 1$ ωH 4 ωP 1 4 Ex: 9.17 | AM | = Rgs = 10 k 1 × 12.5 = 6.25 V/V 2 Exercise 9-4 (1 + gm RL) + RL Rgd = Rsig = 10(1 + 6.25) + 5 = 77.5 k RCL = RL = 5 k τgs = Cgs Rgs = 20 × 10-15 × 10 × 103 = 200 ps τgd = Cgd Rgd = 5×10-15 × 77.5×103 = 387.5 ps τCL = CL RCL = 25 × 10-15 × 5 × 103 = 125 ps τH = τgs + τgd + τCL Ex: 9.19 (a) gm = 40 $mA/V r\pi = 200 = 5 k 40 ron = VAn 130 = = 130 k I 1 rop = |VAp| 50 = = 50 k I 1 RL = ron rop = 130 50 = 36.1 k AM = - = 200 + 387.5 + 125 = 712.5 ps = -1 fH = 2\pi TH ra gm RL ra + rx + Rsig 5 × 40 × 36.1 5 + 0.2 + 36 = -175 V/V 1 = = 223.4 MHz 2a × 712.5 × 10-12 (b) Cin = Ca + Ca (1 + gm RL) GB = 6.25 × 223.4 = 1.4 GHz = 16 + 1.4 GHz = 1.4 GHz = 16 + 1.4 GHz = 1.4 GHz$ $0.3(1 + 40 \times 36.1)$ Ex: 9.18 gm = 2µn Cox = 450 pF W ID L Rsig = r\pi (rx + Rsig) Since ID is increased by a factor of 4, gm doubles: = 5 (0.2 + 36) = 4.39 k gm = 2 \times 1.25 = 2.5 mA/V fH = Since RL is ro /2, increasing ID by a factor of 4, thus RL = 1 × 10 = 2.5 k 4 | AM | = gm RL = 2.5 × 2.5 = $6.25 \text{ V/V} = 10 \text{ k} \text{ Rgs} = \text{Rsig} \text{ Rgd} = \text{Rsig} (1 + \text{gm} \text{ RL}) + \text{RL} = 10(1 + 6.25) + 2.5 = 1 2 \pi \text{Cin} \text{ Rsig} 1 2 \pi \times 450 \times 10 - 12 \times 4.39 \times 103 = 80.6 \text{ kHz}$ (c) Rπ = Rsig = $4.39 \text{ k} \text{ R} \mu = \text{Rsig} (1 + \text{gm} \text{ RL}) + 36.1 = 6.38 \text{ M} = 75 \text{ k} \text{ RCL} = \text{RL} = 36.1 \text{ k} \text{ RCL} = \text{RL} = 2.5 \text{ k} \tau \text{H} = \text{C} \pi + \text{C} \mu \text{ R} \mu + \text{C} \text{L} \text{ RCL} \tau \text{H} = \tau \text{gs} + \tau \text{gd} + \tau \text{CL} = 16 \times 4.39 \text{ k}$ $0.3 \times 6.38 \times 103 + 5 \times 36.1 = Cgs Rsiq + Cqd Rgd + CL RCL = 70.2 + 1914 + 180.5 = 20 \times 10 - 15 \times 10 + 5 \times 10 - 15 \times 2.5 \times 103 = 200 + 375 + 62.5 = 637.5 ps fH = 1 = 250 MHz 2\pi \times 637.5 \times 10 - 12 GB = |AM| fH = 6.25 \times 250 = 1.56 GHz fH = 1 2\pi \times 2164.7 \times 10 - 9 = 73.5 kHz qm (d) fZ = 2\pi Cu$ $= 40 \times 10 - 3 = 21.2 \text{ GHz } 2\pi \times 0.3 \times 10 - 12 \text{ (e) } GB = 175 \times 73.5 = 12.9 \text{ MHz Exercise } 9-5 \text{ Ex: } 9.20 \text{ Rin} = R L + ro 1 + gm ro 500 + 20 = = 20 \text{ k} 1 + 25 \text{ Gv} = RL 500 = 16.7 \text{ V/V} = Rsig + Rin 10 + 20 \tau H = Cgs Rsig + Cgd \times 21 \text{ Rsig} = Cgs Rsig + 0.25 \text{ Cgs } \times 21 \text{ Rsig} = 6.25 \text{ Cgs } \text{ Rsig} 1 2\pi \times 6.25 \text{ Cgs } \text{ Rsig} fH = Rgs = Rsig Rin = 10 20 = 6.7 \text{ k For the}$ cascode amplifier, Rgd = RL Ro τ H Rsig [Cgs 1 + Cgd 1 (1 + gm1 Rd 1)] = 500 280 = 179.5 k where τ H = Cgs Rgs + (Cgd + CL)Rgd Rd 1 = ro 1 Rin2 = ro = 20 × 10-15 × 6.7 × 103 + (5 + 25) × 10-15 × 179.5 × 103 = 134 + 5385 = 5519 ps 1 = 28.8 MHz fH = 2\pi × 5519 × 10-12 2 ro 2 gm = ro = 2 gm + ro gm ro 2ro 2ro = = 2 + gm ro 2 m = ro = 20 × 10-15 × 6.7 × 103 + (5 + 25) × 10-15 × 6.7 × 103 = 134 + 5385 = 5519 ps 1 = 28.8 MHz fH = 2\pi × 5519 × 10-12 2 ro 2 gm = ro = 2 gm + ro gm ro 2ro 2ro = = 2 + gm ro 2 + 40 = Cqs Rsig 1 + 0.25 1 + 21 = Thus, while the midband qain has been increased substantially (by a factor of 9.7), the bandwidth has been substantially (by a factor of 9.7), the bandwidth has been increased substantially (by a factor of 9.7). $+13.8 = 1.73 \text{ mA } 202 + 101 \text{ IC} = \alpha \text{IE} = 0.99 \times 1.73 \text{ mA} = re 50 \text{ Rsig } 50 \text{ v sig Rin re } 50 \text{ (a) IE} = 1.71 \text{ mA } \text{ IC } gm = 68.4 \text{ mA/V } \text{ VT } \text{ VT } 25 \text{ mV } \text{ re} = 14.5 = 1.4645 \text{ k} \text{ (c) When CB is open-circuited, the equivalent circuit becomes that shown in Fig. } 6.59(a). The op amp$ saturates with vA = -13 V, v = 0 V and vO = 0 V. Finally, observe that the curve 2 representing the boundary between the triode region and the saturation region has the equation iD /k n = iD /kn (V2) 1 2 v 2 DS Figure 2 shows the graph for the relationship 1 iD /kn v 20V 2 0 1 V VOV 2 OV vOV (V) Fig. This is a result of the linear v I which gives rise to a constant capacitor current during the diode conduction interval. 8.61 If Q1 has twice the base-emitter junction 2 area of Q2, the bias current I will split I in Q1 3 1 and I in Q2 . 7.15. which can be simplified as follows: C1 + C2 1 1 = R1 + C1 R1 R2 = The LP STC circuit whose response determines the amplifier response at the highfrequency end has a phase angle of $-5.7 \circ$ at f = 1 kHz. Using the relationship for $\angle T$ (j ω) given in Table 1.2, we obtain for the LP STC circuit. To obtain maximum output resistance, we use the largest possible Rs consistent with ID Rs ≤ 0.3 V. Now, if each of the stages has a low-frequency (dc) closed-loop 40 MHz. gain K, then its 3-dB frequency will be K Thus for each stage the closed-loop gain is: K $|G| = (2 f) |1 + (40) G0 2 f 1 + f1 G = overall gain of the cascade is which is 6.4 times greater than the bandwidth achieved using a single op amp, as in case (b) above. Chapter 2-15 for a noninverting amplifier: 1 M 10 V Rin = <math>\infty$ 1 k Case Gain (V/V) Rin R1 R2 a -10 10 k 10 k b -1 100 k b -1 100 $k 100 k 100 k c - 2 100 k 100 k c - 2 100 k 100 k 200 k d + 1 \infty 0 e + 2 \infty 100 k 100 k f + 11 \infty 10 k 100 k g - 0.5 20 k 20 k 10 k (b)$ Inserting a buffer. $r \pi v_0 = x - gm$ (ro RL) vsig $r \pi$ + Rsig O1 vi For I = 1 mA: 1 mA = 40 mA/V = -10 V = 10 k 1 mA A0 = 40 mA/V × 10 k = 400 V/V A0 = 2VA 2VA L 2 × 10 × 0.5 = 50 V/V = = VOV VOV 0.2 gm = 2ID VOV = -303 V/V 7.26 ro = I gm rn 10 μ A 0.4 mA/V 250 k ro A0 1 M 400 V/V 2= 40 mA/V 2.5 k 10 k 400 V/V 0.2 = \Rightarrow 7.25 Refer to Fig. However, it will have a profound effect on Rin, as Rin now is 10 M, and 10 vo = $\times -19.5 = -18.6 \text{ V/V}$ vsig 10 + 0.5 This is nearly double the value we had before! From the figure we can determine the overall voltage gain as Gv = = vo Total resistance in the drain = vsig Total resistance in the sources 1 RL = gm RL 1 1 2 + gm1 gm2 where 7.93 gm = gm1 = gm2 = 5 mA/V Gv = 1 × 5 × 10 = 25 V/V 2 RL 10 k 7.95 Refer to Fig. 3.26 We can write the following node equation at the diode anodes: ID2 = 10 mA - V/R Thus the result is a decrease in the diode voltage by 17.3 mV. 4.5(a) to (d), together with their parameter values. P4.44. 6.26(b), we obtain the circuit shown in next column above. Vp 2Vr vO = vI = 1 V 1 vO = vI = 1 V 1 vO = vI = 1.7 V For vI = -1 V, the diode is cut off. P6.72. Rin = 10 k (smallest gain magnitude) R2 10 k 10 k R1 10 k vO vO vI vI 10 k 10 k vO = -0.5 V/V vI Closed-loop gain is R2 10 k vO = - = -vI R1 10 k 10 k = -1 V/V For vI = +1.00 V, Rin = 20 k (smallest gain magnitude) 10 k 10 k vI v O = -1 × 1.00 vO = -1.00 V The two resistors are 1% resistors are 1% resistors or = 10(1 - 0.01) = 0.98 V/V v 10(1 + 0.01) I min vO = 10(1 + 0.01) = 1.02 V/V v 10(1 - 0.01) I min vO = 10(1 max vO = -2 V/V vI Thus the measured output voltage will range from -0.98 V to -1.02 V. Thus ie isig and ic = α ie isig Thus, v o = ic RC = isig RC 6.73 For Rin = Rsig = 50, re = 50 and, with α 1, VT 25 mV = = 0.5 mA IC re 50 gm = IC/VT = 20 mA/V Rin gm (RC RL) Gv = Rin + Rsig 50 × $20 \times (10 \ 10) 50 + 50 = 50 \text{ V/V}$ Gv = VT 25 mV = = 125IE 0.2 mA IC 0.2 mA = 8 mA/V gm = VT 0.025 V Rin gm (RC RL) Gv = Rin + Rsig 0.125 × 8(10 10) = 8 V/V = 0.125 + 0.5 6.74 Rin = re = Chapter 6-26 v^{\pi} = v^{sig} = 50 \text{ mV v}^{\circ} o = Gv v^{sig} = 50 \text{ mV v}^{\circ} o = Gv v^{sig} = 50 \text{ mV v}^{\circ} o = Gv v^{sig} = 50 \text{ mV v}^{\circ} o = Gv v^{sig} = 50 \text{ mV v}^{\circ} o = Gv v^{sig} = 50 \text{ mV v}^{\circ} o = Gv v^{sig} = 50 \text{ mV v}^{\circ} o = Gv v^{sig} = 8 \times 50 = 400 \text{ mV} = 0.4 \text{ V} 6.75 \text{ Rsig 1 gm RL} (+10\% \text{ above nominal}) = 1.5 \text{ Av nominal} = Av high = 0.93 \Rightarrow v^{sig} = 50 \text{ mV v}^{\circ} o = Gv v^{sig} = 8 \times 50 = 400 \text{ mV} = 0.4
\text{ V} 6.75 \text{ Rsig 1 gm RL} (+10\% \text{ above nominal}) = 1.5 \text{ Av nominal} = Av high = 0.93 \Rightarrow v^{sig} = 50 \text{ mV v}^{\circ} o = Gv v^{sig} = 8 \times 50 = 400 \text{ mV} = 0.4 \text{ V} 6.75 \text{ Rsig 1 gm RL} (+10\% \text{ above nominal}) = 1.5 \text{ Av nominal} = 1.5 \text{ A low = 1.5 + 0.357 = 0.81 (-5% from nominal) 1 = Ro = 0.357 k gm \Rightarrow gm = 2.8 mA/V To find ID, we use gm = 2k n ID i i vsig 2 = 0.85 V/V 2.357 5 = 5.357 50 mV (peak) From the figure above, we have $1 = 0.1 \times RL$ gm = $0.1 \times 2 = 0.2$ k \Rightarrow ID = gm2/2k n 2.82 = 1.6 mA 2×2.5 1 2 ID = k n VOV 2 1 2 $1.6 = \times 2.5 \times VOV$ $2 \Rightarrow VOV = 1.5 \times RL$ gm = $0.1 \times 2 = 0.2$ k \Rightarrow ID = gm2/2k n 2.82 = 1.6 mA 2×2.5 1 2 ID = k n VOV 2 1 2 $1.6 = \times 2.5 \times VOV$ $2 \Rightarrow VOV = 1.5 \times RL$ gm = $0.1 \times RL$ gm = $1.13 V = 6.77 \operatorname{Rsig}(b + 1) \operatorname{gm} = 5 \operatorname{mA/V} \operatorname{gm} = 2 \operatorname{kn} \operatorname{ID} 5 = 2 \times 5 \times \operatorname{ID} \operatorname{ID} = 2.5 \operatorname{mA} \operatorname{At}$ the peak of the sine wave, $0.5 V = 0.25 \operatorname{mA} \operatorname{vsig} = v^{\circ} \operatorname{gs} + v^{\circ} = 0.05 + 0.5 = 0.55 V v^{\circ} = 0.55 V v^{\circ} = 0.5 V \operatorname{RL} = 2 \operatorname{k} \operatorname{RL} \operatorname{RL} + \operatorname{Ro} 2 \operatorname{Av} \operatorname{nominal} = 2 + \operatorname{Ro} 1.5 \operatorname{Av} \operatorname{low} = 1.5 + \operatorname{Ro} 5$ Av high = 5 + Ro For Av high = 1.1 Av nominal 6.76 Av = 5 1.1 × 2 = 5 + Ro 2 + Ro \Rightarrow Ro = 0.357 k v^be = 5 mV From the figure above we see that re 5 mV = RL 500 mV RL = 20 100 VT 25 mV IE = = 1.25 mA re 20 \Rightarrow re = At the peak of the output sine wave, we have $ie = v^{0} = 0.5 = 0.25$ mA RL 2 Chapter 6-27 v^be = 10 mV RL × v^be v⁰ = 10 mV RL × v $re 500 = \times 10 \ 12.5 = 400 \ mV = 0.4 \ Vv^{\circ} 0.4 = 0.488 \ Vv^{\circ} sig = Gv \ 0.82 \ Thus$, $iEmax = 1.25 + 0.25 = 1.5 \ mA$ and $iEmin = 1.25 - 0.25 = 1.0 \ mA$ From the figure, we have $Gv = = vo = v \ sig \ RL \ RL + re + 2.2 + 0.02 + 200 \ 101 \ Rsig \ \beta + 1$ (c) $Gv \ o = 1 \ Rout = re + = 0.5 \ V/V = 111.5 \ Thus$, $v^{\circ} \ 0.5 \ V = = =1V \ Gv \ 0.5 \ V/V \ RL \ RL + Rout \ 500$ $=1 \times = 0.82$ V/V 500 + 111.5 which is the same value obtained in (a) above. Conduction angle = $\pi - 2\theta = 3.04$ rad in each half cycle. Chapter 3-36 This figure belong to Problem 3.85, part b. 1 RS + re ($\beta + 1$) Now VOS can be obtained by dividing VC by Ad = gm RC, VEE Consider only the incremental currents involved. 3, will have 10 M 10 M vi vo Thus, $VC2 = VG2 = 0.7 + VGS = 2.016 VIC2 = 5 - 2.016 VIC2 = 5 - 2.016 VCC - VC2 = 1 mA 3 k 3 Figure 3 Chapter 7-35 no effect on the dc bias of each transistor. (d) <math>vI = -3 V \Rightarrow vO = +3 V vA = +3.7 V v - = 0 V 3.82$ (a) See figure (a) on next page. The input resistance Rin can now be obtained by inspection as $\Rightarrow L = 0.8 \mu m W1 = 25 \times 0.8 = 20 \mu m W2 = 4W1$ = 80 µm 7.18 Refer to Fig. In general, one attempts to identify the lowest possible number of variables and write the corresponding minimum number of variables and write the corresponding = 6.4 V allowing for about 2 V of negative signal swing at the collector. The resulting A0 = 45.5 V/V. With an op amp that has only ft = 40 MHz, the possible closed-loop gain at 5 MHz is |A| = 40 = 8 V/V 5 To obtain an overall gain of 100 would require three such amplifiers, cascaded. If the adjustment mechanism raises one RC and lowers the other, then each need to be adjusted by only (1.6 k/2) = 0.8 k. ro = 2V v DS 1 = 50 k = iD v GS const. The incremental changes around the equilibrium or bias point are related to each other by the circuit shown in Fig. 9.10(c) to determine $\tau C2 : \tau C2 = CC2$ (RC + RL) To make the contribution of fL equal to 10%, we use 1 = $0.1\omega L = 0.1 \times 2\pi fL$ $\tau C2 = 1 = 15.92$ ms $0.1 \times 2\pi \times 100$ Chapter 9-4 Thus, -3 CC2 (20 + 10) $\times 10 = 15.92 \times 10^{-3}$ \Rightarrow CC2 = 0.5 μ F because the required value is very close to 0.5 μ F and because we have selected CC1 and CE larger than the required values. This makes perfect sense since from Fig. \Rightarrow VOV 1 = 0.224 V 7.53 Equation (7.66): VGS1 = Vt + VOV 1 = 0.8 + 0.224 = 1.024 V Rout = ro + (re r \pi)(1 + gm ro) = 1.024 + 0.1 \times 0.05 = 1.03 V For gm ro 1, (b) gm1 2ID1 2 × 0.1 = 0.9 mA/V = = VOV 1 0.224 All transistors are operating at ID = 0.1 mA and have |VA| = 20 V. Thus, their W/L ratios will be equal, $0.2 = \Rightarrow 0 t 1 W \times 0.1 \times \times 0.22 2 L W = 100 L Ro = (gm ro) 2$ ro where v3 -50 mV gm = 2 × 0.2 2ID = = 2 mA/V |VOV| 0.2 ro = $|VA| L 6 \times 0.4 = 12 k = ID 0.2$ Ro = $(2 \times 12) 2 \times 12 = 6.91 M 0 t 7.69$ Refer to Fig. 2.4 i = Gm (v 2 - v 1) v O = Rm i = Rm $11 \mu R(Gm v 2 + Gm v 2 - Gm v 1 + Gm v 1) 2 2 1 v O = \mu RGm (v 2 - v 1) + \mu RGm (v 1 + v 2) 2 v d = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 - v 2 2.6 v cm = 2 sin(2\pi 60)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi 1000)t = v 1 = v cm - v d/2 = 0.005 sin(2\pi$ $sin(120\pi)t - 0.0025 sin(2000\pit) v 2 = v cm + v d/2 = sin(120\pi t) + 0.0025 sin(2000\pi t) 2.7$ Circuit a b c d v o /v i (V/V) -100 = -5 20 -5 -5 Rin (k) 20 20 20 Chapter 2-2 10 k 10 k vI 10 k vO = -0.5 V/V vI 2.8 vO Note that in circuit (b) the 20-k load resistance has no effect on the closed-loop gain because of the zero output resistance of the ideal op amp. 6.72 Refer to the circuit in Fig. I VC1 = VC2 = VCC - RC 2 But the gain required is Gain = 2V v od = 20 V/V v id 0.1 V Thus, RC $20 = 0.05 + 0.45 = 5 - 2 = 3V \text{ v C1} = 3 - 80 \times 0.005 \sin(\omega t) = 3 - 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4 \sin(\omega t) \text{ v C2} = 3 +
0.4 \sin(\omega t) \text{ v C2} = 3 + 0.4$ $v C2 - v C1 = 0.8 sin(\omega t)$ The waveforms are sketched in the figure on next page. Both Q1 and Q2 are operating in saturation at ID = 0.5 mA. \therefore ID = 0.5 mA Maximum current derivation 10%. Now, for our specific design: IL = 3.1 mA I = 0.1 mA 1.5V = 15 k 0.1 mA R1 3.1 = 0.1 1 + R2 R= R1 \Rightarrow = 30 R2 Choosing R2 = 500 \Rightarrow R1 = 15 k. Alternatively, if we set IEmax in Eq. (3) to 1.1 mA and solve Eqs. 1.16(b)]: v o = (Av o v i) RL RL + Ro 200 = (Av o v i) 1000 1000 + Ro (1) 195 = 0.78 200 780 + Ro (2) Dividing Eq. (2) by Eq. (1), we have 1000 + Ro (1) 195 = 0.78 200 780 + Ro (2) Dividing Eq. (2) by Eq. (1), we have 1000 + Ro (1) 195 = 0.78 200 780 + Ro (2) Dividing Eq. (2) by Eq. (1), we have 1000 + Ro (2) Dividing Eq. (2) by Eq. (1), we have 1000 + Ro (2) Dividing Eq. (2) by Eq. (1), we have 1000 + Ro (2) Dividing Eq. (2) by Eq. (2) by Eq. (3) to 1.1 mA and solve Eqs. (3) to 1.1 mA and solve Eqs. (4) by Eq. (4) by Eq. (5) by Eq. (5) by Eq. (6) by Eq. (7) by Esource (Av o v i) = 200[(1000 + 100)/1000] = 220 mV B, second, to boost gain C, third, to minimize loading at 100- output. Since io 1 1 M v i1 = 1 M + 0.5 M 1.5 vs 1 = 20 mV Aisii Ro RL Chapter 1-17 io = (Ais ii) Ro Ro + RL we can write 1 = (Ais ii) Ro Ro + 1 (1) $1001 88 = 20 \log 4(x/100) 1001 \times 100 = 25$, $118.86 4x \Rightarrow x 1\% R3 = R3$ nominal (1 -)R1 = R4 nominal (1 +)R4 = R4 nominal $0.25 \times 10 - 24 \times 104$ That is, the resistor tolerance should be a maximum of 0.25%. 8.31 Require v od = 1 V when v id = 10 mV and I = 1 mA. 1(b), we can determine Gv o from Rin Av o Gv o = Rin + Rsig RL = ∞ Thus, Denoting Rin with RL = ∞ as Ri, we can express Gv o as Rin = Gv o = Ri Av o Ri + Rsig v i = if Rf + (if - gm v i)(R2 RL) v i [1 + Content of C gm(R2 RL) = if[Rf + (R2 RL)] = if[Rf + (R2 RL)] = if[Rf + (R2 RL)] = R1 Rin Rf + (R2 RL) = R1 1 + gm(R2 RL) From the equivalent circuit in Fig. Thus 1 ID = k n (VGS - Vt) 2 2 = 0.08 mA 0.8 1 - VD 1 - 0.2 = 10 k = RD = ID 0.08 0.08 - 0.6 - (-1) - 0.6 + 1 = 5 k ID 0.08 For ID to remain unchanged from 0.08 mA, the MOSFET mustthat is, iD1 = 0.07 mA and iD2 = 0.09 mA, $VDD \ 1 \text{ V}$ id = -0.025 V RD RD 5 k vD1 G1 vid vGS1 5 k vD2 iD1 iD2 Q2 Q1 vS G2 vGS2 I 0.16 mA VSS 1 V 8.5 Refer to Fig. 1 we see that IC = 0.495 mA VC = IB × 200 k + IE × 0.2 k + VBE = $0.005 \times 200 + 0.5 \times 0.2 + 0.7 = 1.18 \text{ V}$ (b) 6.120 Refer to the circuit in Fig. The resistor values are obtained as follows: $V2 = -0.7 V V2 - (-5) 0.5 mA \Rightarrow R1 = 8.6 k R1 = Chapter 4-23$ This figure belongs to Problem 4.59.

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