2.5 LOG AMPLIFIER

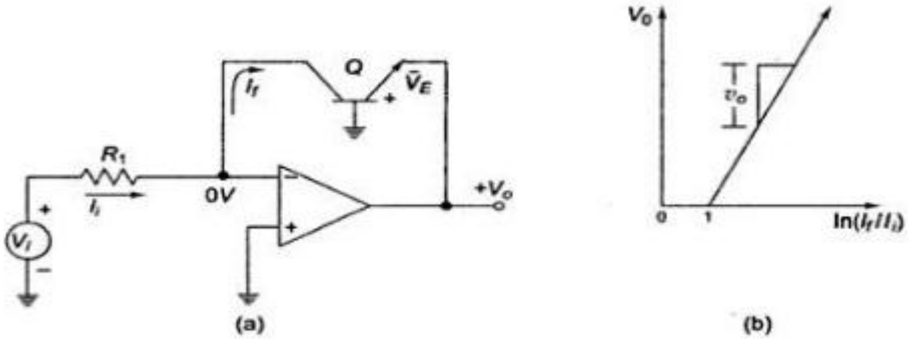

Figure 2.5.1 Fundamental log-amp circuit and its characteristics

[source: https://www.brainkart.com/subject/Linear-Integrated-Circuits_220/]

There are several applications of log and antilog amplifiers.Antilog computation may require functions such as ln x, log x or sin hx.

USES

- Direct dB display on a digital Voltmeter and Spectrum analyzer.
- Log-amp can also be used to compress the dynamic range of a signal.

A grounded base transistor is placed in the feedback path. Figure 2.5.1 is the fundamental log-amplifier circuit and its characteristics. Since the collector is placed in the feedback path. Since the collector is held at virtual ground and the base is also grounded, the transistor's voltage -current relationship becomes that of a diode and is given by,

$$I_E = I_s[e^{\frac{qV_{BE}}{kT}} - 1]$$

and since $I_c = I_E$ for a grounded base transistor $I_C = I_s\, e^{kT}$

Is-emitter saturation current $\approx 10^{-13}$A

k=Boltzmann's constant

T=absolute temperature (in°K)

$$V_o = -\frac{kT}{q} ln\left(\frac{V_i}{R_1 I_S}\right) = -\frac{kT}{q} ln\left(\frac{V_i}{V_R}\right)$$

where $V_{ref} = R_1 I_s$

The output voltage is thus proportional to the logarithm of input voltage. Although the circuit gives natural log (ln), one can find log10, by proper scaling

Log10X=0.4343 ln X

The circuit has one problem.The emitter saturation current Is varies from transistor to transistor and with temperature. Thus a stable reference voltage V ref cannot be obtained. This is eliminated by the circuit given below

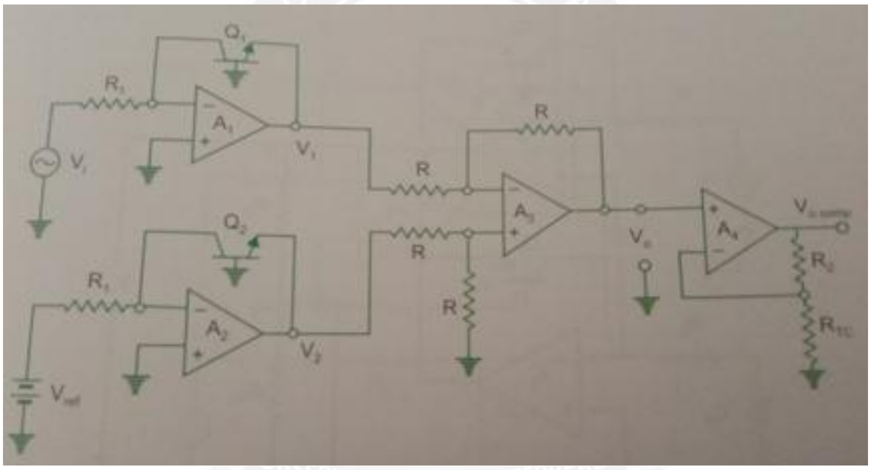

Figure 2.5.2 Log-amp with saturation current and temperature compensation

[source:"Linear Integrated Circuits"by D.Roy Choudhry, Shail Bala Jain, Page-177]

Figure 2.5.2 shows the log-amp with saturation current and temperature compensation.The input is applied to one log-amp, while a reference voltage is applied to one log-amp, while a reference voltage is applied to another log-amp. The two transistors are integrated close together in the same silicon wafer. This provides a close match of saturation currents and ensures good thermal tracking. Assume $I_{S1}=I_{S2}=I_S$

Thus the reference level is now set with a single external voltage source. Its dependence on device and temperature has been removed. The voltage Vo is still dependent upon temperature and is directly proportional to T. This is compensated by the last op-amp stage A4 which provides a non-inverting gain of $(1+R_2/R_{TC})$. Temperature compensated output voltage V_L .Figure 2.5.3 shows the logarithmic amplifier using two op-amps.

$$V_L = \left(1 + \frac{R_2}{R_{TC}}\right)\frac{kT}{q} ln\left(\frac{V_i}{V_R}\right)$$

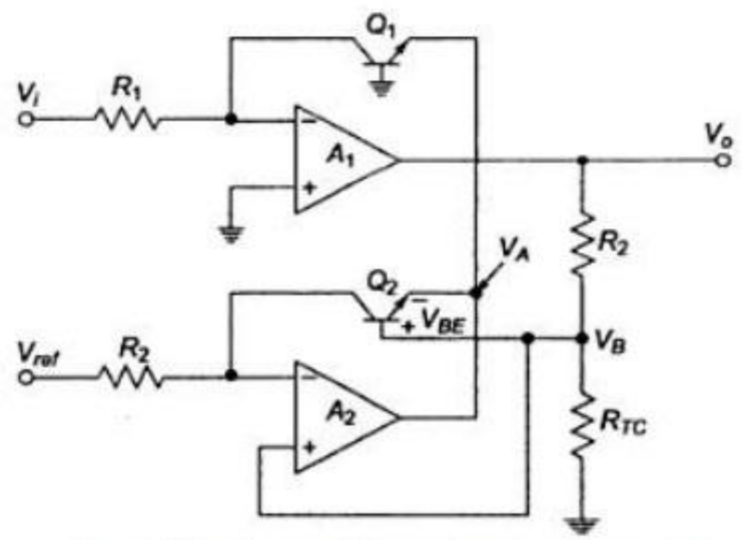

Figure 2.5.3 Logarithmic amplifier using two op-amps.

[source:"Linear Integrated Circuits"by D.Roy Choudhry, Shail Bala Jain, Page-178]

Where R_{TC} is a temperature-sensitive resistance with a positive coefficient of temperature (sensor) so that the slope of the equation becomes constant as the temperature changes.

ANTILOG AMPLIFIER

A circuit to convert logarithmically encoded signal to real signals. Transistor in inverting input converts input voltage into logarithmically varying currents.

The circuit is shown in figure 2.5.4 below is the antilog amplifier.The input Vi for the antilog-amp is fed into the temperature compensating voltage divider R_2 and R_{TC} and then to the base of Q_2. The output of A2 is fed back to R_1 at the inverting input of op amp A_1. The non-inverting inputs are grounded

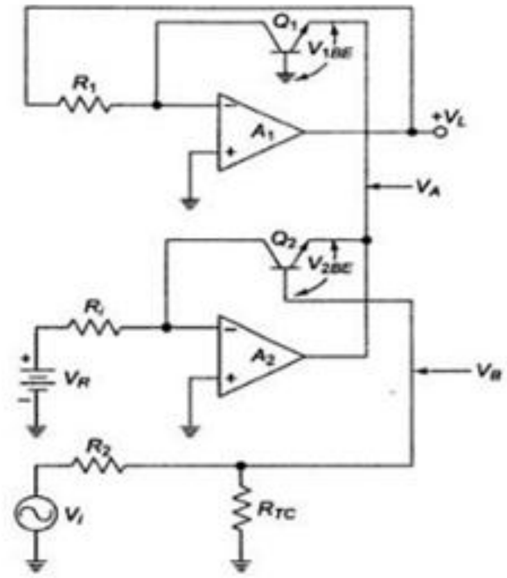

Figure 2.5.4 Antilog Amplifier

[source:"Linear Integrated Circuits"by D.Roy Choudhry, Shail Bala Jain, Page-179]

$V_{1BE} = \frac{kT}{q}\ln[\frac{V_L}{R_1 I_s}]$ and $V_{2BE} = \frac{kT}{q}\ln[\frac{V_B}{R_1 I_s}]$ and $V_A = - V_{1BE}$ and $V_B = R_{TC}/(R_2+R_{TC})\, V_i$

$V_{Q2E} = V_B + V_{2BE} = R_{TC}/(R_2+R_{TC})\, V_i - \frac{kT}{q}\ln[\frac{V_B}{R_1 I_s}]$

$V_{Q2E} = V_A$

Therefore, $$-\frac{kT}{q} ln\left(\frac{V_L}{R_1 I_S}\right) = \frac{R_{TC}}{R_2 + R_{TC}} V_i + \frac{kT}{q} ln\left(\frac{V_R}{R_1 I_S}\right)$$

Rearranging, we get

$$\frac{R_{TC}}{R_2 + R_{TC}} V_i = -\frac{kT}{q} ln\left(\frac{V_L}{R_1 I_S}\right) - \frac{kT}{q} ln\left(\frac{V_R}{R_1 I_S}\right)$$

$$= -\frac{kT}{q} ln\left(\frac{V_L}{V_R}\right)$$

We know that $\log_{10} x = 0.4343\, ln\, x$.

Therefore, $$-0.4343\left(\frac{q}{kT}\right)\left(\frac{R_{TC}}{R_2 + R_{TC}}\right) V_i = 0.4343\, ln\, \left(\frac{V_L}{V_R}\right)$$

$$-0.4343\left(\frac{q}{kT}\right)\left(\frac{R_{TC}}{R_2 + R_{TC}}\right) V_i = \log_{10}\left(\frac{V_L}{V_R}\right)$$

$$-KV_i = \log\left(\frac{V_L}{V_R}\right)$$

$$K = 0.4343\left(\frac{q}{kT}\right)\left(\frac{R_{TC}}{R_2 + R_{TC}}\right)$$

$$V_L = V_R 10^{-KV_i}$$

The output V_o of the antilog- amp is fed back to the inverting input of A_1 through the resistor R_1.Hence an increase of input by one volt causes the output to decrease by a decade.