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JULY 1977

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VOLUME 13 No. 7 JULY 1977

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Our August issue will be on sale Friday, July 8, 1977
(for details of contents, see page 521)

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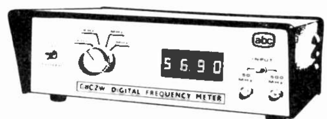

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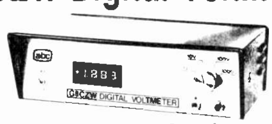

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Volts	No	Price
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5 AMP TO220 CASE

Volts	No.	Price
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Volts	No.	Price
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100	THY10A/100	£0·57
200	THY10A/200	£0·62
400	THY10A/400	£0·71
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U61	30	NPN TO18 2N706 silicon	16141	£0·60
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U70	8	3 amp SCR TO66 case	16150	£1·20

Code Nos. mentioned above are given as a guide to the type of device in the pak. The devices themselves are normally unmarked.

COMPONENT PAKS

Pak No.	Qty.		Order No	Price
C1	200	Resistor mixed value approx. (count by weight)	16164	*£0·60
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C8	10	Reed switches	16171	*£0·60
C9	3	Micro switches	16172	*£0·60
C10	15	Assorted pots	16173	*£0·60
C11	5	Metal jack sockets 3 × 3·5mm 2 × standard switch types	16174	*£0·60
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C24	25	Presets assorted type and value	16186	*£0·60
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S2	6	Slider potentiometers, all 470 ohms	16191	*£0·60
S3	6	Slider potentiometers, all 10kΩ lin	16192	*£0·60
S4	6	Slider potentiometers, all 22kΩ lin	16193	*£0·60
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MC3	24	miniature ceramic capacitors. 3 of each value—470pF, 560pF, 680pF, 820pF, 1,000pF, 1,500pF, 2,200pF and 3,300pF	16162	*£0·60
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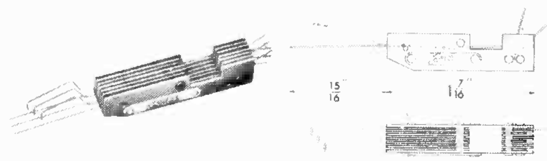

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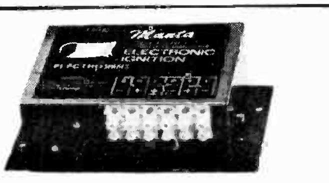

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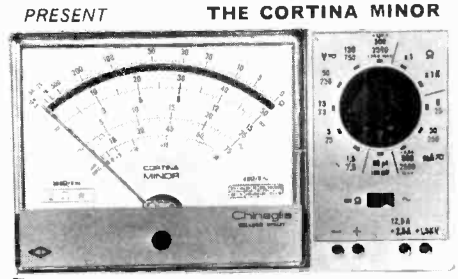

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TIME IS THE ESSENCE

ONE striking phenomenon of modern life is the individual's increasing subservience to time. Not just as periods to occupy some tasks, but as precise moments in the day when personal plans have to be synchronised in accordance with the inevitable programme of happenings we all become involved in some way or another each day.

As ancient clocks bear witness, in the leisurely past sometimes an hour hand alone was sufficient to mark the progress of the day. Now the pace of life has quickened so that a minute hand is often less than adequate and means for measuring the passage of seconds, even submultiples of seconds, have become of importance in many quite ordinary routine activities.

And what has been chiefly responsible for making all of us clock watchers, virtual slaves of time? The principal culprit, without a doubt, is electronics. The modern obsession with time could be reckoned to have begun with radio, for broadcasting introduced the time signal into homes big and small, in places near and far. So this standard measure of time entered our lives and, together with programme schedules, soon became a dominant influence in determining our daily affairs. Time insinuated its way further into our personal affairs when the transistor radio came along and made reception simple at all times in practically all places. We now live by the clock as no previous generation ever did.

From a scientific standpoint electronic developments have brought about a greater precision in the marking and recording of time, commonly to the thousandth or millionth part of a second. One of the biggest growth areas in electronics has been in timer i.c. devices, closely matched by the complementary technology of readout devices. These developments manifest themselves most dramatically on the consumer market in the form of the digital watch. Another very useful application of electronic timer devices is the digital stopwatch. The Pocket Stopwatch design featured in this issue has considerable advantages over its clockwork counterparts and should enjoy widespread popularity.

Electronic computers and the more recently introduced microprocessors will be influencing our lives more and more in various ways in the future. Computing systems are nothing if not time conscious. They are geared to a Lilliputian time scale of micro- or nano-seconds. Clock—not oscillator, it might be noted, has long been the accepted term for the time controlling device employed in the computing world.

So whichever way one looks at it, electronics seems to be inexorably tied up with the question of time/speed. The constant urge and aim of microelectronics designers and manufacturers is to increase the speed of their devices; to permit more functions to be carried out per millisecond. It's an ever-accelerating pacemaker that is moulding our destinies, however subtle some of its effects may be. Shades of the Sorcerer's Apprentice! Would we ever be able to cry halt, supposing we wished to?

F.E.B.

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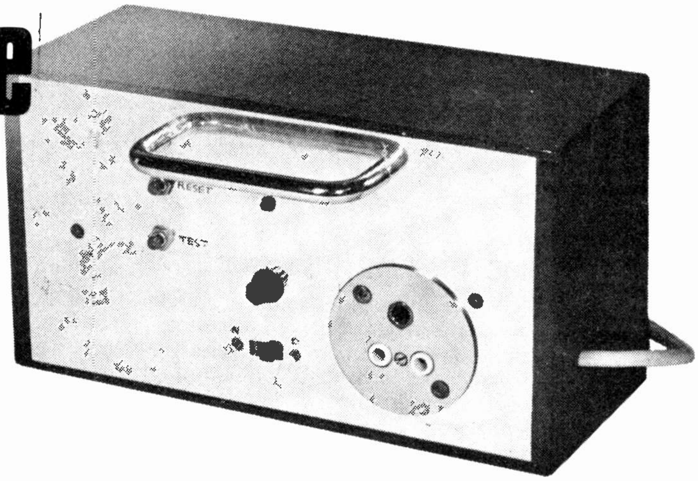
Earth Leakage CIRCUIT BREAKER



By K. A. SMITH

EVERY day more and more electrical equipment goes into service, much of it having metal parts exposed. Regulations demand that the equipment has satisfactory insulation and that the case of the equipment, or the body of, say, a drill should be earthed.

This sounds fine in theory but consider some possible faults. A drill has been in use for some time with all too typical ill-treatment. After much flexing and tension of the cable in use and in storage, the earth conductor finally breaks while the drill is being lowered down a ladder by its cable. Over the last few months a carbon build-up has occurred around the brush gear, and when the drill is switched on at the bottom of the ladder by a person standing on the damp ground, a leakage current of many milliamps passes. The current may have two effects, first a straightforward shock, and secondly a fall due to the muscular contractions and the jerking away of the drill. Either could be injurious, if not fatal.

Table 1: The effect of electric shock (60Hz) on humans

Current intensity (One second contact)	Effect
1mA	Threshold of perception
5mA	Accepted as maximum harmless current intensity
10–20mA	"Let go" current before sustained muscular contraction
50mA	Pain, possible fainting, exhaustion, mechanical injury. (Heart and respiratory functions continue)
100–300mA	Ventricular fibrillation will start but respiratory centre remains intact
6A	Sustained myocardial contraction followed by normal heart rhythm. Temporary respiratory paralysis. Burns if current density is high

EFFECTS OF SHOCK

Table 1 shown gives the figures determined by John M. R. Bruner and presented in "*Hazards of Electrical Apparatus*", *Anesthesiology, Mar–Apr 1967*. This table was reproduced in this form by Messrs Hewlett-Packard in Application Note AN718.

Normally the skin resistance lies between about 50 kilohms and 250 kilohms for people with a fairly dry skin, thus a 250 volt supply would normally give a shock from 1mA to 5mA, but this cannot be relied upon as area of contact and damage to the skin cause differences. Any more than a fleeting contact may produce damage destined to increase the current flow.

Having discussed some of the dangers, what now are the answers? Obviously nothing can be done about a shock between the live and neutral of a mains supply, but it is surprisingly difficult to get such a shock. Probably the only way would be to lean on the live terminations of a transformer or similar unit and get a shock confined to one hand.

LEAKAGE

It is however very easy to handle equipment without an earth connection (e.g. portable lamps) and find a leakage current perceptible to the touch. This leakage may never increase to a dangerous level, but a frayed wire into a metal lampholder of the type used on some older optical apparatus could result in a direct connection. Standing on a wooden floor even such a direct connection may not be felt, but if at the same time another piece of apparatus is touched which may have a sound earth then a severe shock will result. Cases have been known of shock when two photographic lamps have been picked up together.

The answer is in part in an acquired discipline; i.e. touch one piece of apparatus at a time, with the other hand behind the back or in a convenient pocket, and wear insulated soles on shoes. (Rubber or non-porous p.v.c.) There comes a time, however, when certain actions cannot be avoided, and several pieces of mains driven equipment are used together. In this case the only safe way to operate the equipment is to have some means of detecting the fault currents running to earth.

FUSING

If a direct connection occurs then a fuse may be blown if the ratings are correctly chosen. Wiring can arc and cut itself through if the contact is gentle and the fuse an old type 15 amp wired pattern, thus the fusing of equipment should match the duty. Internal fuses will not help here since the faults are cable faults and will not be protected unless the plug or the circuit is fused to a low level.

Obviously faults which could be dangerous can happen inside a unit—when filter capacitors break down, a wire is trapped under a component and eventually plastic flow of the insulator allows contact, or switches arc across. It should be mandatory for suitable fuses to be fitted, but even in this respect difficulties arise, since some transformers have very large magnetising currents, and may require considerably heavier fuses than the normal full load rating would suggest. The use of delay fuses is one solution, lower flux densities in transformer designs another way to reduce inrush and lower the working temperature, but economics seem to be against the latter.

When the neutral line makes contact with earth there will be a slight current flow. It is possible to find several volts from neutral to earth due to the voltage drop in the neutral line when carrying current, a figure of two volts being quite common. It is unlikely that any effect would be noticed unless there happened to be neutral fuses in the system, and even then only if the earth line impedance is much lower than the acceptance figure of one ohm. With a good earth return, having a figure of, say, 0·1 ohm then 20 amps would be possible provided that a much greater current than this was being drawn via the neutral to support this earth return current.

Under normal circumstances an earth fault between neutral and earth is not dangerous. Certain areas of premises having gas mixtures or spray booths, etc. could be in danger if any apparatus having a neutral to earth fault touched an earthed cubicle, since there would be a slight spark, but in domestic situations there would be no danger.

EARTH LEAKAGE DETECTOR

The earth leakage unit described is an answer to the problems, and was originally designed to meet the demand for safety in a colour processing darkroom. The stainless steel top of the processing bench in close proximity to the sensor and heater of the thyristor operated temperature control unit, an accessible enlarger, thyristor lamp controller, enlarger timer, process timer and clock all pointed to the need for an earth leakage unit.

At this point the intention was to fit a commercial model, but the frustration of trying to buy such an article for private use made me determined to make one for myself. Voltage operated relays were offered but I did not relish the idea of holding a piece of equipment with the live supply attached, waiting for the voltage to rise high enough to operate the relay. Should a fault occur then the earth line to the plug is lifted in voltage until the relay trips, Fig. 1. Theoretically this is at a relatively low voltage, say about 30 volts, and someone holding the case of a portable tool and touching an earthed pipe should not even realise that a voltage has appeared. Ultimately the realisation will dawn that the supply has switched off. However, suppose that the earth wire has broken as in the example of the man on the ladder, then the fault current will pass directly from the tool via the person holding it to earth, and the relay will still be waiting for a signal it will never get (at least not by that route).

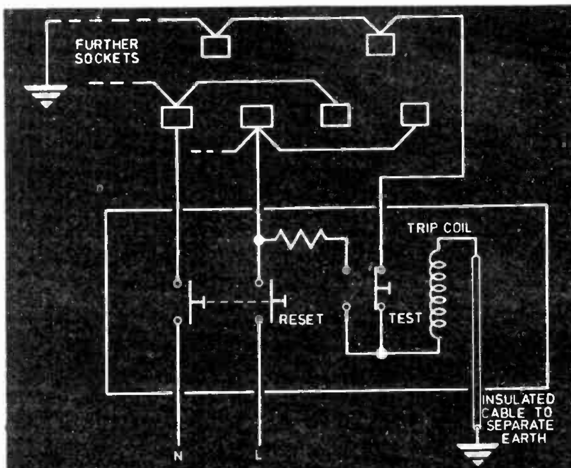


Fig 1. A voltage-operated earth leakage trip system

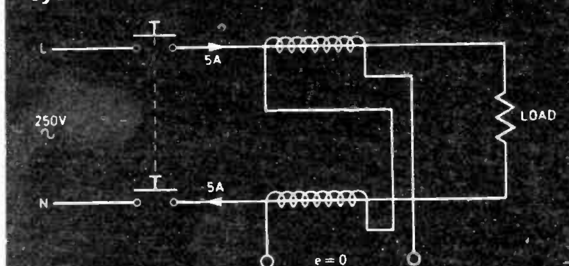


Fig. 2. A current-balance earth leakage detector system

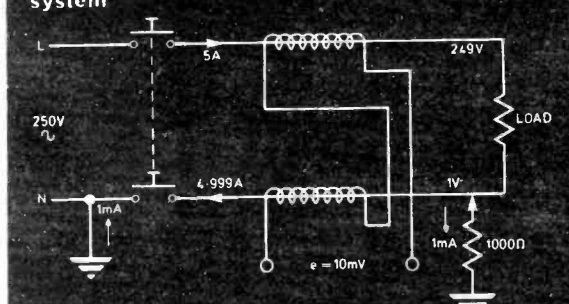


Fig. 3. Effect of leakage from the neutral to earth

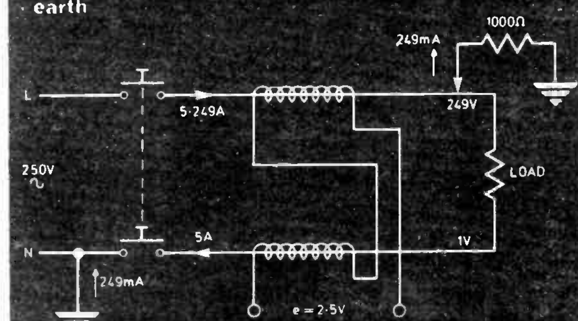


Fig 4. Effect of leakage from live to earth

An alternative method, which overcomes this problem, is the current balance trip system, illustrated in Fig. 2. The current to the load is carried in and out by a pair of conductors. Since a build up of current cannot occur, whatever arrives via one wire must leave by the other if the insulation is perfect. The sum output of the current transformers is zero.

Should a leak develop from either conductor to earth, as in Figs. 3 and 4, the currents in the two wires will not be equal, and the net output of the current transformers will not be zero.

The current transformers if iron cored and having about 2,000 turns could produce an e.m.f. of at least 10mV under the conditions of Fig. 3, whilst if the leakage were from the live conductor, then the current would be 249mA to earth as shown in Fig. 4. With the same current transformers the output could be expected to produce about 2·5V summation.

An output of, say, 100mV which can be considered a safe figure, clear of noise and the residual a.c. left at null balance, would mean a minimum detectable neutral leakage resistance of about 100 ohms and a live conductor leakage resistance of about 25 kilohms, that is a 10mA leakage from either neutral or the live lead. These figures are of course examples to indicate the order of current and voltage readings expected. Any transformer destined for such duty would have to be tested to assess its performance. The use of a low inertia core material such as Radiometal would improve the low current performance.

PRACTICAL SYSTEM

In practice the system does not have two transformers. Both go and return cables are passed through one core to balance out the load current, and leakage currents as low as 2mA can be detected with a load current of 5 amps passing using a modified valve-type loudspeaker transformer.

The advantage of this system is that the monitor is capable of detecting leakage at all times and does not necessarily have to wait for catastrophic failure or a person touching a live case. In the quoted case of a broken earth wire on a drill then this would be the case, but had the earth wire broken by pulling or tripping over the cable of a hedge trimmer lying on the damp lawn prior to use then the earth leakage unit would sense this and trip the supply before the apparatus was touched. Any tendency for leakage to develop even though the earth wire is still intact will trip the earth leakage unit, the apparatus still being intrinsically safe. Any trip of an earth leakage unit should be investigated and not just reset.

CIRCUIT OPERATION

The circuit of the unit is shown in Fig. 5. The output from current transformer T1 is fed to IC1, a standard 741 operational amplifier, which has back-to-back diodes D1, D2 across the input to protect the amplifier from damage due to transients. The input circuit is returned to the centre point of resistors R6, R7 to give an artificial 0V line, so that effectively the amplifier is supplied with +6V and −6V. The exact figures will depend upon the type of 12 volt transformer used and its regulation. Possibly a little more than the r.m.s. value should be found even at 100mA drain when using a 220μF smoothing capacitor.

COMPONENTS . . .

Resistors
R1, R3, R4 10kΩ (3 off)
R2, R6, R7, R9–R12 1kΩ (7 off)
R5 1·8MΩ (see text)
R8 4·7kΩ
R13 3·6kΩ
R14 22Ω
All 5% ½W

Potentiometer
VR1 10kΩ min. horizontal preset

Capacitors
C1 22μF 25V elect.
C2 10μF 25V elect.
C3 220μF 25V elect.

Semiconductors
IC1 741 (8-pin d.i.l.)
TR1 BFY50 TR2 2N3055
D1, D2, D4–D7 1N4003 (6 off)
D3 High-brightness l.e.d.

Miscellaneous
T1 See text
T2 12V-0-12V 250mA secondary
RLA 3-pole changeover, 110Ω 12V coil (Electrovalue)
FS1 5A 20mm with panel-mounting holder
S1, S3 S.P. push to make, 250V (2 off)
S2 D.P.D.T. slide switch (used as s.p.s.t.)
PL1/SK1 Mains plug and socket, type as required
Printed circuit board. Terminal pins. 8-pin d.i.l. socket.
Mounting pillars. Case (see text)

The voltage gain of the amplifier as shown is 180, but this is a starting point and the gain should be lowered to meet the level of sensitivity required. In the final prototype unit, a value of 680 kilohms was used as the feedback resistor R5, giving a gain of 68. Provision should be made for easy changing of the feedback resistor, so that gain levels can be adjusted as the parameters of the circuit become known.

The output at pin 6 of the 741 is a sine wave varying in amplitude with the signal from the differential transformer. Since this signal depends upon the leakage, the output from the amplifier is in proportion to the leakage, though the relationship is not linear.

TRIGGER CIRCUIT

The relay is driven by a standard form of Schmitt trigger circuit. A slightly unusual feature is the use of dissimilar transistors. Normally two small-signal transistors, or an i.c. followed by a power stage are used as the trigger. In this case the signals are large enough to use direct coupling of the trigger circuit to a relay coil requiring about 100mA for operation.

At switch on, the normally closed relay contact RLA3 holds TR1 in a conducting state by returning its base via R11 to the positive supply. The TRIP indicator l.e.d. D3 is also fed from this contact via R8. While TR1 is in a conducting state the collector potential is low and no significant current flows to the base of TR2. The relay RLA is thus de-energised.

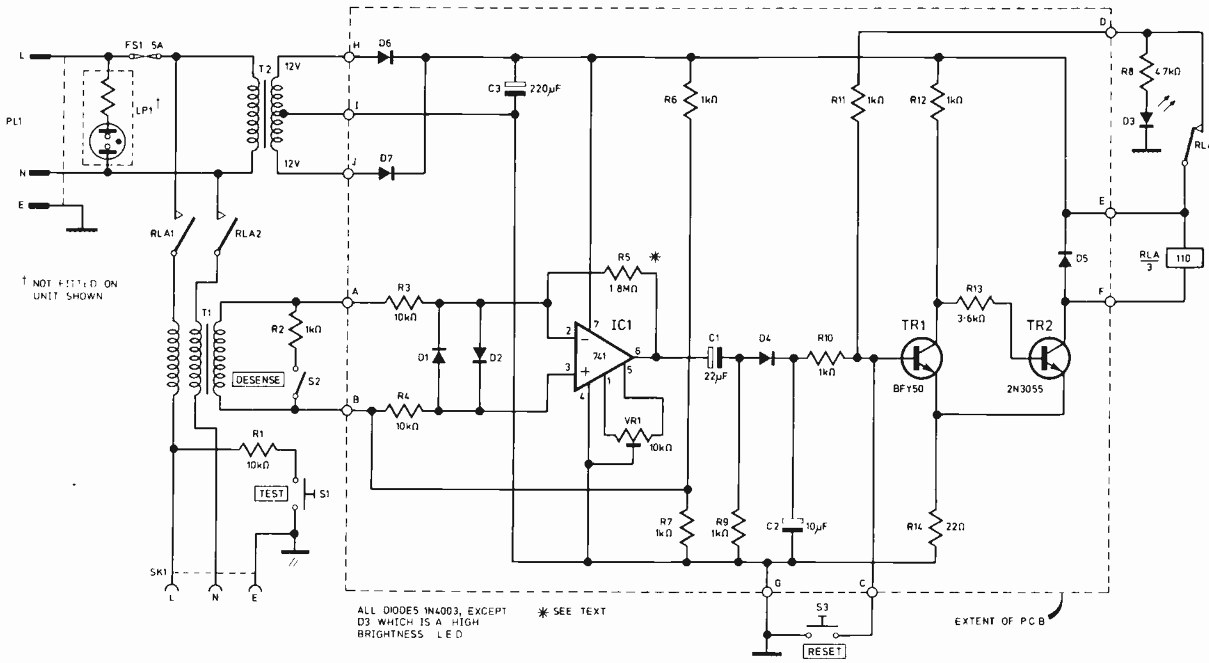


Fig. 5. Circuit diagram of the complete electronic earth leakage circuit breaker

This state can be reversed by operating the RESET button S3. The drive to TR1 base is diverted to earth, the collector voltage now rises and current flows via R12 and R13 to the base of TR2, with the result that the relay is energised. As the relay operates, contact RLA3 opens so that even when the RESET button is released there is no drive to the base of TR1 and the relay remains in the energised state.

The rate at which this happens is accelerated by the change in voltage across R14, causing a rapid snap action. The same action in reverse causes a rapid decrease in energising current in the relay when the base of TR1 is taken to a critical positive level. The action should occur at about 2V to switch on and 1·5V to switch off, with the full supply voltage on the collector of TR2 in the de-energised condition, and under 1V in the energised condition. The relay should snap on and off without hesitation as the limits of input backlash are reached.

When the circuit is operating correctly, the relay should appear to de-energise faster than it energises, which is contrary to normal operation. Should the voltage at TR2 collector during energisation of the relay exceed one volt, then the value of R13 can be reduced or a transistor with higher gain fitted.

RESET

It should be noted that the RESET button takes priority over an incoming signal, but of course it should not be operated after a trip without investigating the fault. If required, a large value capacitor with a high value leak resistor could be wired in series with the contacts of S3 to make the reset impulse-operated.

Having reset the trigger circuit and closed the main contacts RLA1 and RLA2, the system is ready to operate on a leakage signal. The output from the amplifier is fed via C1 to D4 and charges capacitor C2 across the input to the trigger circuit. This provides damping and prevents erratic operation.

Assume the input to IC1 is a positive-going half cycle, then the output will swing negative, C1 will discharge slightly from its quiescent mid-voltage state, and as the signal voltage reverses so the still basically negative-going output waveform will give a positive trigger to TR1. A negative-going input half-cycle will trigger almost immediately. In both cases the relay will release, and will be maintained in that condition by the closing of RLA3. The TRIP indicator D3 will show that a trip has occurred. D3 has no effect on the triggering potential, the voltage at pin D on the circuit board only reaching a sufficiently high value to operate the indicator after RLA3 has closed.

CONSTRUCTION

The prototype unit was housed in a home-made plywood case 258 × 140 × 108mm. The amplifier and trigger circuitry were built on matrix board. Figs. 6 and 7 show a p.c.b. developed from this. The transformers, relay and input terminal block were mounted on a 16

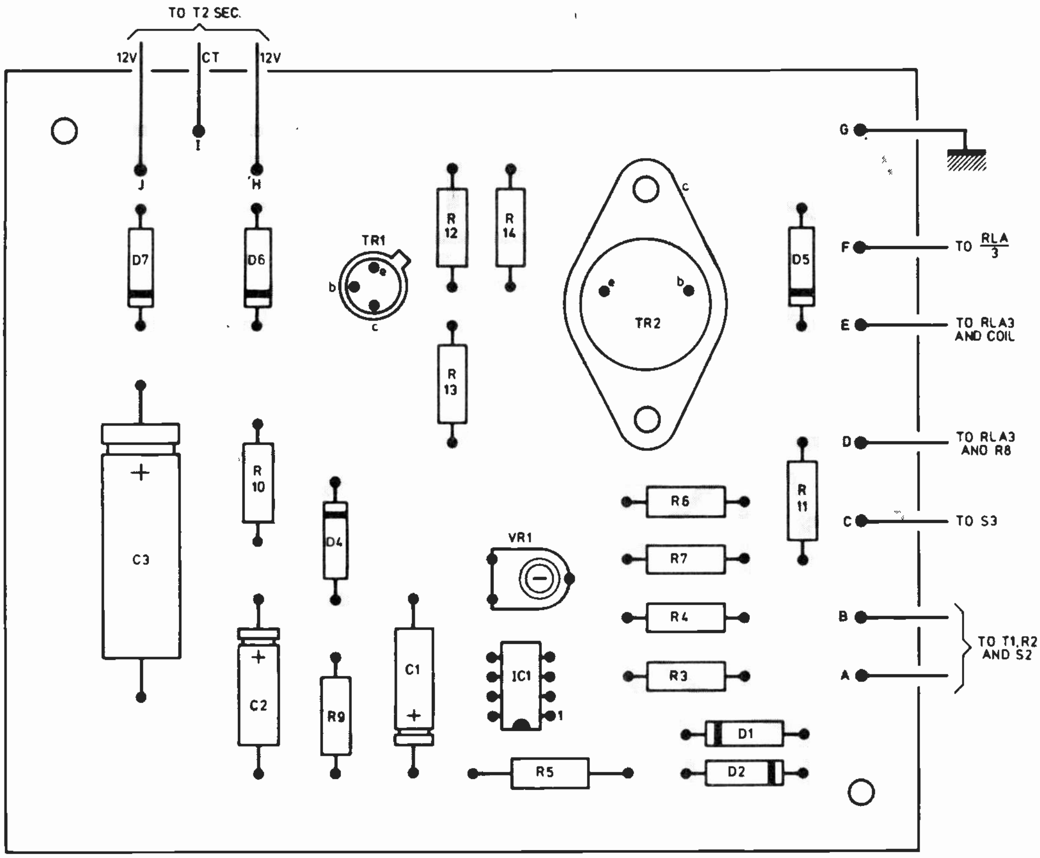


Fig. 6. Layout of components on the printed board

s.w.g. aluminium plate. Board and plate were stood off the 10 s.w.g. aluminium front panel on pillars, as shown in the photograph.

Some of the components used in the prototype differ in style from those shown in the components list and drawings, particularly VR1 and IC1. Those in the prototype were simply to hand at the time.

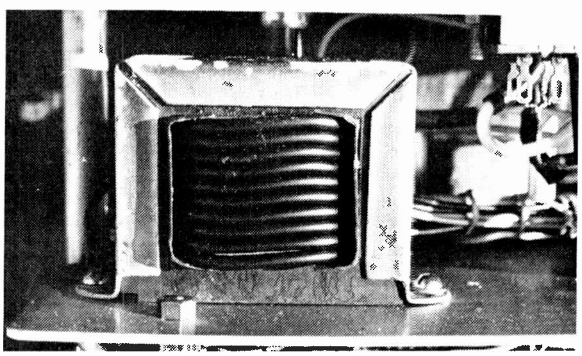
THE TRANSFORMER

The heart of the system is the differential transformer. As mentioned above, this can be made from an old valve-type loudspeaker transformer which has had the secondary winding removed. A transformer with a layered winding, and which has the primary winding terminated with p.v.c.-covered flexible cable should preferably be used. If the only type available brings out the fine primary winding wire for connections, then a sound mechanical attachment should be devised. As an alternative a mains filament transformer can be used, this having the advantage of a good primary connection.

Whichever type of transformer is used the secondary must be removed. In the case of the mains transformer judicious unwinding and cutting should remove the secondary winding without damage to the primary and without the need to open the core, which if varnished could prove almost impossible. The speaker type of transformer should be opened, the secondary (usually about 22 s.w.g.) removed and the core reassembled with the laminations interleaved instead of in the stacked form with paper gap normally employed.

Whilst the size of transformer is not critical, too small a unit may make winding of the current circuit difficult, and too large a unit will have a large core loss making the sensing of small currents impossible. A good practical size is the type rated in mains versions as 6VA with about 12VA taken as the upper limit.

With the secondary windings removed there will be a gap between the outer part of the primary and the core. Into this gap the current windings must be wound by taking two lengths of 32/0·2mm or 40/0·0076in 250V grade wire and feeding them into the slots. The windings should be five turns with the two conductors fed in together and kept flat and symmetrical (Fig. 8).



The prototype current sensing transformer

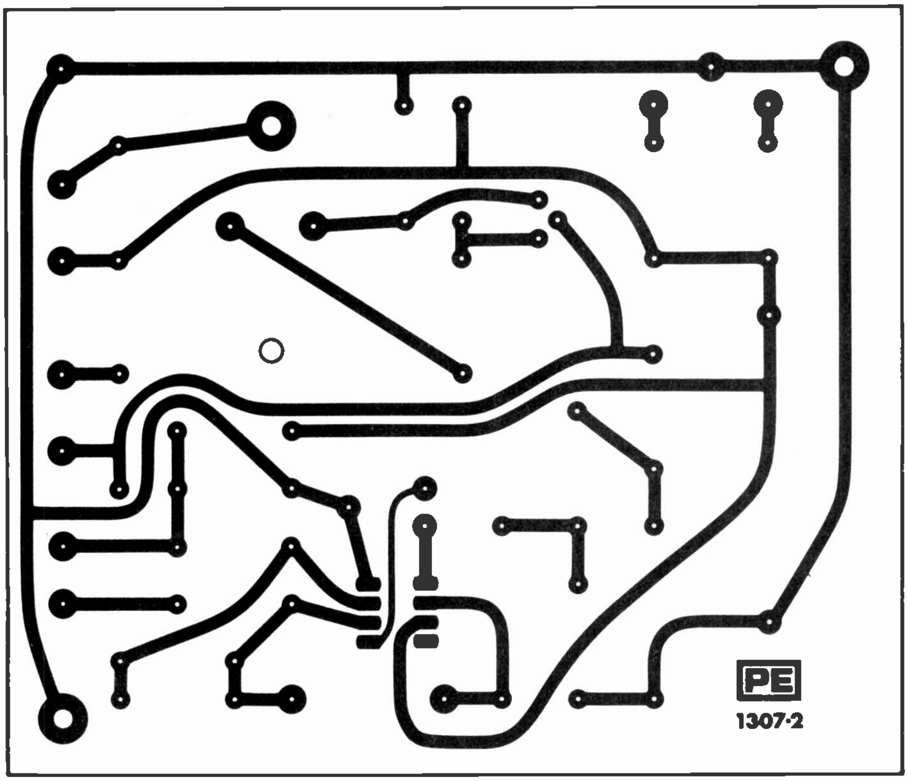


Fig. 7. Printed board track layout, shown full size

This bifilar winding serves to keep the leakage inductance to a minimum, and make a nearly zero null balance possible. The wires should be left long enough to reach the relay and the output socket.

The transformer used in the prototype unit had been wound previously for tests on a current limit circuit and had one winding of 1,500 turns of 38 s.w.g. wire. To achieve the desired 2mA sensitivity, five turns were found necessary for the new winding, now to be called the primary. Since a gap had been allowed for in the original design there was plenty of room to fit the new primary, whereas in some designs of transformer, even with the old secondary removed some difficulty may be experienced.

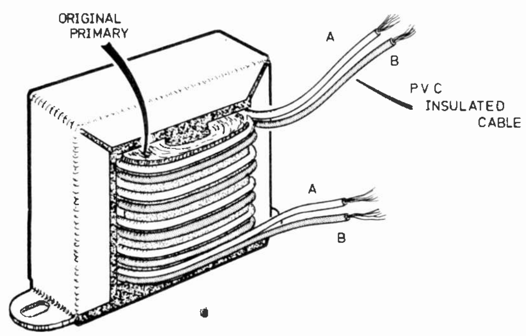


Fig. 8. Adding the new primary winding to the current sensing transformer

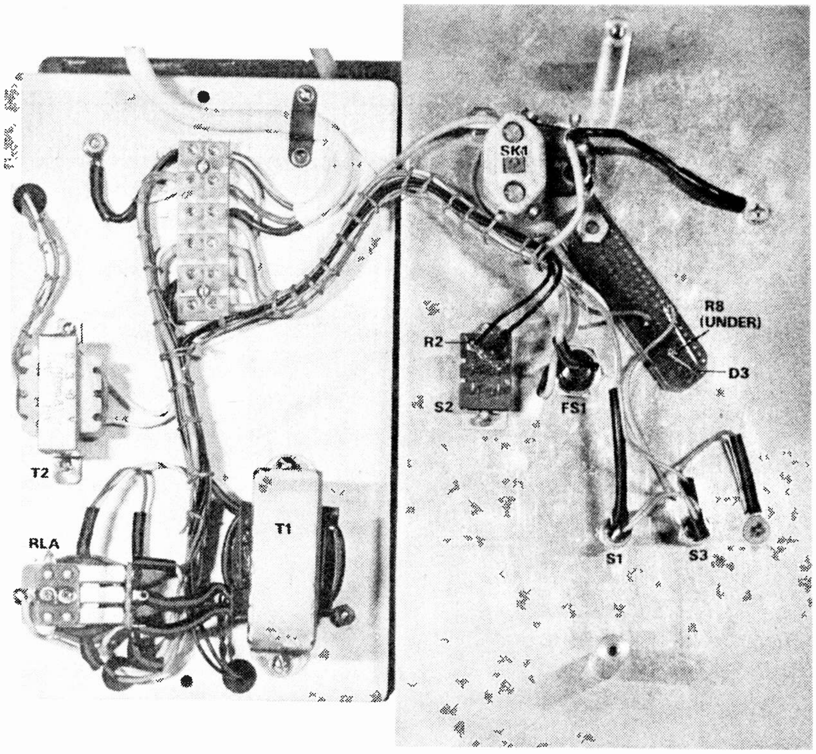
The current limit set for the unit was five amps and was determined by the safe breaking current of the relay. Since only darkroom equipment and the occasional use of portable tools such as a drill or hedge trimmer were envisaged, this was adequate. More could be handled by increasing the relay rating or by a staged system involving a light duty trip controlling a heavy duty breaker.

Naturally all of the current of the protected items must pass through the bifilar windings, but this does not really pose such a problem as many transformers of the 10VA class are wound with current densities of 3,000A/in^2 or more. In this case the heating effect of five double turns of cable on the outside of what is really quite a large heat sink is minimal.

Much more current could be carried by the cable specified if required, or for easier winding the cable size for this current could go down to 16/0·2mm. Using the axiom that one test is worth a thousand opinions then the answer to the problem is simply to try it with a load, preferably a low voltage high current transformer supplying the test current, but even at mains voltage this does not pose a serious problem.

RELAY

The relay used is a standard 3-pole type having a nominal coil resistance of 110 ohms for operation from 12V d.c. This should be a good quality component since it must break the full load of the unit, but the fault level of the supply need not be of any concern as the included five amp fuse will clear line to line faults without harm to the relay.

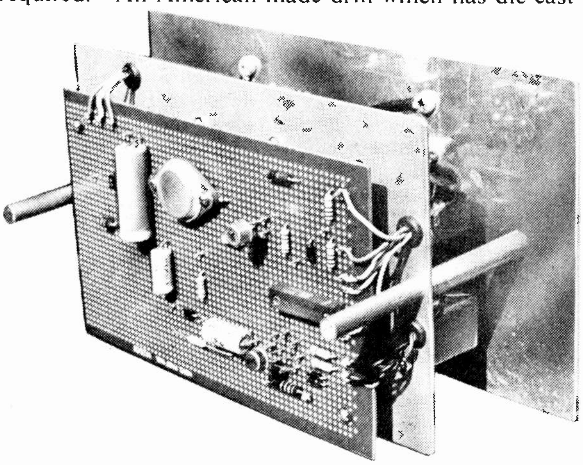


Layout of components on the front panel and chassis plate. Wiring between the two should be made into a cableform as shown, to allow access for construction and servicing

The release time of the relay is given as 20ms, and the half-wave time is 10ms. The total release time is of the order of 30ms or 1½ cycles of 50Hz mains. The current rating is six amps for a resistive load falling to two amps for an inductive load, but it is unlikely that a true inductive load would be switched as transformers would have a secondary load, and power tools have not a particularly large inductance.

TRIP CURRENT SETTING

Although great emphasis has been placed upon the achievement of 2mA trip current, this was partly an academic exercise and the final unit has a desensitise switch to lower the sensitivity. For all of the darkroom equipment, including the 1kW kettle element used with the thyristor controlled water bath controller for the colour developer, the 2mA setting is ideal, but for some power tools a less sensitive setting may be required. An American made drill which has die-cast bearings and a cable fitted directly into the handle without any sleeve or clamp, works perfectly on the 2mA setting, whereas a British made drill requires above 10mA setting, and a hedge trimmer made by an equally famous maker requires about 18mA setting. Because of this resistor R2 was fitted across the secondary of the differential transformer, and gave 18mA trip current when switched in by S2. An alternative to this would have been to reduce the gain of the 741 by switching in a parallel resistor across the feedback resistor R5.



Interior view of the prototype unit, showing mechanical arrangement

The only problem met with the unit was when switching off the colour matching fluorescent lamp. Sometimes the unit would trip on the 2mA setting. This was cured by replacing the rocker type switch by an old tumbler type. Possibly some filtering of the lamp circuit should have been done, but the simple expedient was effective and has been accepted.

CONCLUSIONS

In this article an attempt has been made to give some of the design thinking in order to illustrate how available material has been used. This is felt to be important to enable the constructor to appreciate the snags and overcome them, thus allowing "tailoring" of the finished article to meet requirements.

The finished unit is intended to be a portable device terminating a short extension lead. For this reason great care should be taken to ensure continuity of the earth lead to the unit, unless the double insulated technique is used with all plastics constructional materials.

In all cases the earth to the outlet socket should be sound as this will give the "early warning" protection against equipment which is gradually becoming leaky, as well as giving the same safeguard as is normally afforded should a fault develop in the unit. The test button should be used to check the operation each time that the unit is used, or if the unit is to be left switched on then a weekly test should be given. ★

SEMICONDUCTOR UPDATE

By R.W. COLES

LM3911

SAD-1024

THERMOMETER CHIP

If you wanted to build an electronic thermometer, then until recently you would have had to choose either a thermocouple, a thermistor, or a semiconductor diode as your sensor. Now, thermocouples are expensive and require an expensive "cold junction" reference and considerable amplification, while thermistors are fragile and have non-linear characteristics. Using a silicon diode as a sensor may seem attractive, but changing that 2mV per degree C into a usable output may cause a few headaches, and will certainly require an op. amp. or two.

Enter the **LM3911** and all your problems are over! The LM3911 is an integrated circuit temperature sensor and controller which comes in a choice of either a four lead TO5 can, a four lead TO46 can, or an eight pin epoxy Mini-dip package. For the money, you get a highly accurate temperature measurement sensor which handles a minus 25 degrees C to a plus 85 degrees C range, a stable voltage reference supply, and an operational amplifier.

Temperature measurement is achieved by comparing the emitter base voltages of two identical transistors operating at different current densities giving a scale factor of 10mV per degree C. The output of the sensor section is connected to the non-inverting input of the internal op. amp. but the inverting input is brought out so that the gain can be programmed externally to give any required output scale factor.

An internal shunt regulator Zener diode provides a stable 6·8V supply for the sensor and op. amp., and by appropriate choice of external series resistor, any voltage greater than this can be used for a supply.

Versatility and ease of use are the keynotes of the LM3911 design, making it suitable for use in a multitude of different applications. The internal op. amp. can be hooked up as a comparator so that its output is switched as the temperature passes a set point, giving, in effect, a thermostatic switch which is useful for on-off heating control applications.

The nominal operating current drain is 1mA, although if used as a switch, the op. amp. output can sink 5mA in comfort. Thermal coupling is neatly achieved in the case of the 8-pin epoxy package by using the four unused pins on one side of the package as a thermal input. With the metal can versions the base of the can is the most sensitive region. In still air a thermal time constant of several minutes is achieved.

BUCKET BRIGADE

If you are turned on by such audio effects as echo, chorus, reverberation and tremolo you can now throw away your tape loops, springlines and other bulky gadgets and replace them all with a tiddly 16-pin DIL integrated circuit called, believe it or not, a bucket brigade delay line! (more commonly known as a Charge Coupled Device).

Actually "bucket brigade" is a very apt name for this i.c. since its operation is analogous to that of fire fighters passing buckets of water down a human chain from a water supply to the fire. Varying amounts of water may be put into each bucket, and assuming no spillage, the water output emerges from the end of the line in precisely the same discrete amounts as it entered it.

A bucket brigade delay line is a sort of shift register, but don't confuse it with the digital variety which can only handle "full" and "empty" buckets, because the novelty of the bucket brigade is that it shifts *analogue* quantities.

To my knowledge, the **SAD-1024** device made by Reticon and now available in this country, is the first example of a bucket brigade delay line to be produced at a low price with the audio market in mind, even though the principle has been used in other areas for a number of years.

The SAD-1024 is an *n*-channel MOS chip which uses gate capacitances to act as "buckets", and charge to act as "water". The device has two separate bucket brigade shift registers, each with 512 buckets, and these may be used in series or parallel to produce signal delays ranging from less than a millisecond to more than one second as determined by the clock frequency.

The output at the end of the delay line is a faithful reproduction of the input with a signal to noise ratio of 75dB, and a bandwidth of 0 to 200kHz. Insertion loss is quoted as 0dB and to top it all off the chip consumes only 5mW from a single 15V power supply!

This device is certain to find very wide application in the audio "special effects" department and can also be used for speaker system equalisation in auditoria, and in such high technology areas as speech compression and voice scrambling.

The sole UK distributors for the SAD-1024 is Herbert Controls & Instruments Ltd., Spring Road, Letchworth, Herts.

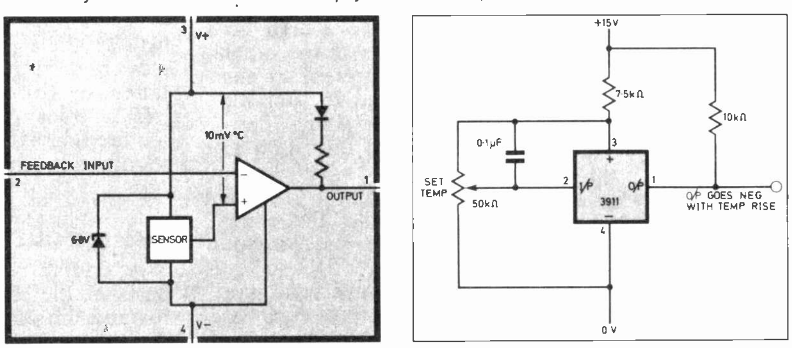
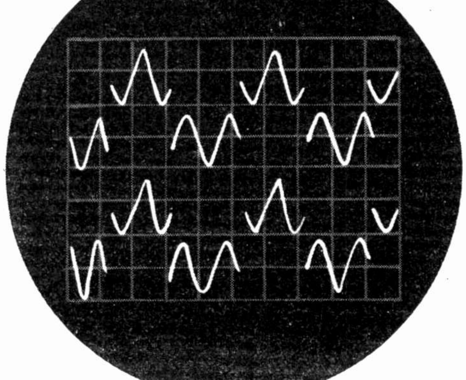
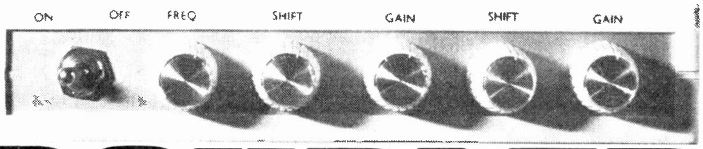


Fig. 1. The internal arrangement of the LM3911 and an application as a temperature controller



Twin Trace DOUBLER



By R.A. PENFOLD

Four trace display for a double beam 'scope

THE twin trace doubler described in this article enables four traces to be obtained on a double beam oscilloscope, and thus the phase relationships of up to four signals can be directly displayed on the scope. The only active devices used in this useful piece of gear are a couple of inexpensive integrated circuits.

Two inputs of the unit have gain controls and switched a.c./d.c. coupling. The input impedance at these inputs is about 40 kilohms. The other two inputs are a.c. coupled and have an input impedance of about 130 kilohms. When an a.c./d.c. switch is in the d.c. position, the relevant beam will respond to d.c. inputs whether the 'scope is a d.c. coupled type or not. The unit is suitable for use at both a.f. and r.f., and the −6dB point on all inputs is in excess of 12MHz.

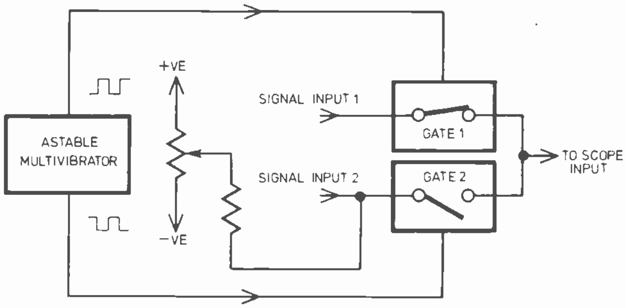


Fig. 1. Block diagram showing the basic operation of the circuit

BASIC PRINCIPLES

Basically the unit consists of a couple of disabling gates controlled by a multivibrator, as shown in Fig. 1. Actually four gates are used in the unit, one for each input. These are used in pairs, one pair feeding each input of the 'scope. Both gate circuits are identical and fed from the same multivibrator. For the sake of clarity only one set is shown in Fig. 1.

When one output of the multivibrator is high the other is low, and thus when one gate is on the other one is off. Only one input signal is present at the oscilloscope input at any one time, and in fact the two input signals are presented to the scope alternately as the multivibrator chops from one state to the other.

A d.c. potential is applied to one input from a potentiometer, and this d.c. voltage has the effect of separating the two traces on the oscilloscope screen.

If the frequency of the timebase waveform is a factor of the multivibrator's operating frequency, or nearly so, the resulting display will be something like that shown in the first oscillogram. Here the chopping action of the circuit can be clearly seen (a).

However, if the multivibrator is adjusted away from one of these frequencies, successive sweeps of the screen will far from properly overlap, and due to the eye's incapacity to perceive fast action, the display will appear as in the second oscillograph. Much the same result will be obtained if the frequency of the multivibrator is adjusted to below the frequency of the timebase. The spot of the c.r.t. will complete one or more sweeps of the screen on each trace, but again this will be happening too fast for the eye to see this action. The eye therefore sees both traces displayed on the screen simultaneously (b).

If a trace doubler for a single beam 'scope is required, it is merely necessary to omit the second set of gates and their associated circuitry.

THE CIRCUIT

A couple of CMOS integrated circuits form the basis of the circuit, one being used as a multivibrator and the other containing the four disabling gates. These i.c.s will operate from any supply voltage from 5 to 15 volts, and unlike conventional TTL i.c.s, they have a very low current consumption. The actual

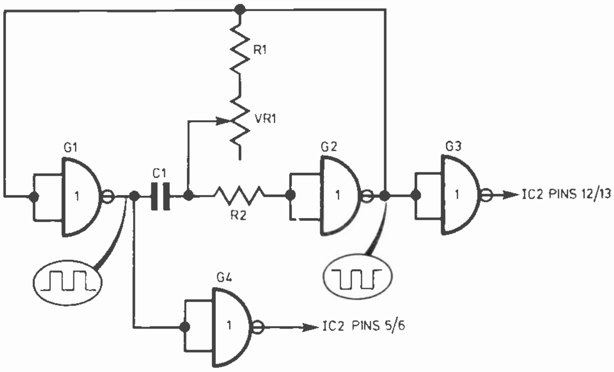


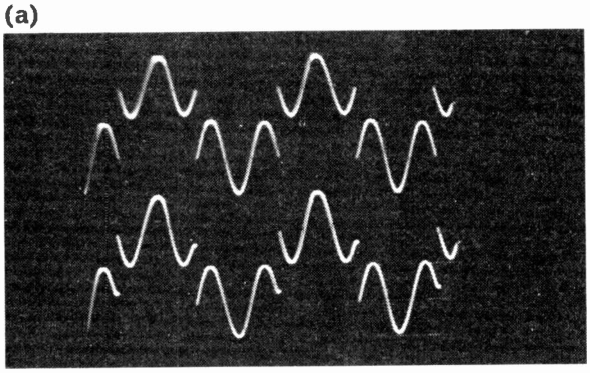
Fig. 2. The astable configuration for IC1. Gates G3/G4 shape the antiphase outputs of G1/G2

current drawn by the complete circuit is only about 400 microamps from a 9 volt PP3 battery, and so running costs are minimal. The complete circuit diagram of the unit is shown in Fig. 3.

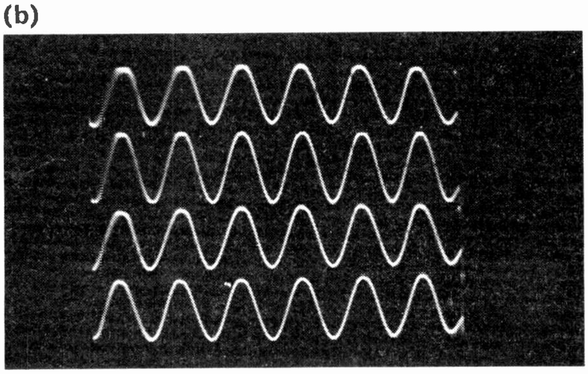
IC1 is a 4001AE quad two input NOR gate, but here each set of two inputs are paralleled and each gate is used as an inverter (Fig. 2). The output of gate G2 is direct coupled to the input of gate G1, and positive feedback is supplied between the output of gate G1 and the input of gate G2 by way of C1 and R2. VR1 varies the time constant of the feedback circuit and permits the frequency of oscillation to be varied from less than 100Hz to above 2kHz.

Doubler oscillographs showing (a) chopping action when timebase frequency is a factor of the astable; (b) the astable adjusted to display four traces

(a)



(b)



COMPONENTS . . .

Resistors
- R1 5·6kΩ
- R2 18kΩ
- R3–R4 470kΩ
- All ½W carbon

Potentiometers
- VR1 100kΩ
- VR2/VR4 47kΩ lin carbon (2 off)
- VR3/VR5 500kΩ lin carbon (2 off)

Capacitors
- C1 47nF
- C2 2·2μF polyester
- C3 0·47μF
- C4 2.2μF polyester
- C5 0·47μF
- C6 100μF elect 10V

Semiconductors
- IC1 CD4001AE
- IC2 CD4016AE

Switches
- S1, S2, and S3 s.p.s.t. toggle (3 off)

Miscellaneous
- Verobox type 75–1410J or similar size case (205 × 140 × 40mm)
- Materials for p.c.b.
- Six 3·5mm jack sockets (SK1–SK6)
- Five small control knobs
- PP3 battery and clips to suit
- Two 14 pin i.c. sockets
- Wire, solder, etc

The output waveform from gate G2 is rather poor, so this is fed to two of IC2 control gates via gate G3, which is used to considerably reduce the risetime of the waveform. The output of gate G1 is fed to gate G4 in order to maintain the correct phase relationship (antiphase) between the two outputs. This signal then operates the other two control gates.

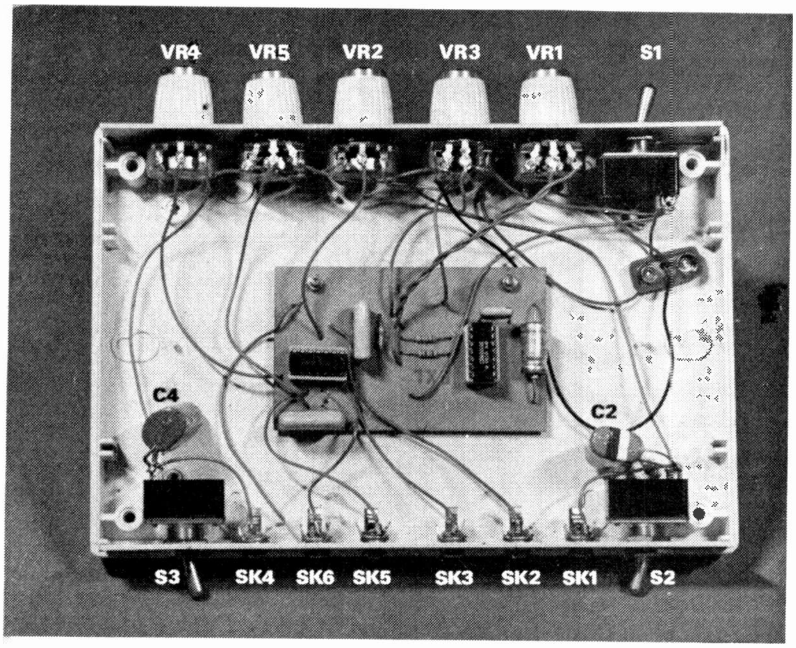
CONTROL GATES

A 4016AE i.c. contains the four control gates. When the control voltage is high, these gates present a series resistance of only about 300 ohms, but with a low control voltage this rises to many megohms. In the "on" state the gates give a low level of distortion and they are perfectly suitable for linear applications.

The shift voltages are provided by VR3 and VR5. Resistors R3 and R4 are included as these two inputs would otherwise be short circuited to earth with VR3 and VR5 adjusted for zero shift. C3 and C5 provide d.c. blocking at these inputs.

VR2 and VR4 are the gain controls for the other two inputs. C2 and C4 provide d.c. blocking at these inputs, and S2 and S3 respectively can short circuit these in order to provide d.c. coupling.

Inputs 2 and 4 will handle signal amplitudes of up to several volts peak to peak without the waveform being clipped, the actual maximum level before clipping depending upon the setting of VR3 or VR5,



Disposition of components external to the p.c.b.

as appropriate. With VR2 and VR4 adjusted for maximum sensitivity, inputs 1 and 3 will handle up to about 2 volts peak to peak before clipping of the negative waveform commences. Higher amplitude signals can be accommodated by turning back the sensitivity controls.

It is advisable to keep the leads connecting the doubler to the 'scope as short as possible. There will then be a minimum of additional input capacitance when the doubler is in use. Of course, these leads must be screened.

If only a single trace doubler is required, R4, VR4, VR5, C4, C5, and S3 are omitted from the circuit.

A convenient feature of the circuit is that it has unity voltage gain at middle frequencies (VR2 and VR4 adjusted for maximum sensitivity) and any calibration devices fitted to the 'scope can be used in the normal fashion.

CONSTRUCTION

A small p.c.b. measuring 89 × 54mm contains most of the small components, only C2 and C4 being absent. These are wired directly across the tags of S2 and S3 respectively. Full details of the p.c.b. are reproduced actual size in Fig. 4.

The board is produced in the normal way and is a relatively simple affair. The two mounting holes are drilled for 6BA clearance using a 3·2mm twist drill. The i.c.s are each mounted in a 14 pin i.c. socket.

A Verobox having dimensions of 205 × 240 × 40mm makes an attractive housing for the project, but any case of about this size could probably be used.

The p.c.b. is mounted in the centre of the bottom of the case using a couple of short 6BA bolts with nuts. It is a good idea to use a 3mm spacer over the mounting bolts, between the panel and the case,

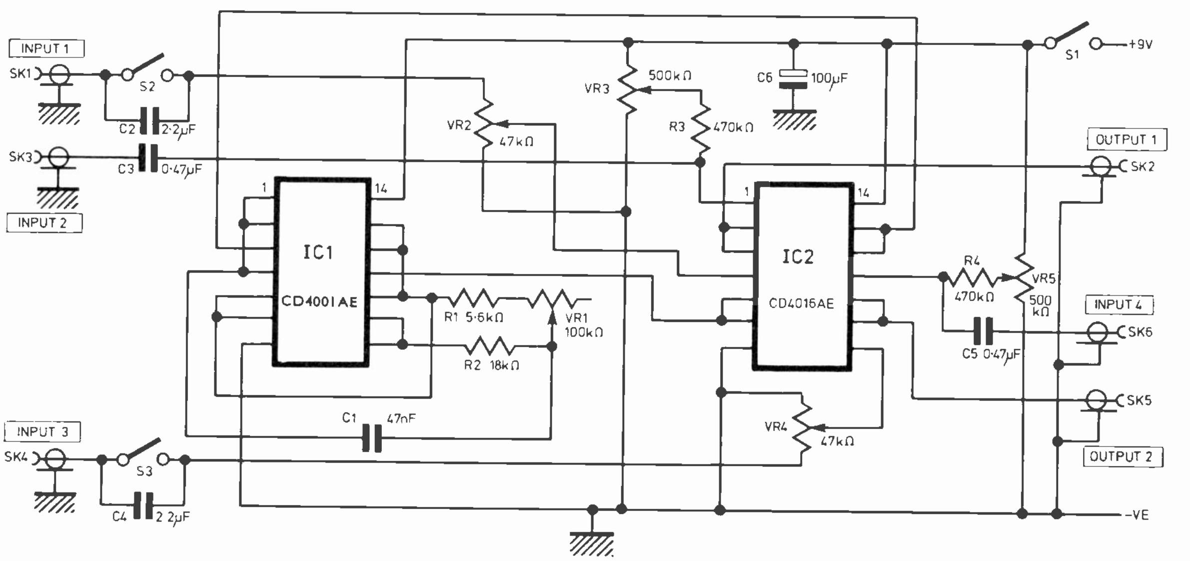
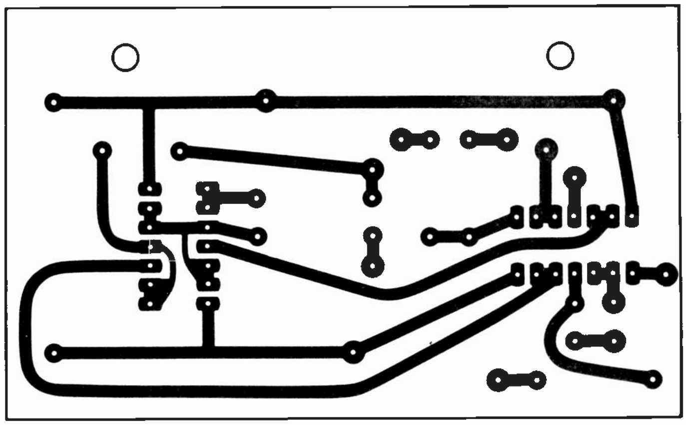


Fig. 3. The complete circuit diagram



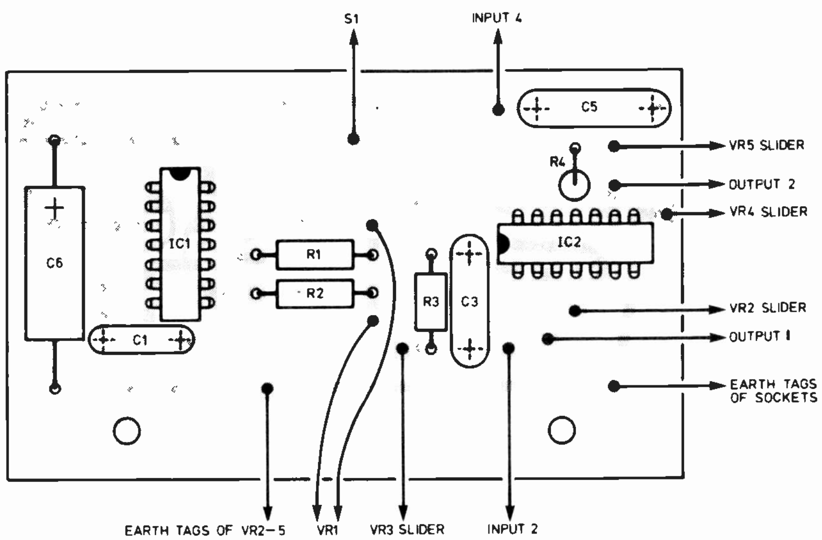


Fig. 4. Showing p.c.b. layout and component assembly details

as otherwise the board could be distorted and possibly even damaged as the mounting nuts are tightened. The panel is not finally mounted until it has been wired up to the rest of the unit.

CHECKING AND USE

If the outputs of the unit are connected to an oscilloscope, it should be found that upon switching on, a squarewave is produced from each output.

Check that VR1 permits the frequency of these to be varied from about 100Hz to 2kHz, and that VR3 and VR5 allow the amplitudes of the outputs to be varied from zero to a few volts peak to peak.

It is then simply a matter of connecting some inputs to the doubler to check that it is working properly in other respects. It is not possible to use the internal sync. of the 'scope as this would tend to synchronise the timebase to the chopping frequency of the doubler, rather than to one of the input signals. External sync. or triggered sweep must therefore be used.

VR1 is adjusted to the frequency that gives the clearest trace. With fairly low frequency input signals it will probably be best to adjust VR1 for maximum chopping frequency. The traces will then be built up from a series of dots (a quite conventional method of trace doubling). ★

MOTOROLA D2 KIT REVIEWED

By D. B. JOHNSON-DAVIES

MICROPROCESSORS are being hailed as the new way of solving design problems in electronics, and the Motorola M6800 family is at present leading the market, both here and in Europe. This article reviews the new D2 development kit based on the M6800, which may provide the answer for those who feel left behind by microprocessors and are looking for a practical way of finding out about them.

It might first be worth considering what requirements should be satisfied if a development kit is to be of any use in developing programs. In the author's opinion these are:

1) *Hexadecimal keyboard entry*. Entering data by a row of switches, one for each bit, is too slow and error prone though by far the cheapest method. Most kit manufacturers have chosen to provide an interface to a Teletype, assuming perhaps that their customers would already be in an environment where one was readily available; unfortunately even reconditioned Teletypes cost around £500 and this puts them outside the amateur's price range.

2) *Some way of permanently storing programs*. Floppy disc is the most attractive solution as it enables large amounts of data to be stored very rapidly, but they are very expensive. A PROM would provide a lower-cost solution; the program being developed would be loaded into it before switching off the power. A CMOS low power consumption RAM with a backup battery would be an alternative.

In the D2 kit the first problem is overcome, as in some other kits, by having data and addresses entered from a keyboard coded in hexadecimal, and displayed on standard seven-segment light-emitting diode displays. The keyboard supplied has a very positive feel about it and in fact this keyboard/display combination is in many ways preferable to a Teletype; the latter is noisy, consumes paper at a high rate, and is slower to respond.

The second requirement is satisfied in the D2 kit by the provision of a cassette interface circuit which enables one to store programs to and load programs from a standard tape recorder. The storage capacity is high (a full 64K words of memory would fit on one cassette) and the cost of building up a library of programs is obviously just the cost of additional cassettes.

COMPONENTS OF THE KIT

The D2 kit consists of two double-sided printed-circuit boards linked by a large ribbon cable. The larger of the two—the main microcomputer board—houses the MPU and all the parts directly associated with it: a thick-film crystal-controlled clock package (which replaces the TTL oscillator circuitry used in the earlier D1 kit); the ROM containing the "Jbug" monitor program which controls all the debugging facilities of the kit; the 128-word RAM used for the stack and for the monitor's variables; the two user RAMs giving 256 words of memory in which to write programs; the PIA (peripheral interface adapter) with parallel outputs used to connect with the keyboard and display, and a second PIA for one's own use; an ACIA (asynchronous communications interface adapter) providing a serial output for the cassette interface circuitry; and lastly, some gates and buffers for address decoding.

There are also sockets provided for two more RAM chips bringing the total on-board capacity to ½K words of memory, and for two further ROMs or PROMs. A clear area in the top right-hand corner of the board, drilled with a matrix of holes, can be used for assembling small circuits to interface with the PIA.

The second board holds the keyboard, the six seven-segment displays, and all the circuitry to interface with the cassette recorder. In addition to the 16 hexadecimal keys there are eight function keys, and these control the diagnostic and debugging facilities of the kit without which programming would be a fairly hit and miss operation.

FUNCTION KEYS

In common with most development kits, memory can be examined and altered. The "M" and "G" keys are used for this. For example, to examine location 002*E* the sequence of keys *002EM* is entered and the displays will show the address and present contents: *002E A1* for example. The new data is now entered if required; entering *73* for example will update that location and the displays will now read *002E 73*. The "G" key will increment the address to the next location and display the contents there, and so on. Thus to enter a program from scratch takes only three keystrokes per instruction.

The "R" key puts the monitor program into "register examine" mode. Repeatedly pressing the "G" key now cycles through the registers one by one, displaying their contents in sequence. The "G" key is also used to begin execution of one's own program at any location.

For example, entering *0032G* will start at 0032. Return to the monitor program is achieved by executing a SWI (software interrupt) instruction which stores all the registers on the stack in memory, and jumps to an address within the ROM. Alternatively pressing the "E" key generates a non-maskable interrupt which will cause an exit from the user program.

On return to the monitor the program is in register-examine mode, so the values of the registers just before the interrupt can be discovered. The values displayed are not of course the actual contents of the registers at that moment—which would be difficult, not to say useless—but the values which were stored on the stack on exiting from one's program. The monitor returns control to one's own program by an RTI (return from interrupt) instruction which then reloads all the registers from the stack. The program counter, which was stacked on first, gets replaced last and so causes the program to jump back and continue execution at the instruction just after the SWI as intended.

To change the contents of a register from the monitor program one just needs to use the memory-change function on the stack location corresponding to that register's previous contents. It is a pity that it is not possible to change registers directly while in register-examine mode.

TRACING FACILITIES

So far the facilities described are shared by most development kits, such as the SC/MP kit with keyboard. However, in addition to these there are four functions which make this kit an efficient tool for developing even fairly large programs: as an example, it took the author a week of evenings to write and debug a "Bull and Cow" (better known these days as "Mastermind") playing program which needed the full ½K of memory.

The single-step key "N" makes it possible to step through the program executing one instruction at a time and then returning to the monitor so the registers can be examined and the effect of the instruction ascertained. With the help of this facility even the most reluctant of programs can be got working; it is immediately obvious, for example, if branch instructions go to the wrong location, as the address and contents are displayed after each step with the "N" key.

The SWI instruction, as already mentioned, is used in the kit to interrupt a program and give control to the monitor. Thus if one is encountered in one's program, execution effectively stops at that point and the contents of the registers just before that point are on the stack. The "V" key enables up to five locations to be specified as breakpoints simply by entering its address; *0025V* for example. Before going to the user's program the monitor will replace the instruction at 0025 by the code for SWI. On return to the monitor it puts back the original instructions where they belonged.

PUNCH AND LOAD

Finally the "P" and "L" keys control the cassette interface part of the kit, respectively recording onto or reading from a standard audio tape. The start and end addresses of the block of data to be recorded are entered in before pressing the "P" key, and only this part of memory is then transferred. The start address and length are included in the format on the tape, so operating the "L" key when replaying the cassette puts the data back into the correct area of memory. It is therefore possible to punch out different parts of a program (subroutines, data, etc.) onto different tapes and then load them independently only when needed.

Unfortunately there is no facility for relocating programs in memory, and if one suddenly realises that one needs a three-word instruction where there was a two-word one, it is necessary to shuffle up all the subsequent instructions and correct all the branch instructions accordingly.

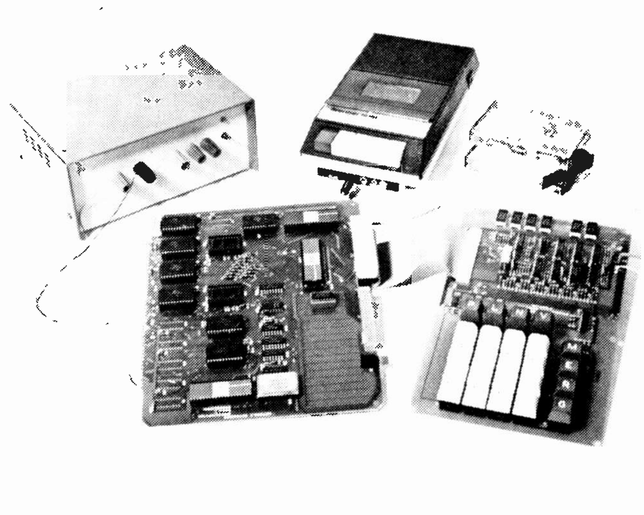
After spending some time trying to get a program working, one soon realises how useful the cassette interface is compared to the alternative of non-volatile memory (or leaving the supply switched on day and night). A wrong instruction often causes parts of the program itself to be overwritten, giving exceedingly puzzling results. It is therefore good practice to dump the program being developed onto tape as a safety measure each time a substantial change is made to it. Thus if the program in memory gets corrupted, the most recent version can be reloaded from the cassette.

The recording format chosen by Motorola for the interface was the Kansas City Standard, decided on during a symposium in Kansas City, Missouri, in the USA, and this standard seems to be gaining wide acceptance; some computer firms are selling software in this format on cassette as an alternative to paper tape. The ones and zeros are coded as 8 cycles at 2,400Hz and 4 cycles at 1,200Hz respectively. Since the load circuit decodes frequencies above and below 1,800Hz as ones and zeros, the circuit will tolerate speed variations of up to ±25 per cent.

Each word consists of a zero as start bit, eight data bits (LSB first) and two or more ones as stop bits, and this serial formatting is performed by the ACIA. The data rate is 30 words per second, and since there is a leader of about 40 seconds of ones at the start of the data, it takes a minute to punch or load the ½K memory used with this kit. The circuit has repeatedly loaded without error even though the recorder being used was the cheapest available. A program given at the end of this article was used to test the interface.

CONSTRUCTION

The only constructional details given in the kit's manual were a page of rather daunting and perplexing warnings for handling MOS devices (e.g. "Cold chambers using CO_2 for cooling should be equipped with



The assembled Motorola D2 kit. The cassette, recorder and PSU are extra items. An additional chip (D/A convertor) is included which the author used to interface the D2 with an audio amplifier. The memory has been extended to 0·5K by two extra memory packages

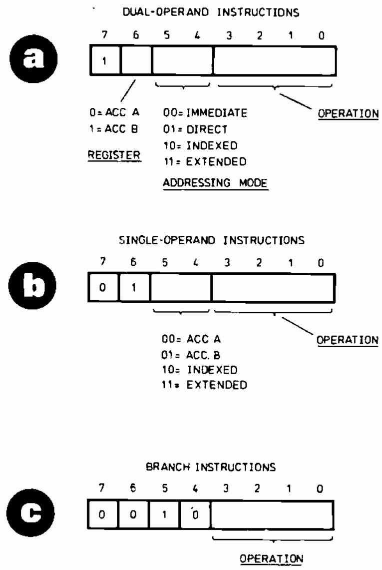


Fig. 1. Format of the first word of the instructions in the three main groups of operations available in the M6800 microprocessor: (a) Dual-operand instructions, (b) Single-operand instructions, (c) Branch instructions.

baffles . . ."). The only precaution taken by the author was to wear a cotton shirt, and no harm came to any of the devices. However, considering the high cost of replacing some of the chips (the MPU is about £22) it *is* worth being over-cautious.

When soldering parts into the board it is a good idea to solder in all the passive components first, leaving until last the integrated circuits. This way it is less likely that the delicate inputs will be left floating and prone to static charges. Sockets are supplied for the main integrated circuits, but it might be worth the extra expense to buy sockets for the smaller i.c.s too, as they would be tricky to unsolder from the double-sided boards.

The kit is very well designed and construction was straightforward. The most frustrating part was inserting the 40-pin i.c.s into their sockets at the risk of breaking off a leg in the struggle. The best method is to rock them gently down, inserting the pins at one end of the socket first to reduce the force needed. The pins on the plastic packaged chips need to be pressed against a flat surface to bend them inwards to the correct spacing for the sockets.

Although the main board is terminated by a 43 plus 43-way edge-connector, the only connections needed for using the kit as it stands are the supply inputs, and these can be provided by wires to the tracks instead. The other connections are the data and address lines for use with external memory boards. A 5V power supply is needed, and this should be regulated and capable of giving about 1·5A. Only one supply rail is required.

FAULT FINDING

The kit should work immediately, and on switching on and pressing reset the "–" prompt should be displayed. However, the author's kit contained an elusive fault and so some general advice on trouble-shooting in microprocessor circuits may be helpful. An oscilloscope is probably essential, but a multimeter is better than nothing.

The most common fault seems to be the bridging of adjacent tracks on the circuit boards. In the author's kit an almost invisible unetched copper bridge proved to be shorting an address and data line together, causing incorrect locations to be addressed; the displays would just go blank on pressing reset. In retrospect it might have been worth while examining the boards carefully and testing for isolation between adjacent tracks with an ohmmeter before soldering in any of the parts.

With only the MPU in the board the memory area will be empty and the program counter should cycle repeatedly through all the addresses looking unsuccessfully for an instruction. As a result, all the address lines should be oscillating, A_0 with the highest frequency and each one with half the frequency of the one below it. The data lines will stay low, and R/W high (read cycle).

Putting the ROM in will now cause the MPU to write to the data lines, and these should have waveforms on them. If two data or address lines look the same, a short between them can be suspected. With the stack RAM and the PIA which interfaces with the keyboard/display both replaced in the main board the kit should function properly and display the prompt.

If the keyboard/display board is suspected and the main board is working correctly one should see the multiplexing of the display lines as the PIA selects each of them in turn.

Finally it must be admitted that getting a microprocessor circuit working might prove to be a very time-consuming and frustrating task. Building a kit like the D2 minimises, but does not eliminate, the possibilities for error.

WRITING PROGRAMS

Out of the 256 possible codes for instructions, 197 are assigned to legal machine codes and so at first sight it might look discouragingly as if it would be necessary to learn the op-codes for all of these in order to be able to write a program. This is untrue for two reasons. Firstly, the allocation of codes to the instructions is not random, but ordered due to the way the MPU decodes the instruction. It is informative to look at how the op-codes for some of the instructions are made up.

The largest group of instructions can loosely be called "dual-operand" as each of them operates on a register (A or B) and a memory location; for example *ADD A 6* will add the contents of location 0006 to the A register. These codes all have the format shown in Fig. 1a. Thus once one remembers that *ADD* has "B" as the second hex digit one can work out the code for any of the eight addressing mode and register combinations: *ADD A 6* is 9B 06 (direct addressing); *ADD A £6* is 8B 06 (immediate addressing) . . . etc.

The second largest group of instructions contains the single-operand ones; these can operate either on a register or on a memory location, enabling one to manipulate memory locations directly while leaving the registers undisturbed. This aspect of the design of the M6800 greatly reduces the amount of loading and storing of variables needed in programs. The code format is shown in Fig. 1b.

BRANCHES

The M6800 provides a wide range of branch instructions—15 in all (see Fig. 1c). The branches are really *add immediate to PC* instructions, whereas the jumps are *load extended to PC* instructions. The conditional branches depend on the states of certain of the condition codes, which are set or cleared by selected instructions. This makes for very concise programs; often there is no need to test explicitly the value of a memory location after an operation.

The second reason for not learning all the op-codes off by heart is that it is far easier and clearer to write programs in "assembler language" which uses mnemonics to stand for the instructions. The program is then "hand assembled" by looking up the code for each mnemonic and writing it down beside the statement. This is fairly rapid, and by choosing suitable names for variables and labels the program is self-documented and its operation is clear. The assembly listing of the "Jbug" monitor provided in the kit manual is a useful program to refer to, and it contains some useful subroutines which can be jumped to from one's own programs.

EXAMPLE PROGRAMS

The following two programs were used to test the cassette interface and the memory. The first writes 01, 02, 03 . . . FF into successive locations after START—these are 0011 to 010F as the program stands.

Location:	Contents:
0000	4F
0001	CE 0010

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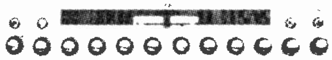

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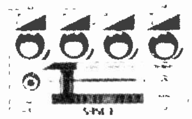

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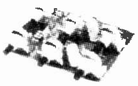

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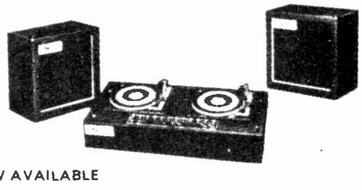

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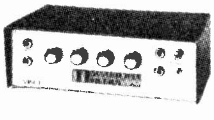

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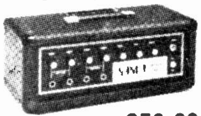

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```
0004        08
0005        4C
0006        A7 00
0008        26 FA
000A        3F
```

Assembler statements:

```
WRITE   CLR  A
        LDX       £START
LOOP    INX
        INC  A
        STA  A    X
        BNE       LOOP
        SWI
```

By making two modifications it is possible to make the program verify that the correct data is stored at each location, and return at the first disparity. If all is well it will return with the X register containing 0110 (at least) showing that it reached the end of the block of data written to without an error.

```
Location:   Contents:
0000        4F
0001        CE 0010
0004        08
0005        4C
0006        A1 00
0008        27 FA
000A        3F
```

Assembler statements:

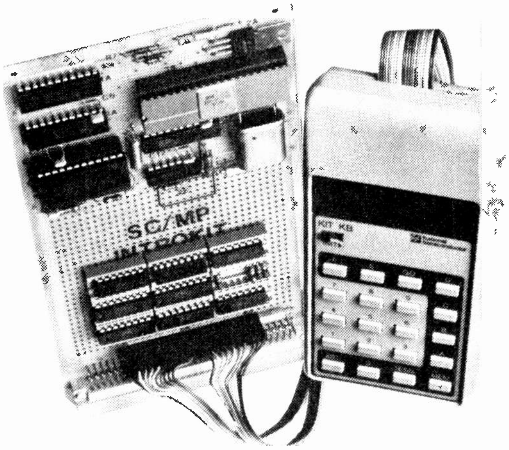
```
CHECK   CLR  A
        LDX       £START
LOOP    INX
        INC  A
        CMP  A    X
        BEQ       LOOP
        SWI
```

COST OF THE KIT

The Motorola D2 kit is currently available from Cramer Electronics for £175·87 plus 8 per cent VAT plus £1·20 p/p. Although this may seem expensive, its facilities make it compare well with other kits available. The integrated circuits alone would cost over £100 to buy, and it is difficult to put a value to the two excellent printed circuit boards and the "Jbug" monitor ROM.

An evaluation system of this order of complexity can actually be recommended to anyone involved in designing with microprocessors even if they intend to progress to a much more extensive set-up with an operating system, assemblers and editors, as it provides a sort of intimacy with the workings of the MPU which forces one to think about and understand what is really going on.

NOTE: *The Intersil microprocessor development and tutorial system* Intercept Junior *reviewed last month is available from Rapid Recall Ltd., 9 Betterton St., London W.C.2. Price £184·06 plus 8 per cent VAT. (Part No. 6950).*



Results

FIRST PRIZE WINNERS

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Mr. S. P. Kenny
Mr. A. Mackintosh

25 Runners-up

Mr. M. J. Bird, Southampton; Mr. N. R. Canham, Hatfield; Mr. D. Chambers, Blackpool; Mr. D. Coates, Oxford; Mr. B. Collins, Mansfield; Mr. T. J. Conroy, Glasgow; Mr. J. H. Cooke, Paisley; Mr. J. Duncan, Glasgow; Mr. J. C. Hamilton, Glasgow; Mr. P. K. Hewitt, Bristol; Mr. A. P. Holden, Braintree; Mr. M. Lord, Basildon; Mr. L. G. Marini, Hassocks; Mr. S. B. Morrison, Tynemouth; Mr. J. Pledge, Exeter; Mr. J. D. Riley, Cambridge; Mr. D. Rivlin, Gosnall, Staffs. Mr. S. J. Roberts, Sleaford; Mr. E. A. Roche, Wigston; Mr. L. Sakowicz, Manchester; Dr. P. J. Skolar, London N2; Mr. D. Trueman, Wallasey; Mr. J. E. Wheeler, Walsall; Mr. K. J. Whit~, Dymchurch; Mr. N. Williams, London SW6.

IN THE January issue we published an exacting competition in which readers were invited to assess microprocessor attributes as being important to the average Practical Electronics reader. Having carefully considered all entries the judges decided that the best received were two identical attempts submitted by *Mr. Andrew Challinor of Stoke-on-Trent* and *Alastair Mackintosh of Brighton.* Both had marked:

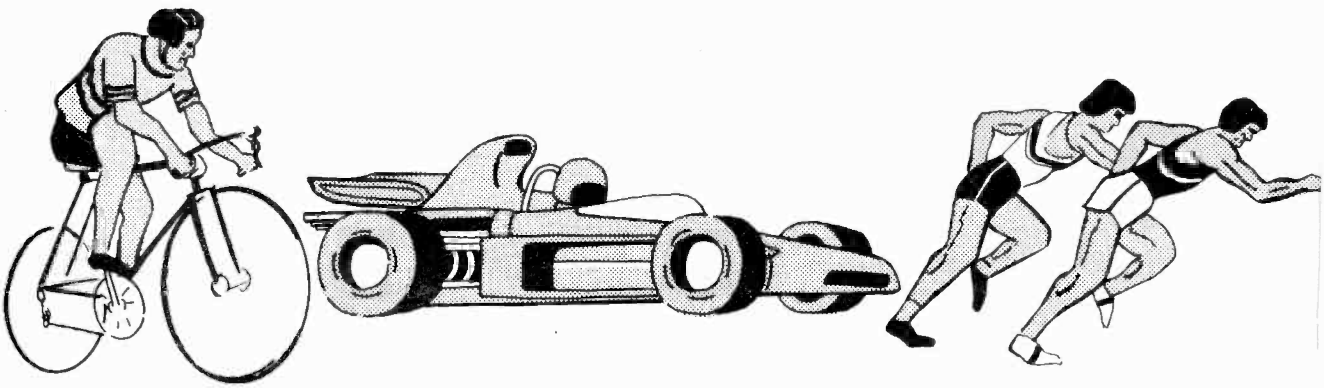
1st-D; 2nd-A; 3rd-F; 4th-G; 5th-E; 6th-C; 7th-H; 8th-B

These readers both win a SC/MP Introkit plus Keyboard Kit worth well over £120. But there were three 1st prizes and to find the 3rd we had to stage a postal eliminating contest among a number of tying competitors who had submitted the next best attempt. When this second contest had been judged, the winner emerged as *Mr. Stephen P. Kenny of London, SE5,* who also receives an Introkit and Keyboard Kit.

Twenty-five runners-up, each received a single-chip 8-bit microprocessor worth around £12 each.

The competition was presented in association with A. Marshall (London) Ltd. and National Semiconductor (UK) Ltd. who with Practical Electronics sponsored the highly successful microprocessor forum held at Berners Hotel, London on February 26th. 1st prize winners Andrew Challinor and Alastair Mackintosh were presented with their prizes at the forum but, because the eliminating contest had not then been resolved, it was not possible to make a similar presentation to Stephen Kenny.

A. Marshall (London) Ltd. and National Semiconductor (UK) Ltd. join with Practical Electronics in warmly congratulating all winners, and express thanks to all who participated in this competition.



DIGITAL

Mechanical stopwatches capable of split timing are of the more expensive kind, but an electronic version can be built using simple wiring and construction techniques, and yet give even greater accuracy. The design described here gives the user both Taylor and split timing, in addition to the convenience of digital readout, all in a compact pocket-size case.

FUNCTIONS

There are three modes of use with this device: (a) normal start-stop-reset, (b) Taylor, or sequential timing, and (c) split, or cumulative timing.

To time the individual laps of a competitor in a race, for example, the user would switch on, select TAYLOR mode, and press the START/STOP button (S5) at the start of the race. After one lap, pressing S5 again would lock the display to give the lap time; whilst "off display" the counter would have already begun timing the next lap. On completion of the second lap, pressing S5 once more would now lock the display to the new lap time. This process would repeat itself for every lap timed.

In SPLIT mode, the user can time the first lap in exactly the same way. So, when pressing S5, the display would lock at the first lap time, but the counter (off display) would continue to count on *from that number*. Hence, when the competitor passed the post the next time, pressing S5 would now lock the display at the total time from the very start—each lap timed being added to the last!

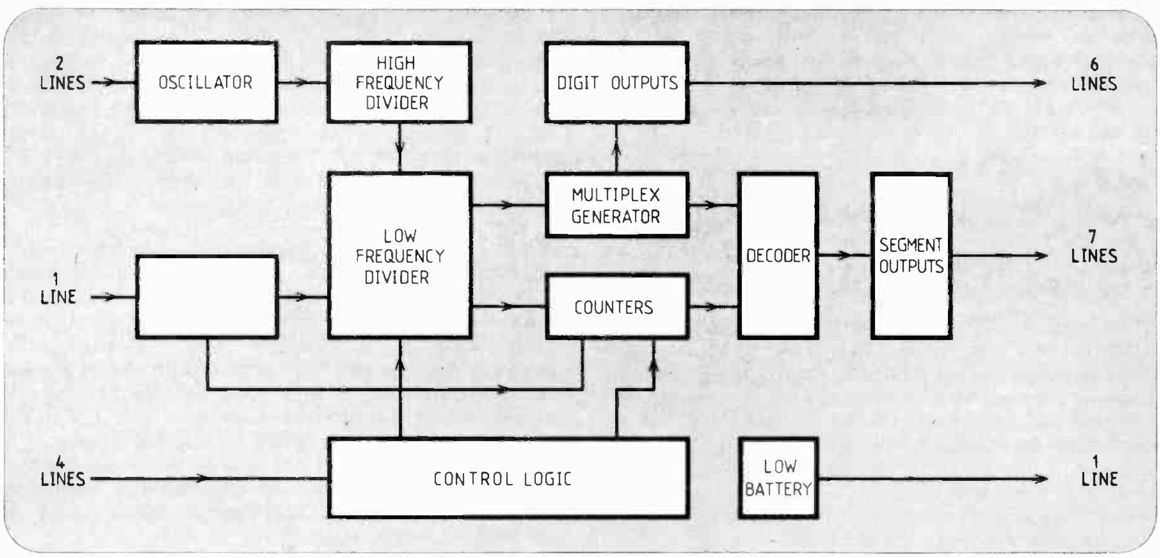
In either mode, pressing DISPLAY UNLOCK will clear the displayed number, allowing the readout to dynamically follow the counter.

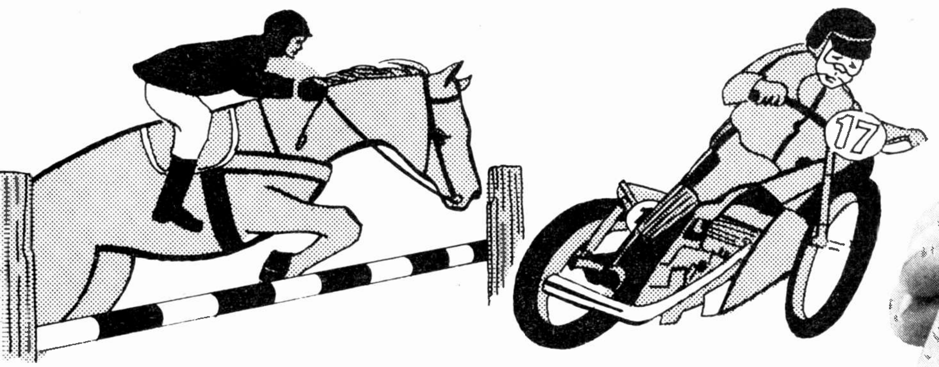
THE CIRCUIT

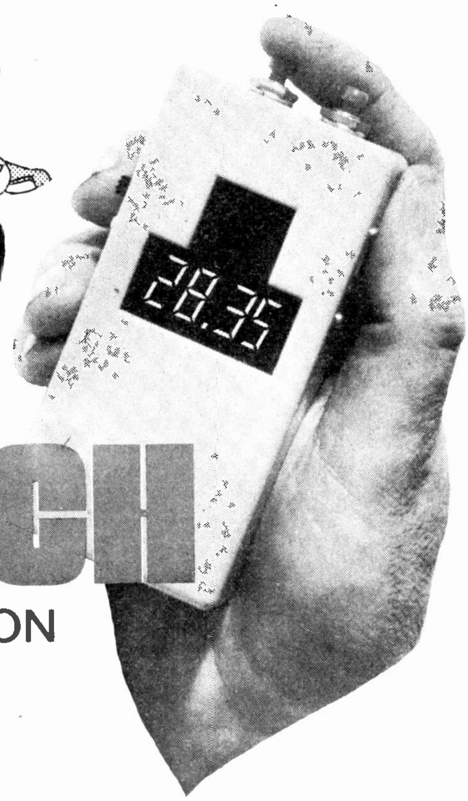
Intersil have made the job easy in terms of design and construction; they have done it all! Apart from a few discrete components, switches, and of course the display, everything is contained within the ICM7205 package.

Fig. 1 shows the basic block diagram of the i.c., and briefly, the high frequency oscillator signal is divided down, gated, counted and displayed via multiplex circuitry. Gating is controlled externally, and in the design shown in Fig. 2, this is done using the operating push-buttons.

Fig. 1. Block diagram showing the relevant functions of the ICM7205







STOPWATCH

By M. W. HEADINGTON

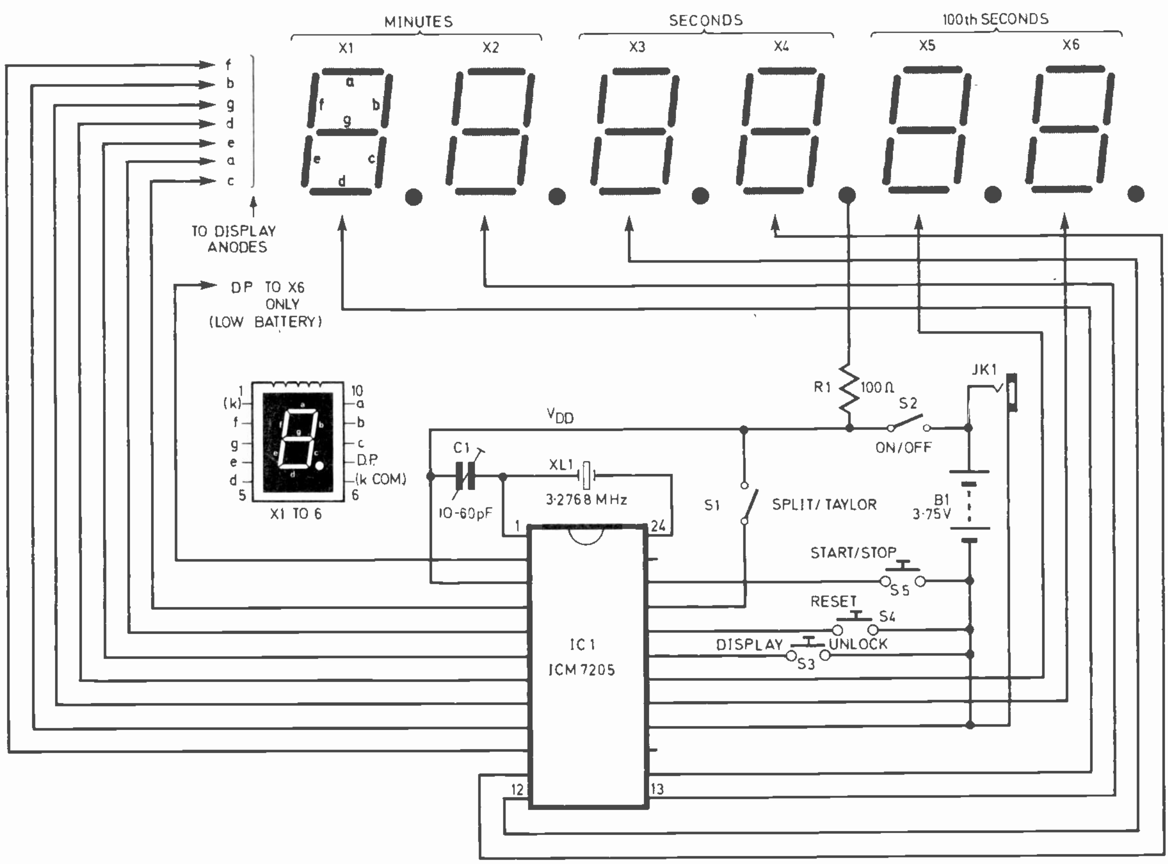
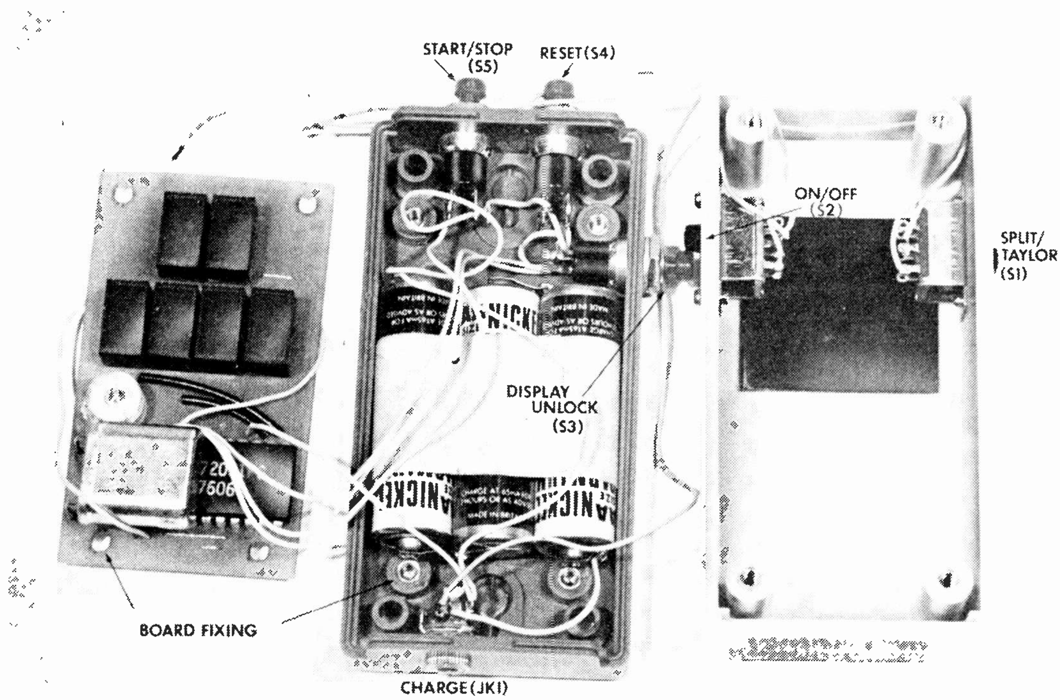


Fig. 2. Complete circuit diagram of the Pocket Stopwatch



Direct l.e.d. drive is one i.c. feature, and another is switch bounce protection circuitry on the START/STOP input, but the RESET and DISPLAY UNLOCK inputs require no protection. A *low battery* indicator circuit is incorporated, and is arranged here so that the extreme right-hand decimal point begins to glow when the supply voltage is low. Accuracy is not affected until about 15 minutes after the indicator has illuminated.

ACKNOWLEDGEMENT

It should be mentioned at this stage that the basic circuit of the stopwatch is that recommended by Intersil.

CONSTRUCTION

A fine tipped soldering iron should be used for the board assembly, as the p.c.b. copper pattern (Fig. 3) is rather delicate. Prolonged heating will lift the track away from the board. The 100Ω resistor and the links should be soldered in position first, the resistor being mounted flush on the board. Mount the displays with their orientation marks at the top of the board as in Fig. 4. The trimmer capacitor should be mounted next. Care is necessary to avoid blocking adjacent holes with solder.

Working on a sheet of earthed aluminium foil, place the p.c.b. and the i.c. (still on its conductive foam) on the foil. Occasionally touch the foil to ensure no static build-up takes place on yourself. Carefully remove the i.c. from the conductive foam, and insert it into the p.c.b. Check that the i.c. is correctly orientated, that is, with the displays upright, the notch on the ICM7205 should be on the left side of the p.c.b., see Fig. 4.

The crystal can now be inserted by bending the leads through 90 degrees, thus enabling its case to rest on top of the i.c.

Wire up the switches, charger socket, push-buttons and p.c.b. as shown in Fig. 5. The wire lengths are indicated, so that the whole loom can be completed prior to insertion into the Verobox.

CASE

The plastics box can now be marked out and drilled as specified in Fig. 6. The slide switch holes, and display aperture will have to be drilled and then filed to shape. Care should be taken when working the plastic, as the heat generated may distort the holes. Finally glue a piece of display filter material over the inside of the aperture.

The three Ni-Cad cells can now be taped together and connected in series as in the loom of Fig. 5. Mount the charger socket and push-buttons on the case. It can be seen from the photographs that the relative positions of the loom components in Fig. 5 are correct for dropping directly into the box.

Check nothing can short out and locate the battery assembly in the base of the box, with the negative terminal at the top left-hand side. Place a 35mm square of soft foam rubber not more than 10mm thick, over the battery pack; carefully locate the push-button wires across the foam, and place the p.c.b. assembly over the top. The push-button wires now run under the p.c.b. around the lower end, and into their respective connections.

Four stand-off spacers made from 3mm bore p.v.c. sleeving, each 17mm long, can now be positioned between the p.c.b. and the Verobox mounting bushes. Four 6BA cheesehead screws are used to fasten the board. Since the mounting bushes are blind holes, the screws will automatically tighten the assembly, whilst slightly compressing the spacers.

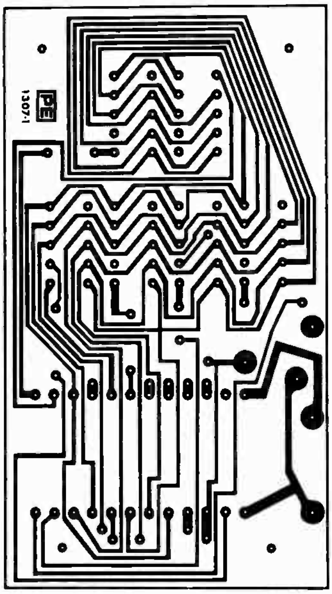


Fig. 3. **Printed circuit board** (Full size)

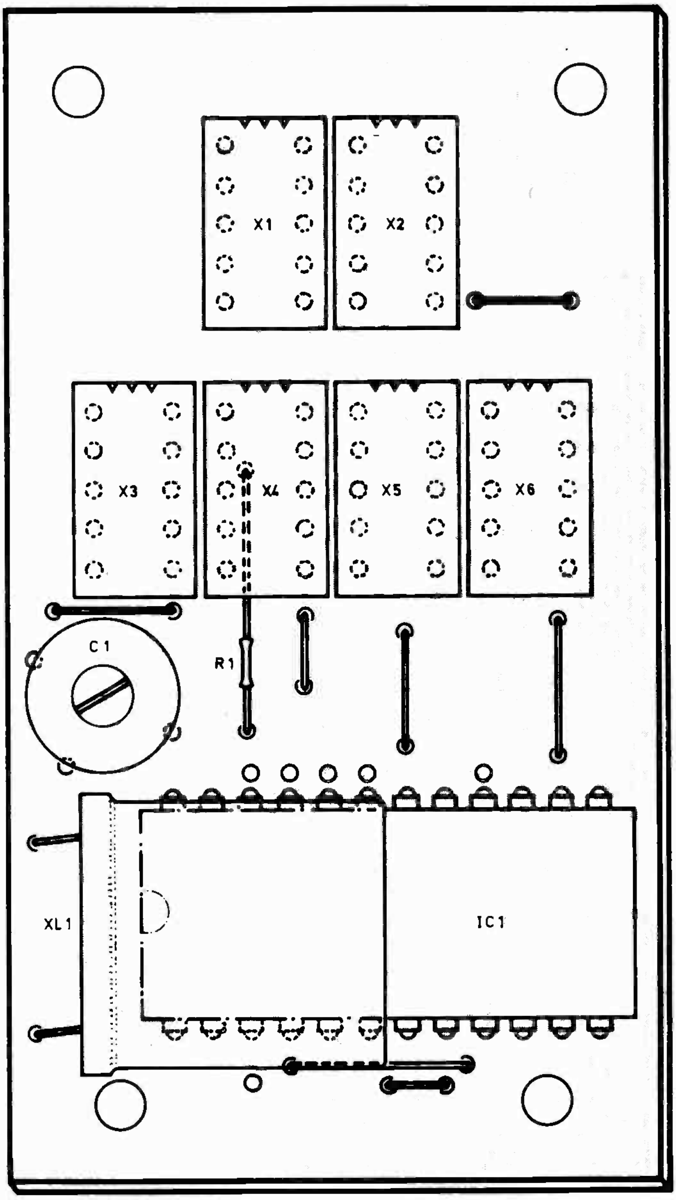


Fig. 4. Component layout shown at twice full size. The crystal leads should not be bent closer than 2mm from the can

COMPONENTS . . .

Resistors
R1 100Ω $\frac{1}{8}$W

Capacitors
C1 10–60pF Piher type CADsA1 (Doram)

Semiconductors
IC1 ICM7205 IPG Intersil
X1–X6 FND357 Fairchild

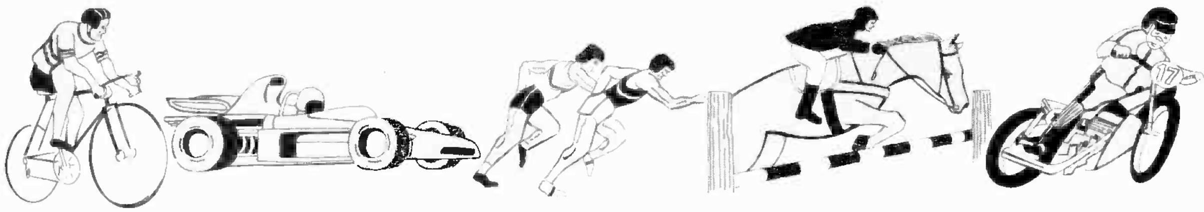
Miscellaneous
XL1 3·2768MHz in HC33/U package
S1–S2 Eagle SS3271 slide switch, or similar
S3–S5 Eagle SW5 pushbutton, or similar
JK1 3·5mm jack socket
Printed circuit board, 3 × Ni-Cad AA size cells, Verobox 100 × 50 × 40mm (type 65-2516G), display filter, screws, and p.v.c. sleeving.

CONSTRUCTOR'S NOTE

In this compact design, it is important that suitable l.e.d. displays are used. The specified FND357 units are available from: **Eurocom, Blenheim Road, High Wycombe, Bucks, HP12 3RS.** They may also be obtained from **Comway Electronics Ltd.**, of **Bracknell, Berks.**

The ICM7205 i.c. is available from **Rapid Recall, 9 Betterton Street, Drury Lane, London WC2 9BS,** for approximately £12·00 + VAT, etc.

The crystal XL1 and also IC1 are available from **Watford Electronics, 33-35 Cardiff Road, Watford, Herts.**



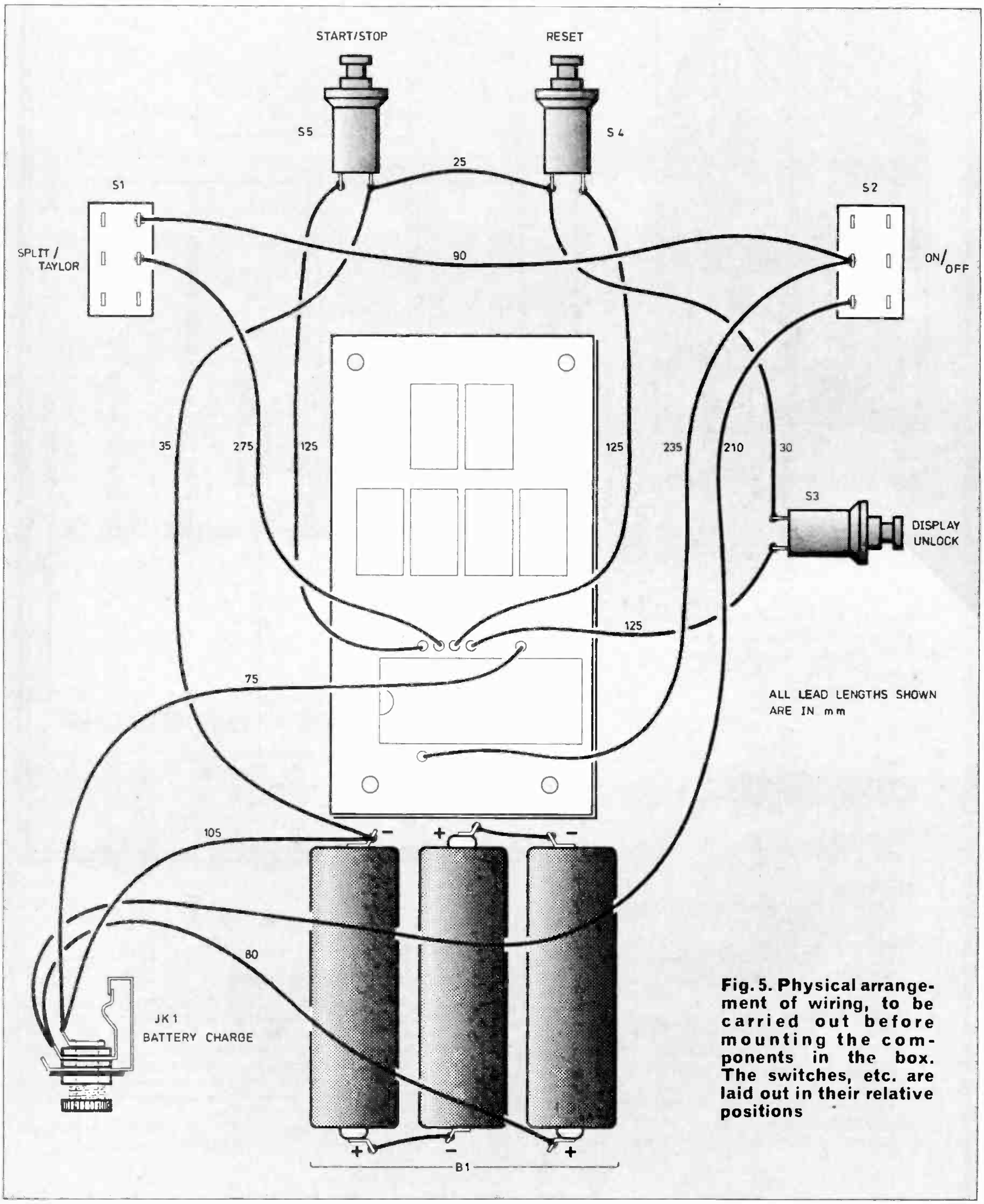


Fig. 5. Physical arrangement of wiring, to be carried out before mounting the components in the box. The switches, etc. are laid out in their relative positions

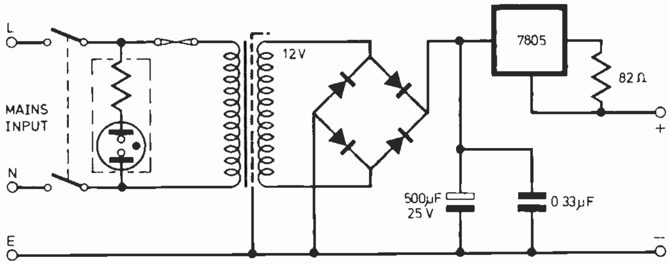
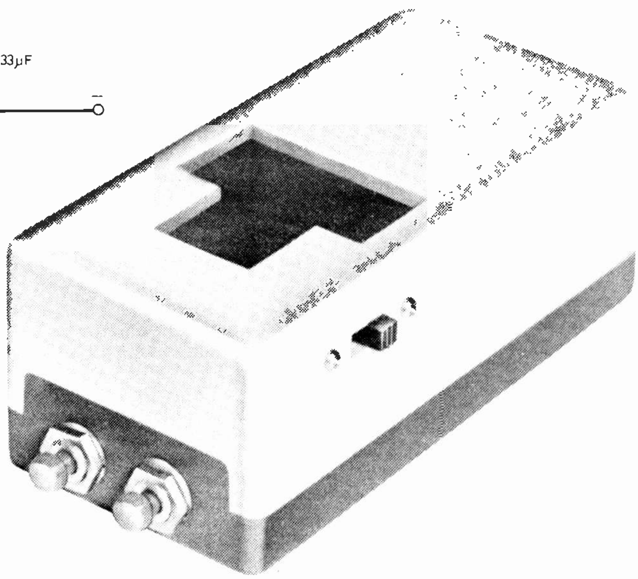


Fig. 7. Suggested charger circuit



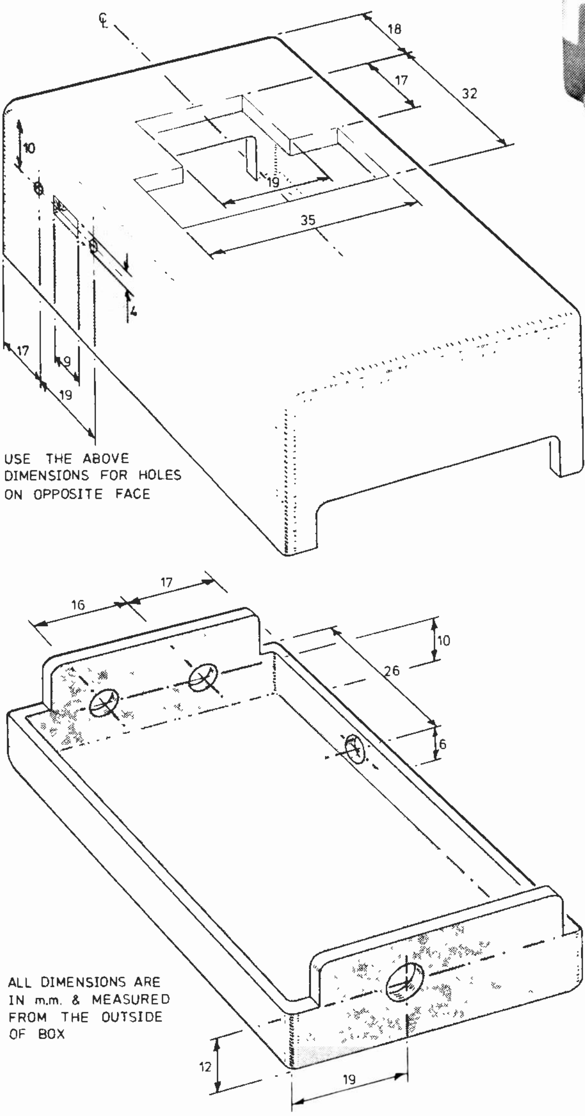


Fig. 6. Details of holes to be cut in the box to accommodate switches, etc.

The switches are mounted so that in the completed arrangement, the ON/OFF switch is to the right of the display. The wire between the two slide switches should be wrapped around the two top pillars in the box, and pushed neatly down. This should be done before one of the switches has been fitted. The remaining wires should also be wrapped around the lid pillars, which will keep them clear of the display when the lid is screwed down.

Please note that the p.c.b. layout detailed in this article has been improved over the original prototype featured in the incidental photographs, where the 100Ω resistor was mounted on the underside of the component board.

Owing to the nature of the application of this device, operation will probably need to be instinctive, therefore there is little merit in labelling the switches, although this can be done with dry letter transfers if felt necessary.

NI-CAD CELL CHARGER

The cells will need to be constant current charged, which for the recommended battery should be about 65mA. A circuit is shown in Fig. 7 which would perform this function, and also behave as a power supply for normal use, provided the cells are still **in circuit.** The 3·5mm jack socket (JK1) is used for this purpose, with the tip wired positive.

ELECTRONIC CONTROL

At the expense of portability, this unit can be hooked up to a photo-electric, or some other type sensor, to give completely electronic timing. This would of course give greater timing accuracy and repeatability, but would require a suitable multiway connector for the control inputs. ★

INDUSTRY NOTEBOOK

By Nexus

MEMORIES

Seventeen years ago when ITT Semiconductors at Foots Cray, Kent, were just about getting going on a semiconductor programme, few of us imagined that Foots Cray would one day be the leading memory house in ITT world-wide. How could we? We used to call the company STC in those days and memories were magnetic core stores.

This points up the big problem of keeping abreast of events in electronics. Not only who is making what, but very often who owns whom? Anyway, ITT have plunged £1·6 million on production and test facilities at Foots Cray in a major bid to capture a big chunk of the 4K RAM market with a 4027 emulator of the Mostek device.

The ITT strategy is based on a sales prediction that the 4027 is potentially the biggest seller. By next year ITT expect to be pumping 4027s out of Foots Cray at a rate of about three million a year.

Samples went out to industry at the tail end of 1976 and have been well received. If all comes true for the crystal-gazers at Foots Cray, about 80 per cent of the output will go to computer manufacturers in the USA and mainland Europe.

There was a crash development programme in which it is said that Foots Cray used Computer-Aided-Design (CAD) through the transatlantic cable to a powerful processor in the United States.

The business stakes are high and well worth a gamble. ITT forecasters suggest a world market for 4K RAMs peaking at £90 million in the early 80s.

But bubble memories are still a long way off according to data storage specialists BASF whose computer interests lie mainly in magnetic discs and tape. Head of BASF's data processing sales organisation, Dieter Heuer, reckons that bubbles won't make much impact until the mid-80s.

THE GAME'S THE THING

Those who are engaged in the sober professional side of electronics tend to scorn the gimmicks of electronics as almost beneath contempt. How wrong they are, at least from the business point of view. This came to me very forcibly when I heard that General Instrument Microelectronics had sold eight million chips for TV electronic games in a year. And next year could see the sale of up to 15 million electronic games. Quite a nice sideline while the market for new TV is still trying to recover.

The GIM 8500 chip provides facilities for half a dozen games and is probably the most successful dedicated chip for games ever produced. Details of the 8500 were described in the *TV Sportcentre* published last month.

But this is only a beginning. The microprocessor is due in the games business soon and will broaden the scope considerably, not only for more types of game from one piece of equipment but more complicated games, many of which will be not only fun to play but educational as well.

The big fear of the chip manufacturers is that the novelty of TV games will soon wear off. This could well be so, but the semiconductor fraternity are well skilled in business gamesmanship and will no doubt think up a few more ideas to keep us all spending our money.

A TESTING PROBLEM

With millions, even billions, of i.c.s pouring out of the factories the test gear manufacturers are doing well. I refer to that branch of the test and measurement industry which makes Automatic Test Equipment (ATE).

Next November at Brighton we shall see the biggest collection of ATE ever assembled in one place and have the opportunity of attending the most comprehensive ever conference on the subject.

Like every other market sector, the nature of ATE business is changing. At one time the only people who bought semiconductor ATE were the semiconductor manufacturers. Today less than half the total sales go to the manufacturers and far more is bought by semiconductor users. On the face of it this seems ridiculous because the user is only doing again what his supplier has already done once.

The user's problem is that if there is a bad apple in the barrel from his supplier and it gets assembled among a cluster of other i.c.s on a printed circuit board, it's quite a problem to find out where the fault is and quite a job to get an i.c. out from the board without damage. And a complex board can cost a lot of money, not to mention the cost per hour in trouble-shooting and repairs, and delay in production.

So better safe than sorry! Many companies are now doing 100 per cent checks on semiconductor devices at goods-inwards—it's cheaper that way. Not that devices are not tested well at the semiconductor plant—they are. But there can be transit and handling damage and it's not unknown for devices to be wrongly marked or for poorly marked devices to be stored in the wrong bins.

QUEEN'S AWARDS

Quite a lot of people have been questioning whether the Queen's Awards to industry have outlived their usefulness. Perhaps it's churlish to say so in Jubilee Year, but more often these days it's not so much patriotic fervour that spurs a company into bigger exports as the sheer need to survive. And so far as technological innovations are concerned, electronics companies live on them and so it's almost routine that a few should emerge every year.

This year GEC-Marconi brought their grand total up to 18 in 11 years since the scheme was started. Marconi Instruments won two of the four that went to GEC-Marconi, one for a 40 per cent jump in exports, the other for the TF2370 spectrum analyser, a technological development that was tipped by me as a world-beater when it was first announced in 1974 and has been mentioned before in this column.

Marconi Space and Defence Systems won their technological achievement award for the "Blindfire" tracking radar for the Rapier missile system. This is not only a fine radar but it has enormously improved the export potential of the Rapier system, already one of Britain's biggest export earners. And Marconi Marine got theirs for exporting 70 per cent of annual sales.

But when it comes to exports nobody can touch Racal. A fraction of the size of GEC-Marconi, the Racal Group has scored eight Queen's Awards. Now Racal-Tacticon has scored again with 86 per cent of production exported and it is this vigorous sub-group of companies which has now won six of Racal Group's eight Awards.

Congratulations to all the Award-winners this year and let's all hope that the losers will try that little bit harder. After all, it's a lot more fun to be successful as well as more profitable for everyone concerned.

Part 5 — PERIPHERAL CHIPS: INPUT/OUTPUT DEVICES

MICROPROCESSORS explained

By R. W. Coles

A microprocessor is a sociable animal, destined by its makeup and its programmed inclinations to establish friendly relationships with hardware external to its own immediate and cosy environment of warm 5 volt power supplies and chatty RAMs and PROMs.

To follow its sociable inclinations the microprocessor requires communication channels through which it can establish a dialogue with an often hostile outside world inhabited by thirsty l.e.d.s, bouncy switches, impatient printers, punchy tape perforators and a host of other "wierdos" who all require careful handling if they are not to become offended.

Of course, hardly any of these cranky gadgets speak a word of binary. Some gabble away in ASCII, others need it spelled out for them in terms of "motor on" or "lamp off", and still other uncouth layabouts require, of all things, a couple of hundred volts or a few amps before they'll play ball.

Now the microprocessor is a pretty smart cookie, and by and large it can handle all of these with ease as long as a thoughtful hardware designer provides some kind of interface circuitry so that the MPU chip doesn't have to get its delicate digits dirty.

The channels of communication are termed ports, and from the **inside** *a port looks quite similar to a memory location, making communication kid's stuff as far as the MPU chip is concerned. On the* **outside** *can be hung all the switches, gates, transistors and thyristors apparently so necessary to all those peasants beyond the system boundary!*

Without a complement of ports, a microprocessor is really nothing more than a fiendishly clever and expensive waste of time, and so this month we'll be looking at how these simple hard working appendages operate, and how the practical microprocessor fulfills its external obligations

PORTS can be input only, output only, or bidirectional in nature, and they can be arranged to transfer data a bit at a time (serial) or a word at a time (parallel), to suit the requirements of the external hardware.

SERIAL PORTS

Data transfers on a bit-by-bit basis are useful because only a single pair of wires is necessary to carry out the transfer, and this is important where sender and receiver are separated by sizeable distances. Of course speed of data transfer will be limited, but this isn't always important and in fact a whole family of computer peripherals, typified by the Teletype, do operate in this serial mode.

Teletypes and their derivatives operate asynchronously, a character at a time, and microprocessors can be programmed to send or receive information in the Teletype code (usually ASCII) via a serial port. Some MPU chips have a special serial output port actually on the chip, while with other systems to establish a *serial* port it is normal to simply use a small part of what is really a parallel port.

The fact that a parallel port can be considered as consisting of a collection of separate serial ports makes it unnecessary for us to consider serial ports in great detail since if parallel ports are available it will always be possible to write programs which treat the port as a serial interface.

For the special case of the asynchronous serial communications link mentioned above, we will see later that a special class of peripheral chip called variously UARTS and ACIAS can be used to implement this more efficiently than the MPU alone can.

PARALLEL PORTS

The MPU chip sends data to or reads data from a port via the same data bus that it uses for memory data transfers. This means that the parallel ports have the same word length or number of bits as the microprocessor itself, and in an eight-bit MPU system for example, the ports will be eight bits wide. The microprocessor can therefore change the logic state on eight output wires simultaneously by loading an eight-bit word from its accumulator to a selected output port, or it can load its accumulator with the logic state existing on eight input wires by reversing the procedure.

The number of input and output lines required in any particular application can range from just one of each, to perhaps hundreds of each in all sorts of combinations. This means that even 16-bit MPU systems will often require more than one input or output port, and this in turn means that some method of selecting, or addressing, the appropriate port is required. Different MPU chips tackle the problem of I/O port selection in different ways, but there are two main methods.

DEDICATED I/O INSTRUCTIONS

The instruction sets of some MPU chips contain special instructions which can be used to select a port and read data from it or write data to it. A good example of this simple I/O format is provided by the Intel 8080 microprocessor which has two instructions called *IN* and *OUT* which are used to transfer data between the accumulator register and selected ports. These instructions are of the two-byte variety, the first byte specifying the operation and the second specifying which of the possible 256 input or 256 output ports is being addressed. The eight-bit port address is sent out on the address bus like a memory reference address, but the port address is made unique by its association with an *INPUT READ* or *OUTPUT WRITE* signal on the MPU control bus.

MEMORY MAPPED I/O

An often used alternative to ports controlled by dedicated I/O instructions are memory mapped input/output ports which share the same address range as program and data memory. With memory mapping no special I/O instructions are required because input and output ports are treated as though they are memory locations which are written to and read from by means of the standard memory reference instructions provided in the instruction set.

Being able to use these standard memory reference instructions makes memory mapped I/O more versatile and sometimes more efficient, but because the ports are indistinguishable from memory locations as far as the MPU is concerned, the useable memory area is reduced and program debugging can be more difficult.

Memory mapped I/O can really be used with *any* microprocessor, although some like the Motorola M6800 and the SC/MP rely on it exclusively. We feel that an MPU chip which has the special I/O instructions is a better bet, because it leaves you free to choose the right type of port addressing for your particular application.

PORT HARDWARE

An output port consists, in its basic form, of a number of bistable latches with their inputs connected to the MPU data bus and their outputs available as output wires. The latches are loaded in parallel by a common write strobe which is generated at the appropriate time by the MPU itself. Selection logic can consist of a few simple gates or alternatively, TTL decoders such as the 7442 can be used to provide address decoding for a number of separate ports. See Fig. 5.1.

Input ports are normally three-state devices because their outputs have to drive the multiplexed MPU data bus only during the correct time slot in the MPU control cycle.

Normally the outputs of several input ports are connected together along with memory outputs from RAM and ROM and so it is essential that only one of these possible drivers is allowed to control the bus at any given instant. All other potential bus drivers must be in their third, high impedance, stage while the selected device is sending its data to the MPU chip.

Three-state logic is now freely available in the standard TTL and CMOS families, and an input port need consist of little more than a collection of three-state buffers with their "output disable" pins controlled by the MPU "read strobe". Selection of a particular input port is achieved in the same way as for output ports. See Fig. 5.2.

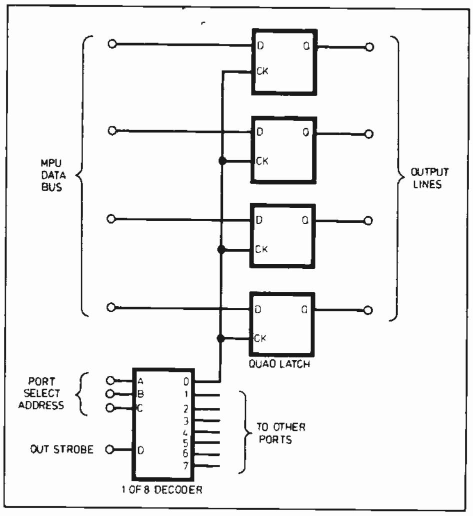


Fig. 5.1. A simple four-bit output port which can be built using standard TTL or CMOS components

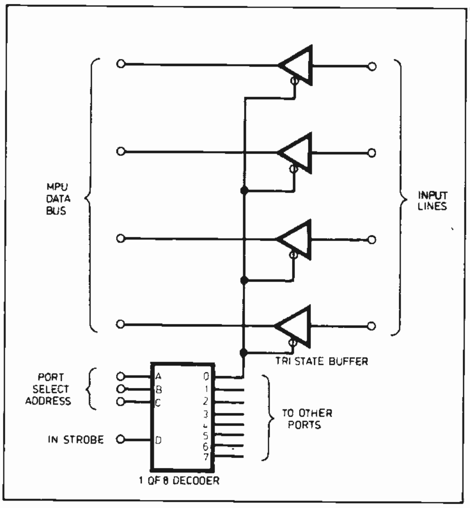


Fig. 5.2. A simple four-bit input port

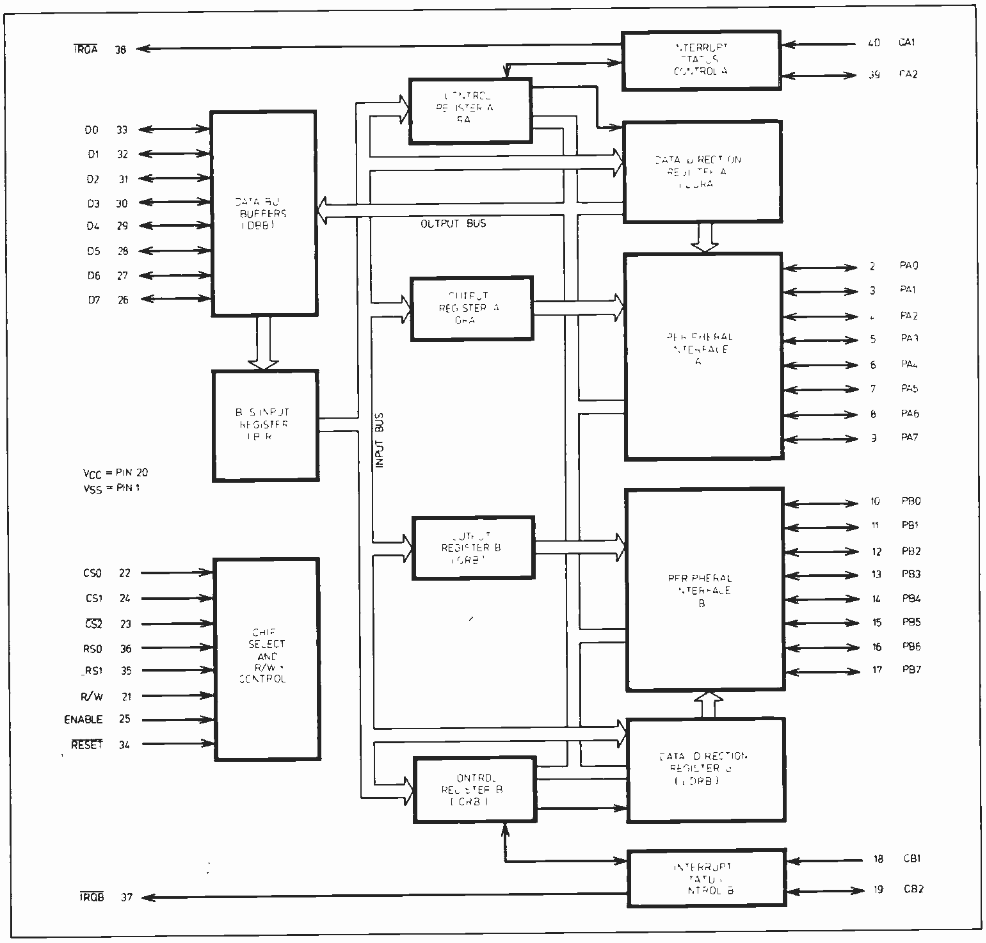


Fig. 5.3. The Motorola MC6820 Peripheral Interface Adapter (PIA) for use with the M6800 MPU. Two Programmable eight-bit ports are provided and comprehensive control and interrupt facilities are available. The MC6820 provides the universal means of interfacing peripheral equipment to the MC6800 MPU through two eight-bit bidirectional peripheral data buses and four control lines. No external logic is required for interfacing to most peripheral devices. The functional configuration of the PIA is programmed by the MPU during system initialisation. Each of the peripheral data lines can be programmed to act as an input or output, and each of the four control/interrupt lines may be programmed for one of several control modes. This allows a high degree of flexibility in the over-all operation of the interface

PROGRAMMABLE PERIPHERAL INTERFACE CHIPS

While it is fairly simple to put together your own input and output ports using TTL or CMOS components, this is not always the best solution since MPU manufacturers have designed some very versatile *programmable* input/output chips for use with their particular miroprocessors which can save you a lot of board space and add flexibility to your design.

The chips to which we refer are MOS LSI devices containing several I/O ports which can be individually configured as inputs or outputs under program control.

Devices of this type allow the "Deferred Design" concept discussed in Part 1 to be extended into the I/O area, because decisions regarding the number of input and output lines required for a particular job can be sidestepped at the hardware design level and not defined absolutely until the software design is undertaken. Examples are:

1. The Intel 8255 which consists of three eight-bit ports in a 40-pin package. The three ports can be programmed during system initialisation into one of three possible modes under the control of the 8080 program.

2. The Motorola MC 6820 which consists of two eight-bit ports in a 40-pin package configureable as input or output ports under the control of the M6800 MPU to which it is connected. See Fig. 5.3.

PROGRAM CONTROLLED I/O

The simplest way of *controlling* input/output transfers is to keep the whole business under the rigid control of a program, but this can raise problems when complex or high speed peripheral devices have to be dealt with.

In program control of, say, a keyboard array, the MPU must spend a great deal of its time examining the keyboard input ports to see if any keys have been pressed. The program must incorporate a "wait loop" through which the MPU cycles continuously until a key is pressed, and when it finds a key depression it must deal with it quickly to ensure that it does not miss any subsequent depressions. If the MPU does not have

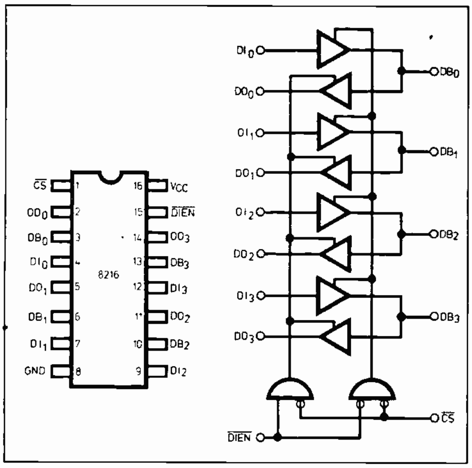


Fig. 5.4. The 8216 four-bit Parallel Bi-Directional Bus Driver/Receiver. All inputs are low power TTL compatible. For driving MOS, the DO outputs provide V_{OH} (3·65V), and for high capacitance terminated bus structures, the DB outputs provide a higher I_{OL} (50mA) capability. All outputs may be tri-stated. The 8216 is ideal as the data bus buffer/driver for the 8080 CPU. It may also be used with other MCS CPUs. By using a device such as this the fan-out of the bi-directional MPU data bus can be increased and bi-directional ports can be implemented

much else to do, this is not really a problem, but if it also has a printer, a tape cassette, and a lawn sprinkler to look after, it would not be able to cope adequately and recourse to a more sophisticated type of I/O control is necessary.

INTERRUPT DRIVEN I/O

You may have noticed that most microprocessor chips have one or more INTERRUPT inputs, and by making use of these it is possible to make our overworked MPU chip much more efficient in its dealings with the outside world, and well able to deal with a large number of peripheral devices all clamouring for attention.

The interrupt line, when asserted, causes the MPU chip to finish off the instruction it is currently engaged on and to jump to a special address called the "interrupt vector" where our trusty programmer has located a special program called an "interrupt handler". In our keyboard example for instance, the "wait loop" is no longer necessary if the keyboard array produces a common output which means "key pressed", and this is connected to the MPU interrupt line. In between key presses the MPU chip can tend the rest of its flock without fear of missing anything. The interrupt handler program is written rather like a subroutine (see Part 2) and when it has done its job (in the keyboard case it would read the code representing the depressed key into memory, for example) a *BRANCH BACK* is carried out to put the program counter back to where it was before it was interrupted.

INTERRUPT EXPANSION

The basic single-line interrupt facility can be expanded to handle any number of separate interrupt inputs if required, and as you might expect, a great deal of hardware and software ingenuity is often employed to make the interrupt system as efficient as possible.

When there are a number of possible interrupt sources it is advantageous to allocate a priority status to each of them so that a definite "pecking-order" is established. With a priority-ranked interrupt scheme, interrupt service routines already running can themselves be interrupted by interrupt sources with a *higher* priority, although sources with a *lower* priority have to wait until the current service routine is completed.

This concept of interruptable interrupts is similar in many ways to the concept of nested SUBROUTINES discussed in Part 2, and the MPU chip keeps track of its hectic input/output operations with the aid of the STACK which is used to store program counter values for orderly returns to lower priority interrupt routines and eventually to the main program.

DETERMINING PRIORITY

The criteria used to decide which devices should have the highest priority can be complicated, but a good rule of thumb is that the faster a device is, the higher the interrupt priority it should be allotted. Of course such signals as "power fail" must be right at the top of the priority tree, so that the MPU can make a rapid response to this potentially damaging event by saving valuable

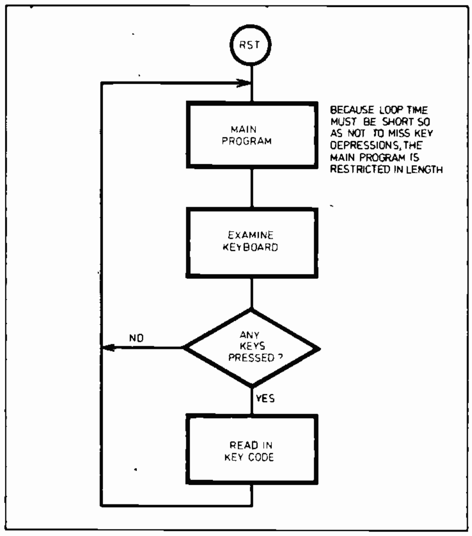


Fig. 5.5. Keyboard interface using program-controlled input/output

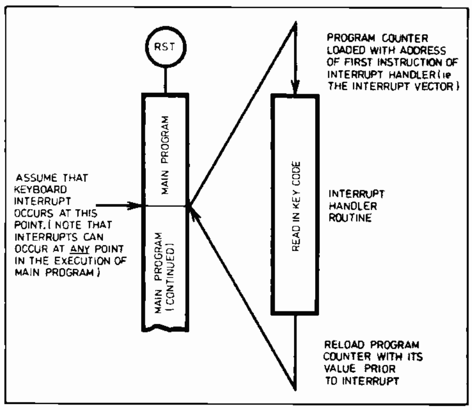


Fig. 5.6. Keyboard interface using interrupts

data in non-volatile storage and carrying out other important housekeeping jobs in the few milliseconds it has left before it gets the chop!

Prioritisation can be established by software with the use of such aids as the "Skip-chain" (Part 3), where once interrupted, the MPU goes off to ask each of the possible devices in turn whether *it* was responsible for the interrupt, with the highest priority devices being asked first, a technique known as "polling". A more powerful alternative is to establish a priority interrupt structure with *hardware*, and there are a variety of possible circuit techniques available to do this, the fastest requiring a lot of circuitry external to the MPU chip with others using less but requiring a certain amount of software support.

SINGLE-CHIP SUB-SYSTEMS

Interrupts are a little scary at first, but the MPU manufacturers are doing their best to make the use of this powerful technique as simple as possible, and one way in which they have improved matters is by introducing complete interrupt hardware sub-systems on a single chip.

An example of this interrupt hardware is given in Fig. 5.7, which shows the Intel 8259 "Programmable Interrupt Controller" for use with the 8080 MPU. This device handles eight priority-ranked interrupt inputs and produces a single interrupt output to the MPU along with an address vector to one of eight possible service routines. The 8259 can be cascaded to give extra interrupt levels, and the priority allocations can be changed *while a program is running* to provide a flexible response to the system environment.

OTHER PERIPHERAL CHIPS

In addition to input/output ports and associated interrupt circuitry, there is now a wide selection of "special" peripheral chips which are designed to take some of the load off the MPU chip and the poor overworked programmer! These chips really represent a reversal of the trend away from hardware and towards software in the interests of making the larger systems more efficient and easier to program.

As an example, LSI chips can now be obtained which perform all the "refreshing" required by the dynamic

Glossary of Terms

ACIA—Asynchronous Communications Interface Adapter. A peripheral chip which can control the transmission and reception of data to and from a seriel asynchronous peripheral such as a Teletype or a VDU. The ACIA converts the raw MPU data into a required peripheral format and transmits it at the correct speed. On reception of a data word from a peripheral, the ACIA latches it and tells the MPU of its availability via an interrupt or other control line. (Also see UART).

ASCII—American Standard Code for Information Interchange. A binary type code for communications purposes. The code includes upper and lower case alphabets, numerals, punctuation, and special control characters.

BAUD RATE—Refers to the rate of data transmission in serial communication links. More particularly it describes the number of message elements transmitted each second. For comparison, Telex machines operate at 50 bauds whereas normal ASCII Teletypes (often used with microprocessor systems) operate at 110 bauds.

FSK—Frequency Shift Keying. A commonly used modulation technique for sending serial binary data over communication links (e.g. telephone lines). Binary 1's and 0's are represented by separate audio frequency tones to produce a sort of keyed f.m. signal which is compatible with any channel normally used for speech transmission. Also useful for recording binary data on standard audio tapes or cassettes.

INTERRUPT—A hardware based facility which allows the suspension of a current program while an alternative "Interrupt Handler" program is executed. At the end of the interrupt sequence the original processor status is restored and the previously executing program is allowed to continue from the point at which it was interrupted. Interrupts are a powerful and widely used tool for the handling of peripheral input/output transfers.

INTERRUPT LINE—An asynchronous input to the microprocessor chip which when asserted causes the MPU to enter the interrupt state. Some microprocessor systems have a number of interrupt lines, and each of these is assigned a priority so that the one with the highest priority is serviced first.

INTERRUPT VECTOR—This is the address at which the start of an "Interrupt Handler" program will be found. Some microprocessors used fixed interrupt vectors set by the chip manufacturers, while more sophisticated systems with many possible interrupt sources allow the interrupting device to provide its own vector via an input port.

MODEM—MODulator/DEModulator. A widely used data communication terminal which allows a two-way (transmit/receive) serial data link to be established over standard telephone lines. These terminals use FSK modulation and demodulation techniques. A complete "Modem on a chip" is available as part of the Motorola M6800 microprocessor family.

SCRATCH PAD—A general name for a read/write random access memory which is used by an MPU chip as a "jotter" for immediate results or constants. The main requirement is for easy addressing and fast access, and many MPU chips have scratch pads, in the form of a register array, actually on the chip.

UART—Universal Asynchronous Receiver/Transmitter. UART is an alternative (and more popular) name for the ACIA.

USART—Universal Synchronous/Asynchronous Receiver/transmitter. This is an improvement on the UART or ACIA in that it may be programmed to operate as a synchronous communication link, making it a truly universal microprocessor communication peripheral chip.

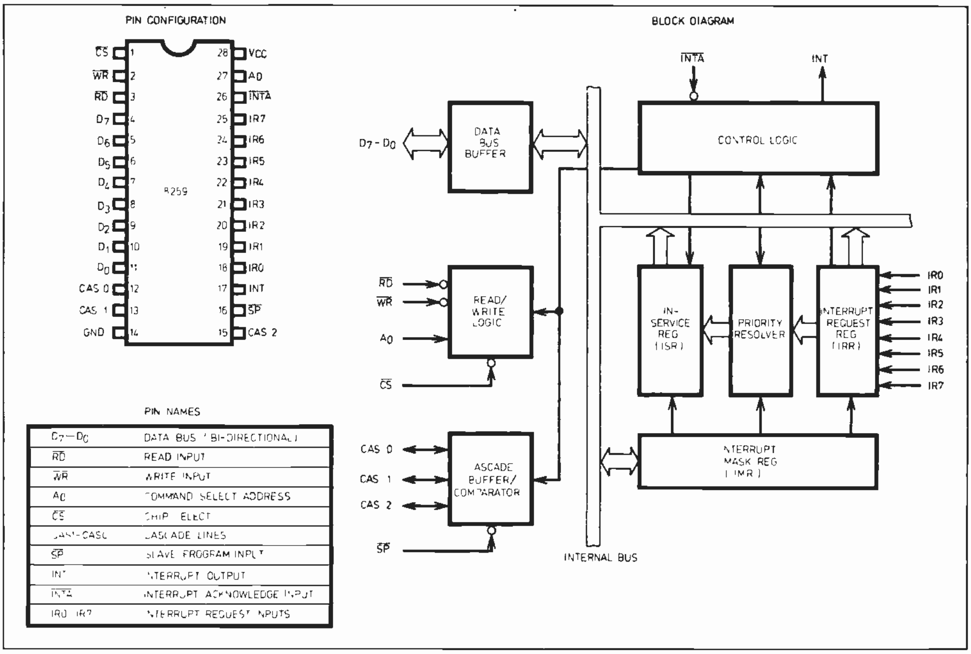


Fig. 5.7. The Intel 8259 Programmable Interrupt Controller. Note the eight prioritised interrupted inputs and the single resultant interrupt output which goes to the 8080 MPU chip. Setting up data and interrupt vector addresses pass to and fro on the eight-bit data bus

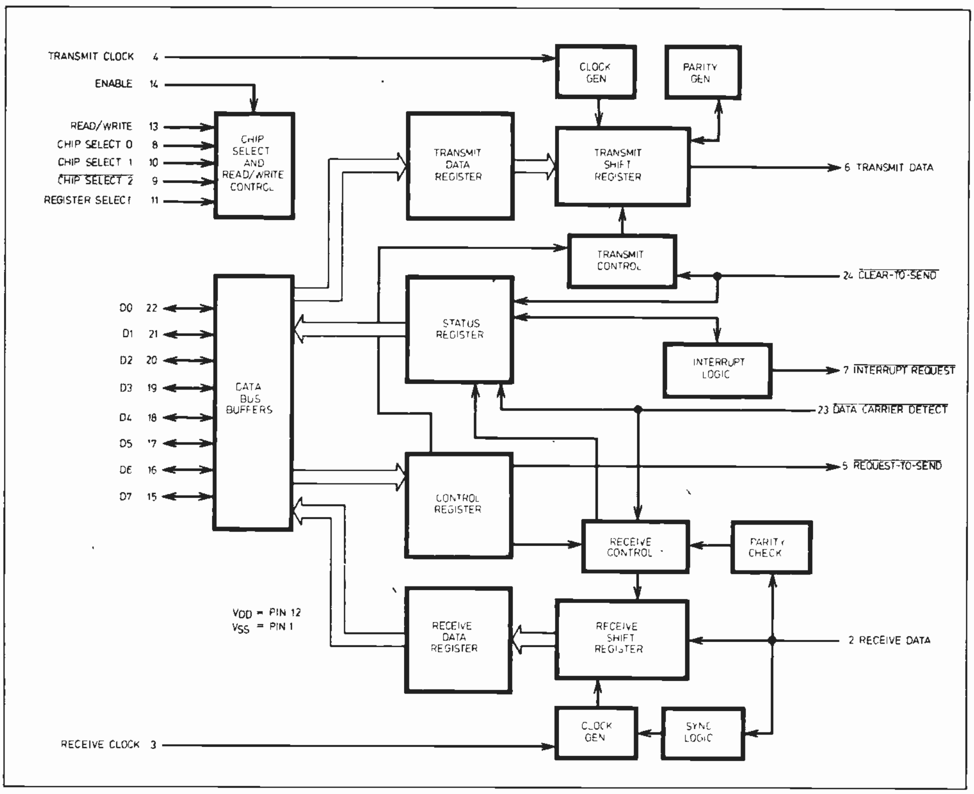


Fig. 5.8. The "innards" of the Motorola MC6850 Asynchronous Communications Interface Adapter (ACIA). Note the eight-bit data bus for communication with the MC6800 microprocessor, and the single-line TX and RX data paths for communication with serial peripherals

RAM chips often used for data storage in microprocessor systems. Chips like these make the refreshing operation completely "transparent" to the programmer, who would otherwise have to control it himself via software.

Another valuable peripheral chip relieves the MPU of the tedious job of providing time delay functions, normally produced by making the MPU chip sit in a loop incrementing cascaded storage locations until some pre-programmed terminal count is reached. This wasteful exercise is analogous to the seeker in a game of hide and seek who has to count to a hundred before setting off.

If the seeker has a stop-watch which "buzzes" after a hundred seconds, he or she could perhaps be better occupied reading a book during the waiting period, and similarly the microprocessor can be better occupied doing arithmetic or responding to interrupts!

The delay time chip referred to contains a number of independent binary counters which can be incremented by the system clock and are preset and started under MPU control. When a terminal count is reached an interrupt is generated to inform the MPU that the time period has expired.

SERIAL INTERFACE

One other important class of peripheral chips is commonly used to provide communication channels to serial peripheral devices like Teletypes and VDUs. These chips have names such as UART (Universal Asynchronous Receiver Transmitter), USART (Universal Synchronous Asynchronous Receiver Transmitter) and ACIA (Asynchronous Communications Interface Adapter) and are produced by most major microprocessor companies. See Fig. 5.8.

The chips relieve the MPU of a lot of the housekeeping and timing operations which are necessitated by the strict format and protocol demanded by serial peripherals, and enable the MPU to treat such serial I/O transfers as simple parallel word transfers to or from the UART, USART or ACIA chips themselves.

Apart from parallel-to-serial, and serial-to-parallel conversion, the chips add start and stop bits to the transmitted data, and can also provide and test a parity (error check) bit when this is desirable. The actual speed of transmission (or baud rate as it is usually called) can be programmed by use of an external clock oscillator over the range of d.c. to several thousand bits per second, so that a wide range of terminal equipment can be handled.

As if that wasn't enough, Motorola have introduced a complete "modem" on a chip (the MC6860L) so that the output of their ACIA can be converted into an FSK (Frequency Shift Keying) signal for transmission over telephone lines!

NOT ESSENTIAL

In the midst of this proliferation of special peripheral hardware it is important to remember that most of it is *not* essential and that it *can* be economically replaced with software in many small to medium sized systems. After all, replacing hardware with software is *supposed* to be the name of the game!

NEXT MONTH: Choosing a microprocessor. This is the concluding article of the present introductory series.

A constructional project will be featured in a new series starting in September 1977.

NEXT MONTH

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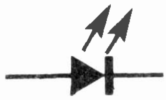

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THE CHAMP IS COMING!

PRACTICAL
ELECTRONICS
AUGUST ISSUE ON SALE JULY 8, 1977

Synthesiser TUNING INDICATOR

By C. Yallop

THE infinitely variable tuning capability of the synthesiser oscillator, presents problems with accurate tuning for multi-tracking and live performance applications. However, since relative tuning of the keyboard is set with the span control, the problem can be overcome by providing a tone of fixed pitch at several octaves range. A visual indication of frequency difference from this reference will then allow rapid and easy tuning, which can be carried out silently. The circuit described provides these facilities, and with a three octave keyboard, allows tuning over the range 16·35 to 8,372Hz directly.

CIRCUIT DESCRIPTION

Fig. 2 shows the complete circuit. The reference note is generated by IC1 connected as a stable relaxation oscillator, the frequency of which is set by VR1. Fig. 1 shows the basic oscillator format and the law governing the frequency of oscillation. Metal oxide resistors are used to promote stability.

In the OFF position, S1a disables the oscillator to eliminate audio and beat frequency break-through when not in use (for the benefit of those who build the device permanently into their synthesiser). The output of IC1 is a high amplitude square wave, and this is buffered by TR1 to be TTL compatible. A 4-stage octave divider is formed by IC2, and the outputs are selected by S2, and fed to the reference input of the indicator circuit.

The indicator circuit is basically that used in the Tuning Fork of *PE November 1975*, but since a high level continuous signal is available from the v.c.o.s, only one stage of preamplification is necessary. A further modification at the SAMPLE INPUT, is a switched low pass filter. This attenuates higher octave signals than those of the reference, so that indicator D4 only provides a beat indication when the sample and reference pitches approach unison.

CONSTRUCTION

The unit is primarily intended to be built into the synthesiser, and operated from its supply. The circuit will operate from ±9 to ±15 volts, with R5 and R15 selected to match the supply voltage used. The circuit can be assembled on 0·1in strip-board. When using the layout shown in Fig. 3, C4 through to C7 are wired directly on switch S2b. The SAMPLE INPUTS are taken from the v.c.o. outputs, before their level controls. The reference signal can be taken from S2a common, to an audio amplifier for audio tuning. The arrangement shown was used in the *Minisonic* Synthesiser.

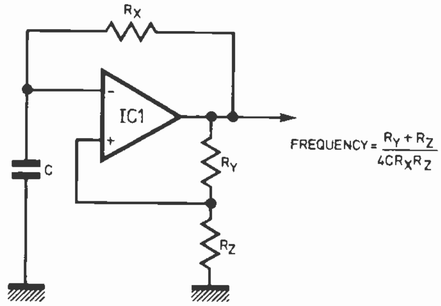

Fig. 1. Basic oscillator, and equation governing the frequency of operation

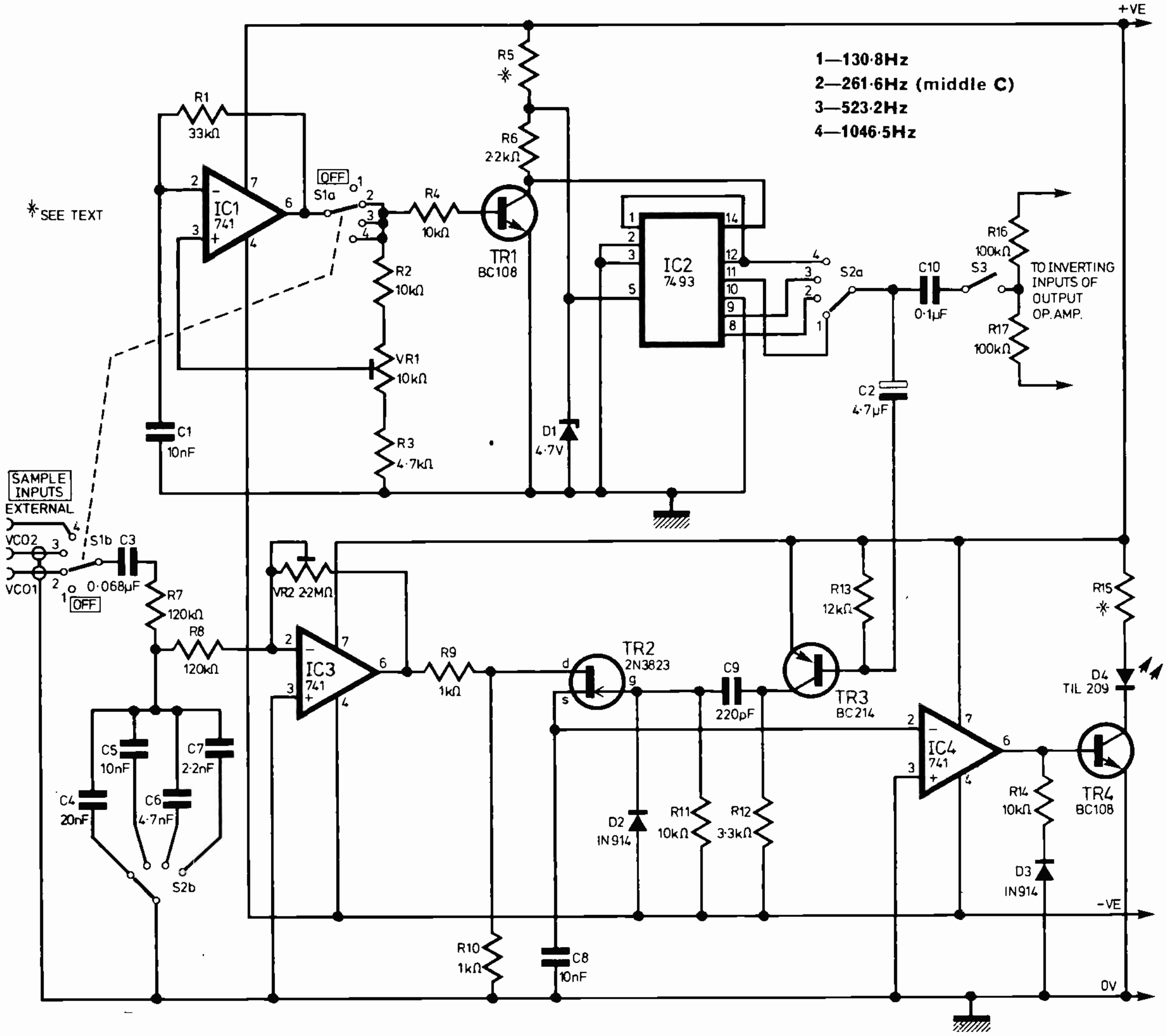

Fig. 2. Circuit diagram of the synthesiser tuning reference. Beat frequencies are indicated by D4

COMPONENTS . . .

Resistors

R1	33kΩ 2% m.o.
R2	10kΩ 2% m.o.
R3	4·7kΩ 2% m.o.
R4	10kΩ
R5	220Ω (for ±9 volt rails) 470Ω (for ±15 volt rails)
R6	2·2kΩ
R7	120kΩ
R8	120kΩ
R9	1kΩ
R10	1kΩ
R11	10kΩ
R12	3·3kΩ
R13	12kΩ
R14	10kΩ
R15	220Ω (for ± 9 volt rails) 470Ω (for ±15 volt rails)
R16	100kΩ
R17	100kΩ

All 5% ¼W unless otherwise stated

Potentiometers

VR1	10kΩ multiturn preset (min cermet)
VR2	2·2MΩ min horizontal preset

Capacitors

C1	10nF poly
C2	4·7µF 16 volt
C3	0·068µF ceramic
C4	20nF 2% poly* (can be 10 ‖ 10nF)
C5	10nF 2% poly*
C6	4·7nF 2% poly*
C7	2·2nF 2% poly*
C8	10nF 2% poly*
C9	220pF 2% poly*
C10	0·1µF ceramic

*Available from Doram Electronics Ltd

Transistors

TR1	BC108
TR2	2N3823 f.e.t.
TR3	BC214
TR4	BC108

Diodes

D1	BZY88 4·7 volt Zener
D2	1N914
D3	1N914
D4	TIL209

Integrated Circuits

IC1	741C
IC2	7493
IC3	741C
IC4	741C

Miscellaneous

S1, S2	2-pole 4-way rotary switch
S3	1 pole push-to-make

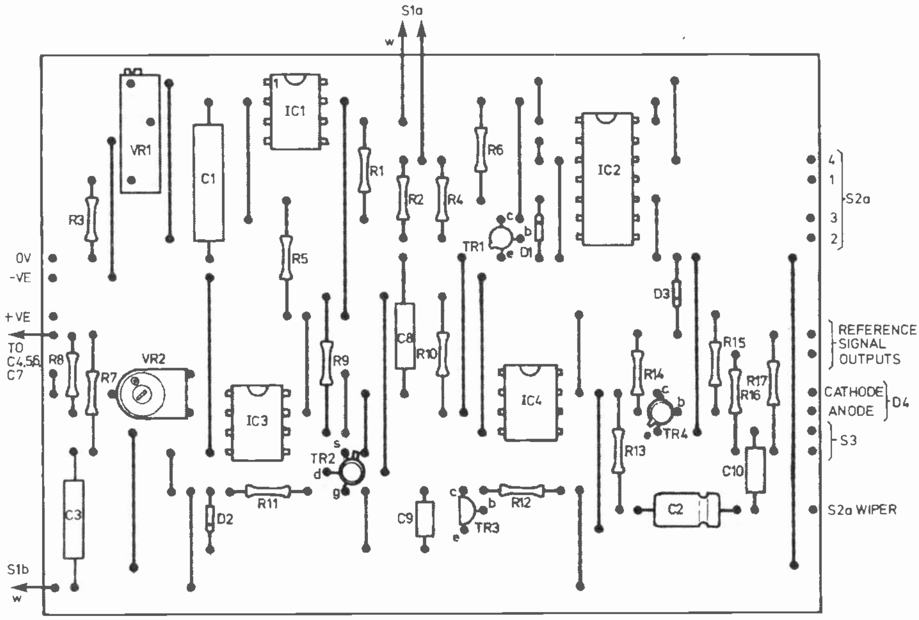

Fig. 3. Component layout and circuit board copper strip cutting details

SETTING UP

Where a C to C keyboard is used, the reference oscillator is best tuned to C at 2,093Hz. The exact frequency can be chosen to suit the application. For example, where the synthesiser is used with a fixed pitch instrument, the reference can be tuned to this, using the EXTERNAL SAMPLE INPUT.

The gain of the SAMPLE INPUT stage is set by VR2, so that with the v.c.o. input one octave above the reference, D4 does not quite light. Check this at all positions of S2. With the v.c.o. and reference approaching unison, a good beat indication should be given by D4.

To tune the v.c.o.s, their frequency is adjusted until D4 lights, and then further adjusted to give the slowest beat frequency indication obtainable. Audible tuning will facilitate initial coarse tuning. ★

NEWS BRIEFS

Video Disc '77

THE FIRST public UK demonstration of the Philips and MCA optical video disc system will be given at this year's Video Disc '77 Conference. Until now, the system has only been seen by invited audiences in Japan, USA and in Europe: Berlin and Cannes.

The Video Disc '77 Conference is to be held on November 8 and 9 in the Princess Anne Theatre at the British Academy of Film & Television Arts in Piccadilly, London. This auditorium was chosen because of the ceiling suspended colour monitors, ideal for video presentation to large audiences.

Teach-in

A FIVE day course with tutorials on the subject of "Logic, Interfaces and Microprocessors" is to be conducted by Prof. D. Zissos at the Southgate Technical College, London, N.14.

Approximately three days will be devoted to the design of logic circuits, design of procedures for instrument and minicomputer interfaces. The last two days will examine in depth microprocessors and their use in digital systems.

Details and reservations can be obtained from the organisers Interprojects Ltd., 29 Church Street, Edmonton, London, N9 9DY.

Pilots Eyes

THE Special Components Department of Ferranti at Gem Mill are hoping to help American Army helicopter pilots to overcome visibility problems when in action.

They have supplied several of their 1in CRTs to Hughes Aircraft Co. for incorporation in experimental helmet-mounted head-up displays. In the display, the tube is attached to the helmet and an image is projected through optics onto the pilot's visor, with focus at infinity. Thus, he sees the CRT image superimposed on whatever outside scene he is looking at.

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2N697	0·30	2N3704	0·15	40361	0·45	BC159	0·14	BD116	1·20	BFX87	0·40
2N698	0·62	2N3705	0·15	40362	0·48	BC160	0·50	BD131	0·51	BFX88	0·40
2N699	0·55	2N3706	0·16	40363	1·20	BC161	0·50	BD132	0·54	BFX89	1·25
2N706	0·24	2N3707	0·18	40406	0·58	BC167	0·12	BD135	0·37	BFY50	0·34
2N706A	0·12	2N3708	0·16	40407	0·45	BC168	0·12	BD136	0·37	BFY51	0·38
2N708	0·21	2N3709	0·18	40408	0·65	BC169	0·12	BD137	0·35	BFY52	0·36
2N709	0·50	2N3710	0·16	40409	0·65	BC170	0·16	BD138	0·38	BFY53	0·34
2N718	0·27	2N3711	0·18	40410	0·65	BC171	0·14	BD139	0·40	BFY90	1·37
2N718A	0·30	2N3712	1·20	40411	2·85	BC172	0·12	BD140	0·40	BRY39	0·50
2N720A	0·80	2N3713	2·30	40594	0·75	BC177	0·20	BD239	0·40	BSX20	0·31
2N914	0·35	2N3714	2·45	40595	0·85	BC178	0·20	BD240	0·45	BSX21	0·32
2N916	0·30	2N3715	2·55	40673	0·73	BC179	0·23	BD241	0·45	BU105	1·50
2N918	0·38	2N3716	2·80	AC126	0·37	BC182	0·11	BD242	0·47	BU205	2·20
2N929	0·25	2N3771	1·85	AC127	0·44	BC182L	0·14	BD243	0·60	MEO402	0·20
2N930	0·26	2N3772	2·00	AC128	0·37	BC183	0·11	BD244	0·62	MEO404	0·15
2N1131	0·60	2N3773	2·90	AC151V	0·35	BC183L	0·14	BD245	0·65	MEO412	0·20
2N1132	0·60	2N3789	2·90	AC152V	0·50	BC184	0·12	BD246	0·66	ME4102	0·10
2N1613	0·35	2N3790	3·10	AC153	0·49	BC184L	0·14	BD529	0·42	ME4104	0·10
2N1711	0·37	2N3791	3·10	AC153K	0·35	BC207	0·12	BD530	0·47	MJ480	1·35
2N1893	0·38	2N3792	3·50	AC176	0·40	BC208	0·11	BDY20	1·13	MJ481	1·55
2N2102	0·60	2N3794	0·20	AC176K	0·60	BC212	0·14	BF115	0·38	MJ490	1·35
2N2218	0·33	2N3819	0·36	AC187K	0·55	BC212L	0·17	BF117	0·70	MJ491	1·85
2N2218A	0·37	2N3820	0·38	AC188K	0·55	BC213	0·14	BF121	0·55	MJ2955	1·25
2N2219	0·30	2N3823	0·75	AD161	0·85	BC213L	0·16	BF123	0·55	MJE340	0·58
2N2219A	0·32	2N3904	0·21	AD162	0·85	BC214	0·16	BF152	0·25	MJE370	0·58
2N2220	0·35	2N3906	0·22	AF106	0·55	BC214L	0·17	BF153	0·25	MJE371	0·60
2N2221	0·22	2N4036	0·67	AF109	0·75	BC237	0·17	BF154	0·25	MJE520	0·45
2N2221A	0·26	2N4037	0·55	AF124	0·65	BC238	0·12	BF159	0·35	MJE521	0·65
2N2222	0·25	2N4058	0·20	AF125	0·65	BC239	0·16	BF160	0·30	MJE2955	1·40
2N2222A	0·25	2N4059	0·20	AF126	0·65	BC251	0·15	BF161	0·60	MJE3055	0·85
2N2368	0·25	2N4060	0·20	AF127	0·65	BC253	0·22	BF166	0·40	MP8111	0·35
2N2369	0·25	2N4061	0·17	AF139	0·69	BC257A	0·17	BF167	0·38	MP8112	0·40
2N2369A	0·29	2N4062	0·18	AF186	0·50	BC258A	0·17	BF173	0·38	MP8113	0·45
2N2646	0·75	2N4126	0·17	AF200	0·70	BC259B	0·18	BF177	0·30	MPF102	0·30
2N2647	1·40	2N4289	0·20	AF239	0·74	BC261A	0·21	BF178	0·35	MPSA05	0·23
2N2904	0·36	2N4919	0·65	AF240	0·98	BC262B	0·19	BF179	0·35	MPSA06	0·24
2N2904A	0·37	2N4920	0·70	AF279	0·80	BC263C	0·30	BF180	0·40	MPSA12	0·35
2N2905	0·37	2N4921	0·50	AF280	0·85	BC300	0·45	BF181	0·40	MPSA55	0·24
2N2905A	0·38	2N4922	0·53	BC107	0·15	BC301	0·45	BF182	0·45	MPSA56	0·24
2N2906	0·28	2N4923	0·70	BC108	0·15	BC303	0·60	BF183	0·45	MPSU05	0·50
2N2906A	0·25	2N5190	0·60	BC109	0·15	BC307	0·20	BF184	0·38	MPSU06	0·56
2N2907	0·21	2N5191	0·70	BC113	0·17	BC308	0·18	BF185	0·30	MPSU55	0·55
2N2907A	0·22	2N5192	0·75	BC115	0·19	BC309C	0·25	BF194	0·14	MPSU56	0·60
2N2924	0·15	2N5195	0·90	BC116	0·19	BC317	0·14	BF195	0·13	TIP29A	0·45
2N2925	0·17	2N5245	0·35	BC116A	0·20	BC318	0·13	BF196	0·14	TIP29C	0·60
2N3019	0·55	2N5294	0·40	BC117	0·22	BC327	0·20	BF197	0·17	TIP30A	0·49
2N3053	0·30	2N5295	0·40	BC118	0·16	BC328	0·19	BF198	0·18	TIP30C	0·65
2N3054	0·60	2N5296	0·40	BC119	0·30	BC337	0·19	BF200	0·35	TIP31A	0·50
2N3055	0·70	2N5298	0·40	BC121	0·45	BC338	0·21	BF225J	0·25	TIP31C	0·66
2N3390	0·25	2N5447	0·15	BC132	0·30	BC547	0·12	BF244	0·35	TIP32A	0·50
2N3391	0·25	2N5448	0·15	BC134	0·15	BC548	0·12	BF245	0·34	TIP32C	0·75
2N3391A	0·25	2N5449	0·19	BC135	0·15	BC549	0·13	BF246	0·75	TIP33A	0·80
2N3392	0·16	2N5457	0·32	BC136	0·19	BCY30	1·03	BF254	0·24	TIP33C	1·10
2N3393	0·15	2N5458	0·33	BC137	0·14	BCY31	1·06	BF255	0·24	TIP34A	0·90
2N3394	0·15	2N5459	0·29	BC140	0·40	BCY32	1·70	BF257	0·37	TIP34C	1·20
2N3439	0·88	2N5484	0·34	BC141	0·45	BCY33	1·00	BF258	0·45	TIP35A	2·50
2N3440	0·64	2N5486	0·38	BC142	0·30	BCY34	1·20	BF259	0·49	TIP36A	3·35
2N3441	0·85	2N6027	0·53	BC143	0·30	BCY38	2·00	BF459	0·45	TIP41A	0·70
2N3442	1·35	2N6101	0·65	BC147	0·12	BCY42	0·60	BFR39	0·28	TIP41C	0·85
2N3638	0·16	2N6107	0·42	BC148	0·12	BCY58	0·25	BFS21A	2·60	TIP42A	0·80
2N3638A	0·16	2N6109	0·42	BC149	0·13	BCY59	0·25	BFS28	1·04	TIP42C	0·95
2N3639	0·30	2N6121	0·38	BC153	0·27	BCY70	0·25	BFS61	0·30	TIP2955	0·65
2N3641	0·20	2N6122	0·41	BC154	0·27	BCY71	0·26	BFS98	0·27	TIP3055	0·55
2N3702	0·17	2N6123	0·43	BC157	0·12	BCY72	0·24	BFX29	0·38	TIS43	0·30

INTEGRATED CIRCUITS

CA3020	1·78	LM1808	1·92	TAA550	0·60
CA3020A	2·29	LM1828	1·75	TAA560	1·60
CA3028B	1·01	LM3301N	0·85	TAA570	2·30
CA3028A	1·29	LM3302N	1·40	TAA611B	1·85
CA3030	1·24	LM3401	0·70	TAA621	2·15
CA3030A	1·89	LM3900	0·75	TAA661A	1·32
CA3045	1·40	LM3905	1·60	TAA661B	1·32
CA3046	0·89	LM3909	0·68	TAA700	3·91
CA3048	2·23	MC1035	1·75	TAA930A	1·00
CA3049	1·66	MC1303	1·47	TAA930B	1·05
CA3052	1·62	MC1304	1·85	TAD100	1·95
CA3053	0·60	MC1305	1·85	TBA120	0·65
CA3080	0·68	MC1306	1·00	TBA400	1·50
CA3080A	1·88	MC1310	1·91	TBA500	2·21
CA3086	0·51	MC1312	1·98	TBA500Q	2·30
CA3088	1·59	MC1327	1·54	TBA510	2·21
CA3089	2·52	MC1330	0·92	TBA510Q	2·30
CA3090	3·80	MC1350	0·75	TBA520	2·21
CA3130	0·94	MC1351	1·20	TBA520Q	2·30
LM301A	0·65	MC1352	0·97	TBA530	1·98
LM301N	0·44	MC1357	1·45	TBA530Q	2·07
LM304	2·45	MC1458	0·91	TBA540	2·21
LM307N	0·65	NE555	0·53	TBA540Q	2·30
LM308C	1·82	NE556	1·05	TBA550	3·13
LM308N	1·17	NE565	1·30	TBA550Q	3·22
LM309K	2·10	NE566	1·65	TBA560Q	3·22
LM317K	3·00	NE567	1·80	TBA570	1·29
LM318N	2·25	SAS560	2·50	TBA570Q	1·38
LM323K	6·40	SAS570	2·50	TBA641B	2·50
LM339N	1·75	S042P	2·50	TBA651	1·80
LM348N	1·91	76001N	1·57	TBA700	1·52
LM360N	2·75	76003N	2·55	TBA700Q	1·61
LM370N	3·00	76008K	2·50	TBA720Q	2·30
LM371N	2·25	76013N	1·70	TBA750	1·98
LM372N	2·15	76013ND	1·57	TBA750Q	2·07
LM373N	2·25	76018K	2·50	TBA800	1·20
LM374N	2·25	76023N	1·70	TBA810	1·16
LM377N	1·75	76023ND	1·57	TBA820	1·03
LM378N	2·25	76033N	2·55	TBA920	1·79
LM379S	3·95	76110N	1·46	TBA920Q	2·99
LM380-8	0·90	76115N	1·87	TBA940	1·62
LM380N	0·98	76116N	2·06	TCA160C	1·85
LM381A	2·45	76131N	1·30	TCA160B	1·61
LM381N	1·60	76226N	1·94	TCA270	2·25
LM382N	1·25	76227N	1·51	TCA280A	1·30
LM384N	1·45	76228N	1·75	TCA290A	3·13
LM386N	0·80	76530N	0·91	TCA420A	1·84
LM387N	1·05	76532N	1·50	TCA730	3·22
LM388N	1·00	76533N	1·30	TCA740	2·76
LM389N	1·00	76544N	1·44	TCA750	2·30
LM702C	0·75	76545N	2·09	TCA760	1·38
LM709C	0·65	76546N	1·44	TCA800	3·13
LM709N	0·45	76550N	0·41	UAA170	2·00
LM710C	0·60	76552N	0·65	UAA180	2·00
LM710N	0·60	76570N	2·08		
LM723C	0·85	76620N	1·10		
LM723N	0·75	76650N	1·10		
LM741C	0·65	76660N	0·60		
LM741N	0·50	76666N	0·92		
LM741-8	0·40	TAA310A	1·50		
LM747N	0·90	TAA320A	1·15		
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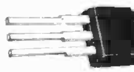

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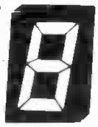

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CD4009	0·57	CD4024	0·79	CD4049	0·56
CD4010	0·57	CD4025	0·20	CD4050	0·56
CD4011	0·20	CD4027	0·56	CD4510	1·54
CD4012	0·20	CD4028	0·91	CD4511	1·54
CD4013	0·57	CD4029	1·17	CD4516	1·40
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7402	0·21	7414	1·80	7441	1·03	7472	0·38	7490	0·61	74121	0·49	74162	1·41	74188	2·00
7403	0·21	7416	0·61	7442	0·78	7473	0·43	7491	0·98	74122	0·45	74163	1·41	74189	3·99
7404	0·26	7417	0·61	7445	1·35	7474	0·43	7492	0·61	74123	0·58	74164	1·23	74190	1·91
7405	0·26	7420	0·21	7446	1·23	7475	0·58	7493	0·61	74141	1·03	74165	1·23	74191	1·91
7406	0·74	7423	0·39	7447	1·17	7476	0·51	7494	0·74	74145	1·06	74167	3·70	74192	1·62
7407	0·74	7425	0·39	7448	1·17	7480	0·45	7495	0·78	74151	1·11	74174	1·52	74193	1·62
7408	0·29	7427	0·39	7450	0·29	7481	1·10	7496	1·03	74153	1·11	74175	1·35	74196	1·17
7409	0·29	7430	0·21	7451	0·21	7482	0·67	7497	4·60	74154	1·85	74176	1·23	74197	1·17
7410	0·21	7432	0·39	7453	0·21	7483	1·33	74100	1·15	74155	1·11	74180	1·77	74198	2·93
7411	0·29	7437	0·55	7454	0·21	7484	0·85	74107	0·43	74157	0·98	74181	3·70	74199	2·93

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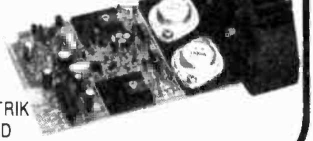
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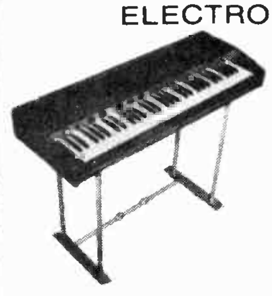

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PATENTS REVIEW...

UNDERWATER SAFETY

A modification of calculator technology to make underwater diving safer is proposed in BP 1 461 277, by E. T. Skinner & Co. Ltd. of Barnes, London.

As shown in Fig. 1, a pressure transducer has a diaphragm which is subjected to prevailing water pressure and backed by a stiff spring so that large pressure variations cause only a small linear movement of the diaphragm, e.g. 10–50 thousandths of an inch.

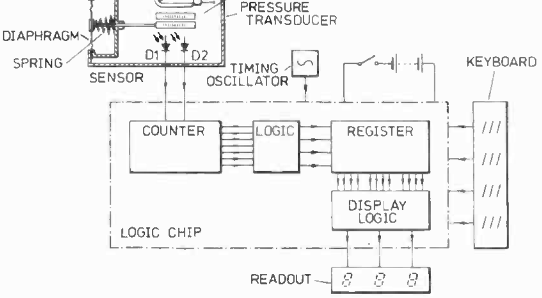
The small movement of the diaphragm causes relative movement between two crossed diffraction gratings of Moiré type. Such relative movement causes magnified movement of Moiré fringes produced by illumination from the lamp.

These fringe movements are detected by photocells D1, D2, of which the output is fed to a counter, so that a pulse train from photocell D1 creates an increment on the counter and a train from D2 creates a decrement. The accumulated count is fed via the logic circuits to the register, which supplies display logic and l.e.d. readout information to indicate pressure or depth. All the logic components are integrated in one chip, which is fed also with signals from a timer oscillator.

Thus, under the control of the keyboard the diver may display either depth or time under water or the product of time and depth, the resulting figure being representative of the air consumed by the diver and the available safe time left at the sensed depth. By computing the product of time and depth to a chosen power, a decompression product can be displayed, to advise the diver on a safe rate of ascent.

Integration should allow the unit to be worn as a wrist calculator, with an alarm function signalling divergence from the safe decompression product and consequent risk of "the bends".

BP 1 461 277



HEAT WARNING BP 1 462 461

In BP 1 462 461, Robert Parker Research Inc., of California, USA, patents an electro-chemical device for warning users of equipment, such as irons, whether they are hot and can cause a burn. The object is to provide a heat danger indicator device which need not necessarily be in thermal contact with the appliance.

A thin transparent Mylar or similar plastics film is masked to denote appropriate warning symbols.

A thin coating of liquid crystal composition is then applied with a dark backing of ink or paint. A heating element, for instance of carbon impregnated paper, heater sheet film or foil, is applied to this backing, and the whole aggregation sealed in a protective casing. The heating element is connected in parallel with the power source for the appliance.

When the appliance is switched on the subsidiary element generates heat which warms the liquid crystal layer and causes it to change from its transparent to visible and coloured state. This transformation in turn makes the symbols masked in the Mylar film legible.

By using strips of different liquid crystal composition with different transition temperatures, or spacing the heating element asymmetrically so that a heat gradient is created over the crystal material, the device can provide a tell-tale readout of the transition between cold, warm, hot and very hot. This is representative of the temperature and condition of the remote appliance.

Details are given of suitable crystal compositions for a range of temperature differentials and ambient conditions.

IN BRIEF

BP 1 464 744—H. P. Vinet: *Automatic Workshop Installation*. A complicated electronics "overseer" system, intended to allow members of the public to service their own cars, TV, radio, etc. using specialised workshop facilities on a hire basis.

Separate service areas are electronically unlocked by payment of a fee, and free access for a limited time is then given to hand and power tools. At the end of the service period, electronic sensing devices (e.g. magnets and reed switches) sound an alarm if any tool has not been returned to its proper place. Power tools are connected to the power supply via leads which sound an alarm if cut.

BP 1 464 037—C. B. Richmond: *Automatic Cross Feed Device*. Voltage controlled amplifiers in adjacent sound channels are governed in up-and-down gain directions by exponential ramp voltage generators and inverters connected to the v.c.a. inputs. This provides automatic cross-pan between sound channels, with one channel coming up while the other goes down.

BP 1 465 094—H. Peiker: *Dynamic Loudspeaker for Speech Transmission*. A heavy duty speech band transducer, e.g. loudspeaking telephone or speech address type, capable of long periods of use without breakdown.

Commonly such heavy duty use results in "open-circuit" voice coil connections due to l.f. excursions of the diaphragm. To cure this, the diaphragm is rear-loaded by a cavity which is vented to the atmosphere via apertures, selected in size and number, to tune the rear enclosure as a low pass filter to curtail unnecessary l.f. excursions.

Copies of Patents can be obtained from the Patent Office Sales, St. Mary Cray, Orpington, Kent Price 95p each

MARKET PLACE

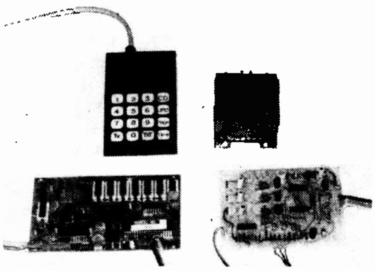
Items mentioned in this feature are usually available from electronic equipment and component retailers advertising in this magazine. However, where a full address is given, enquiries and orders should then be made direct to the firm concerned. All quoted prices are those at the time of going to press.

TELETEXT DECODER

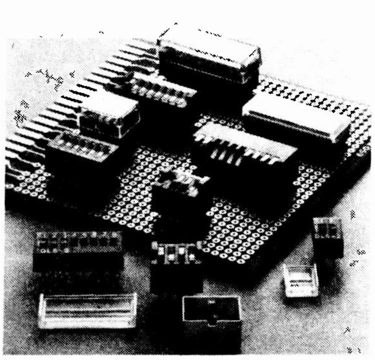
A Teletext decoder at less than half the cost of any comparable decoder currently available is announced by **Videocraft.** It is supplied as a kit comprising an assembled and tested Texas Tifax Teletext decoding module, power supply and interface module kit, and an assembled and tested cable-connected remote control. The interface module and installation instructions vary according to your TV receiver type.

The decoder output feeds directly into the receiver video circuitry, and in most cases the unit can be fitted inside the receiver cabinet. Facilities include seven colours, upper and lower case characters, graphics, time coded display, and newsflash and subtitle inserted in the TV picture. The complete kit costs £180 plus 8% VAT.

Full details of this and other decoders are available from **Videocraft, Assetts House, Elverton Street, London SW1P 2QR.**



Videocraft Tifax Teletext kit



DIP Switches from Contraves

AMPLIFIER MODULE

Intended for use in "personal" record players, tape recorders, stereo amplifiers and cassette/cartridge players **Bi-Pak Semiconductors** have just introduced the AL-30A low power audio amplifier module.

Capable of delivering 5–10W r.m.s. into 8 to 16 ohm loads, the module has a sensitivity of 90mV for full output and a claimed frequency response of 60Hz to 25kHz $\pm$ 2dB. The input impedance is 50kΩ and the claimed total harmonic distortion is less than 0·5 per cent; typically 0·3 per cent.

The required power supply for the module is 22 to 30V. The circuit for the module uses a complementary symmetry output stage and the specification of the output devices ensures good performance and reliability. The particular choice of the power transistors used determine the supply and output conditions. It is recommended that a heatsink should be used with this module.

The cost of the AL-30A is £3·60 and further particulars, including a suitable power supply and preamplifier module, can be obtained from **Bi-Pak Semiconductors, The Maltings, 63A High Street, Ware, Herts.**

For the bargain hunter Bi-Pak list several semiconductor and component pack offers in their new 127 page Components Catalogue. The catalogue also lists individual items ranging from CMOS integrated circuits to ordinary wire.

A separate price list is issued with each catalogue and is updated when necessary. The charge for the catalogue is 50p plus 15p pp.

MULTI-POLE SWITCHES

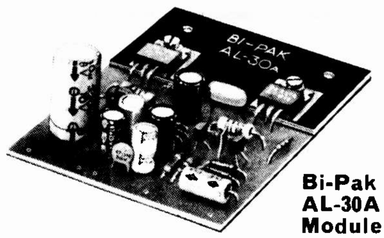
Miniature on/off switches conforming to standard dual-in-line package dimensions have been introduced by **Contraves Industrial Products.**

The new d.i.p. switches are designed for use on printed circuit boards. Up to 10 single pole switches can be specified on a single module, and the switch contacts are rated at 100mA at 50V d.c.

The pole positions are numbered on the body of the switch to facilitate easy setting. Dust covers and locking mechanisms prevent accidental operation. The switches can be used with sockets or soldered directly to the printed circuit board.

A range of different configurations is available including switch toggles arranged vertically instead of horizontally, changeover contacts instead of standard single pole single throw contacts and low profile designs.

Further information on the complete range of switches available can be obtained from **Contraves Industrial Products Ltd., Times House, Station Approach, Ruislip, Middlesex.**



Bi-Pak AL-30A Module

CATALOGUES

At long last we have had the pleasure of receiving and looking at the new **Maplin Electronic Supplies** component catalogue.

With over 4,000 items and over 1,000 photographs and drawings it has been well worth the wait and must figure in our "musts" for readers-to-collect list.

Containing 216 pages it gives details for several "build-it-yourself" kits including a professional 4 to 16 channel audio mixer; organists/guitarists 13-note bass foot pedal; light show with a.v.c. and an electronic ignition system.

Also, there are 30 pages of i.c. information together with complete circuits.

The catalogue costs 50p and prices are guaranteed for two-monthly periods. A bi-monthly newsletter/price list is issued and customers can receive a years supply for 30p.

Copies of the Maplin Components Catalogue can be obtained from **Maplin Electronic Supplies, P.O. Box 3, Rayleigh, Essex, SS6 8LR.**

Another new components catalogue we have received is the 28 page Orchard Electronics components catalogue. The charge for this is 50p but includes two vouchers value 25p each, refundable with an order over £3·25 or 25p off 2 orders value £1·50p.

Copies are available from **Orchard Electronics, Flint House, High Street, Wallingford, OX10 0DE.**

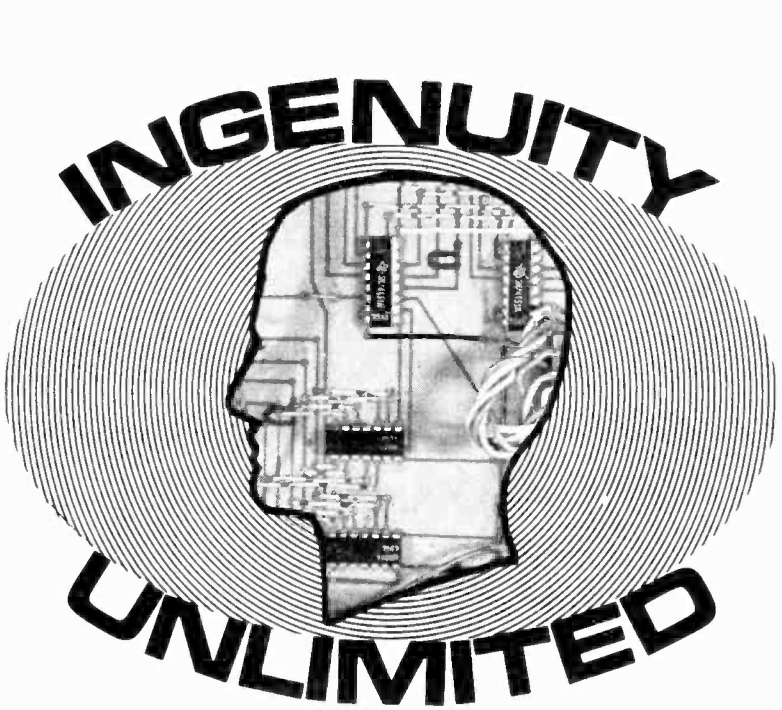
NOTE

A number of past PE projects have specified panel meters made by SEW (Shinohara) which were formerly sold by G. W. Smith and Laskys.

These instruments are now available from **ITT Instrument Services, Edinburgh Way, Harlow, Essex CM20 2DF,** who will accept small orders on a cash with order basis. There is no minimum order charge but 75p is added to cover post and packing. A price list is available on request.

We have been informed that the Neosid A6 assemblies called up in the P.E. Orion articles are not available direct from Neosid Ltd.

However, orders for one-offs should be placed with **Potters Market Ltd., of 35 Hydeway, Welwyn Garden City, Herts.,** who have agreed to handle small orders for Neosid Ltd.



A selection of readers' original circuit ideas. It should be emphasised that these designs have not been proven by us. They will at any rate stimulate further thought.

Why not submit *your* idea? Any idea published will be awarded payment according to its merits.

Articles submitted for publication should conform to the usual practices of this journal, e.g. with regard to abbreviations and circuit symbols. Diagrams should be on separate sheets, not inserted in the text.

Each idea submitted must be accompanied by a declaration to the effect that it is the original work of the undersigned, and that it has not been accepted for publication elsewhere.

SOLAR PANEL CONTROLLER

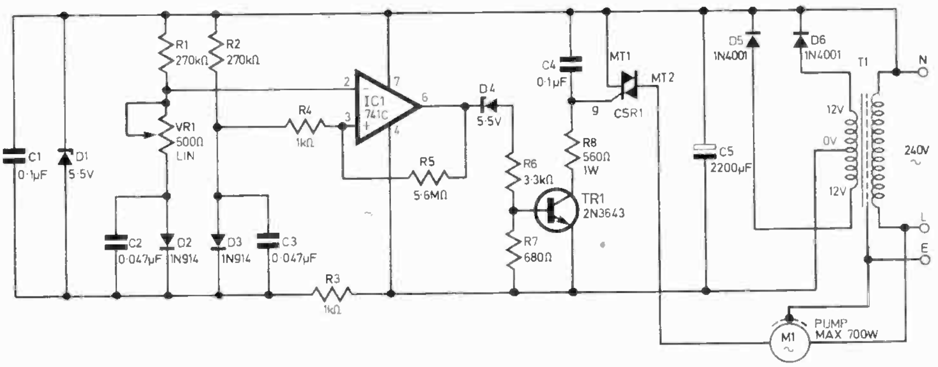


Fig. 1

This simple circuit (Fig. 1) was originally designed to control the 240 volt water pump in a solar panel heating system, where water in a heat absorbing rooftop panel is heated by the sun's radiation. The pump cycles the water through a heat exchanger (immersed in the household hot water tank), only when the panel temperature is at a preset level above the tank temperature.

Diodes D2 and D3 are the temperature sensors, which should be a matched pair, since their forward conducting voltage is compared by the circuit. Considering VR1 to be short-circuit, when the temperature of D2 (panel sensor) exceeds that of D3 (tank sensor), the voltage at pin 3 of IC1 will be more positive than that of pin 2, therefore pin 6 will swing positive, turning the triac on via TR1, and hence energising the pump.

Potentiometer VR1 allows the offset to be introduced whereby the temperature of the panel can be set x degrees C above that of the tank, before switching takes place. The maximum temperature difference obtainable is 5 degrees C. If a linear pot is used, it can be calibrated linearly from 0 to 5 degrees C. The resistors R4 and R5 provide a small amount of positive feedback to give a hysteresis of about ±0·5 degrees C, which will prevent erratic operation.

No doubt other temperature comparison applications could be found for this circuit.

P. R. Williams,
Stevenage, Herts.

SEQUENTIAL TIMER

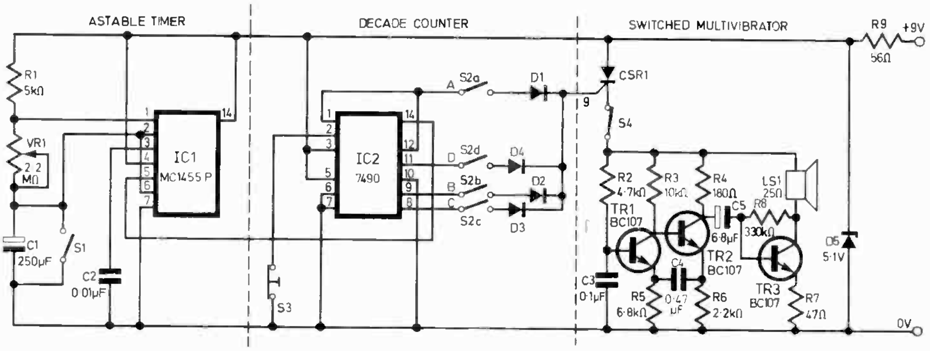


Fig. 1

In this circuit (Fig. 1), the MC1455P is set to run in the astable mode of operation. The frequency is controlled by VR1 and C1. The pulses from the astable are fed directly to a BCD decade counter. The output lines A B C D, give multiples of the input pulse period in the ratios: 1, ½, ¼, and ⅛. Thus a two minute period, when passed through the counter, becomes: 2, 4, 8, and 16 minutes, depending upon which output is selected by the switches S1a, b, c, and d. When the selected output is raised to logic 1, the thyristor is triggered. This in turn causes the multivibrator to oscillate, creating an audible note via the output stage.

The audio output may be cancelled by disabling the counter output and briefly opening S4. The other reset buttons, S1 and S3, are operated when it is required to reset the counter or discharge C1. These reset buttons enable one to reproduce a preset series of time intervals as often as is required. The multivibrator may be replaced by an external load, such as a bell or relay.

The device could prove useful in many fields where sequential timing is required. For example, the C output would give a "half-time" facility when timing games.

P. R. G. Reynolds,
Benfleet, Essex.

TOUCH SWITCH

This switch will change to the complement of its previous state ("on" or "off") each time the touch plate is touched.

When the plate is touched the Darlington triple TR1, TR2, TR3 turn on so that the input of A1 goes higher than zero logic; this will occur at a frequency of 50Hz, so therefore a 100µF capacitor is connected from ground to the input of A1 to smooth the signal.

The signal is now transmitted to A3 via A2. So therefore, the output of A3 will change from a high level to a low level every time the touch plate is touched. Hence the signal is taken to the flip flop made up of A5 and A4 and the state of this transmitted to TR4 via A6.

Transistors TR1 to TR3 can be any low power silicon devices such as BC157; all the diodes are silicon types, such as 1N4001.

N. Nazo a-Ruiz,
Wimbledon, SW20.

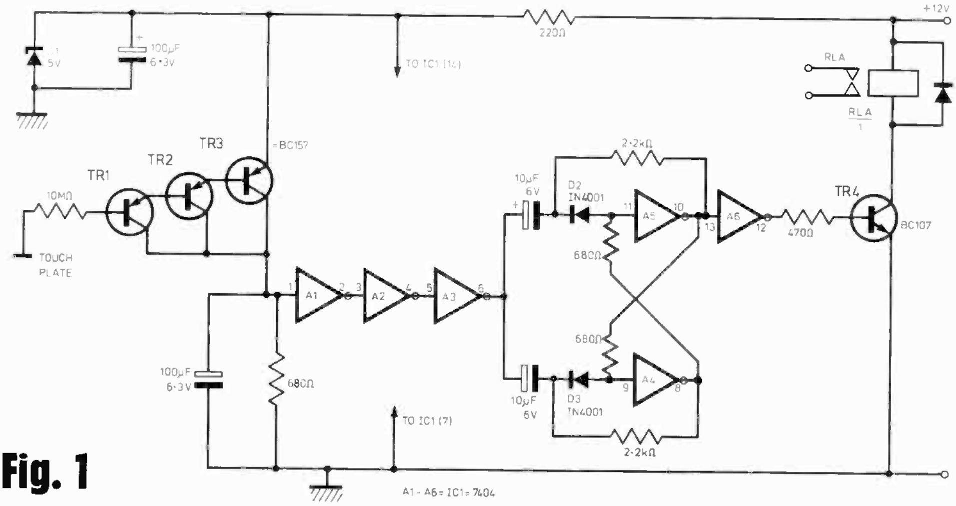
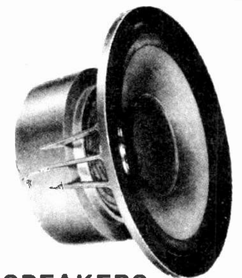


Fig. 1



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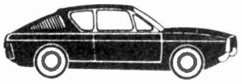

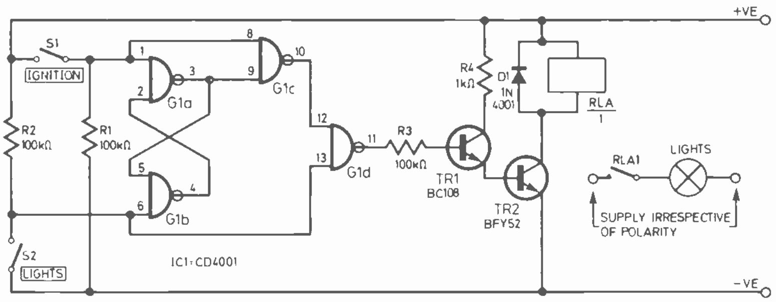

Fig. 1

Table 1

step	ignition switch	light switch	logic gate outputs G1a	G1b	G1c	G1d	Relay
1	off	off	1	0	0	0	off
2	off	on	1	0	0	1	on
3	on	on	0	1	0	1	on
4	off	on	0	1	1	0	off
5	off	off	1	0	0	0	off

Table 2

A	B	J
0	0	1
0	1	0
1	0	0
1	1	0

With dark mornings and bad visibility, drivers are prone to forget to switch their side-lights off, on arrival at work, which can of course result in a discharged battery before returning to go home.

The novel little circuit in Fig. 1 is not an alarm; in fact it goes one better by cancelling the lights automatically! Whenever the side-lights are on at the time of turning off the ignition, they too will go off, otherwise everything else remains the same.

When the lights have been *automatically* turned off, the side-light switch will be left in the ON position, and therefore, should it be desired to keep the side-lights on, they can be reset by turning the light switch to OFF and then ON again.

Table 1 shows the logic output of each gate and relay condition, step by step. The logic behaviour of the CD4001 quad NOR gate ($J = \overline{A + B}$) is given in the truth table 2. Gates G1a and G1b form a latch, and when S2 is switched off the relay is always de-energised. Transistors TR1 and TR2 are in a Darlington pair configuration to produce high enough gain to drive the relay. Potentially destructive back e.m.f. from the relay coil is shunted by D1. The original wires to the light switch should go to the contacts of RLA1. Some vehicles already have relays to operate the lights; if so, the relay shown can be left out, and the original relay driven direct from TR2.

J. W. Willis,
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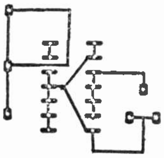

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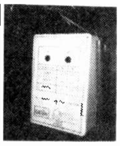

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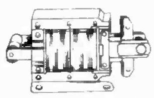

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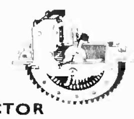

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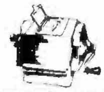

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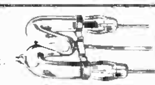

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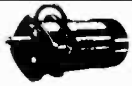
GEARED MOTORS



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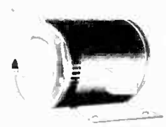

200/240V A.C. motor. 2,850 r.p.m. 480W approx. ½ h.p. Driving a centrifugal pump with 1½ inlet and outlet delivering approx. 40 gallons per min. at 10 ft. head. Ideal for pumping or circulating any non corrosive light viscosity liquid. Dozens of uses in industrial labs, etc. Note this pump is not self priming. Price **£15·00.** Post 75p.

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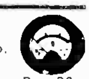

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