Practical Electronics

MAY 1966

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24-PAGE BOOKLET

TRANSISTOR GUIDE

4 AIDS FOR THE MOTORIST

- *AUTOMATIC PARKING LIGHT*
- *REV. COUNTER*
- *INDICATOR UNIT*
- *THIEF ALARM*

VOL. 2 No. 5
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Practical Electronics

SPACE FOR EXPANSION

AS a new Parliament assemblies, it will be shortly revealed whether or not our politicians really do understand the unique and potentially commanding position in economic affairs occupied by the electronics industry. For healthy growth, this key industry is dependent upon the right kind of stimulus. In the past, this stimulus has been supplied chiefly by defence requirements, but the position is now changing. Expenditure on defence projects is likely to be reduced and in any case the present trend toward interdependence with other nations would seem to curtail severely the stimulation to be expected from this quarter.

Where do we look for new stimuli—up in space, or may be down beneath the oceans? Oceanography will no doubt become an important technology in the future, but today all eyes are directed upwards.

To propose that the U.K. embark on a space programme is not to suggest that we attempt in any vain glorious way to emulate the more spectacular achievements of the two leading nations in this field. A comparatively modest programme of communication satellites, perhaps originally for our own military purposes, would stimulate our designers and provide industry with the right kind of exercise it needs to develop advanced techniques in component and equipment manufacture.

The above ideas, amongst others, have been put forward by The Electronic Engineering Association—a body representing leading firms in the British electronics industry.

The EEA has at the same time strongly supported the proposals for a European Space Programme recently announced by the Eurospace organisation. This body comprises some 160 members of European industry engaged in aerospace work. Definite recommendations by Eurospace for urgent attention are Satellite Telecommunications and Television Distribution by Satellite.

The distribution of television by satellites of the "Syncom" or "Early Bird" type has certain inherent faults. The authorities operating the very powerful receiving stations have complete control over what material they cut out from programmes relayed in their countries. This situation is however likely to change before long, immediately it becomes possible to equip satellites with a power supply of some 40kW, for example, instead of the present 40W. A domestic receiver with a conventional Yagi aerial, it is claimed, would then be able to pick up direct transmissions from the satellite without any interference.

Must it be left to the U.S.A. and U.S.S.R. alone to exploit this modern instrument for propaganda, culture, or commercial publicity; would it not be disastrous for international relationships if Europeans were denied the opportunity of broadcasting in this manner to other regions.

For the last few years we have followed the exploits in space of the two major powers. Enthralled with their achievements we have consoled ourselves with the thought that our absence from this area of endeavour was inevitable on account of our limited financial resources. But events are now moving so fast that the urgent, pertinent question has become can we afford *not* to participate in space?

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Is your car still fitted with old-fashioned semaphore "trafficators"? You can bring it up to date by changing them for flashing indicators for a very low cost. Perhaps you have the flashing type already but would like a more reliable system which does not use a bimetal strip. In either case electronic flashing is becoming popular and can boost your status symbol one step further.

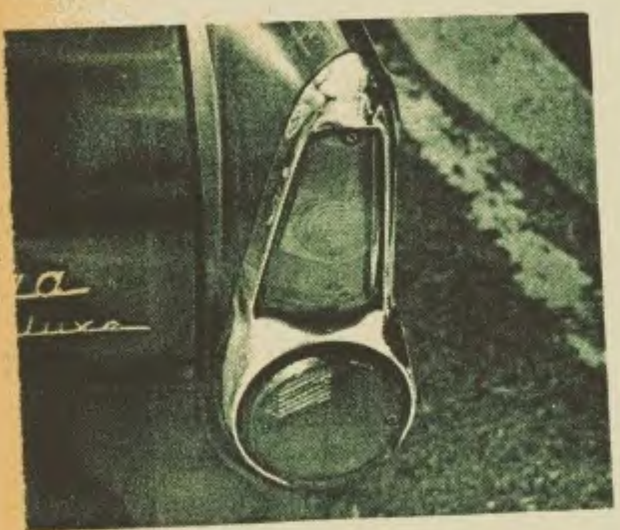
This article describes a simple economic unit which can be fitted to your car in an afternoon. One point to observe before going any further: this circuit is designed for 12 volt car electrical systems with the *negative* terminal of the battery connected to the body of the car. Modifications for *positive* "earth" systems are outlined later in the article, but it must be remembered that it may be more expensive and involve an additional relay, and possibly a modification to the lamp wiring.

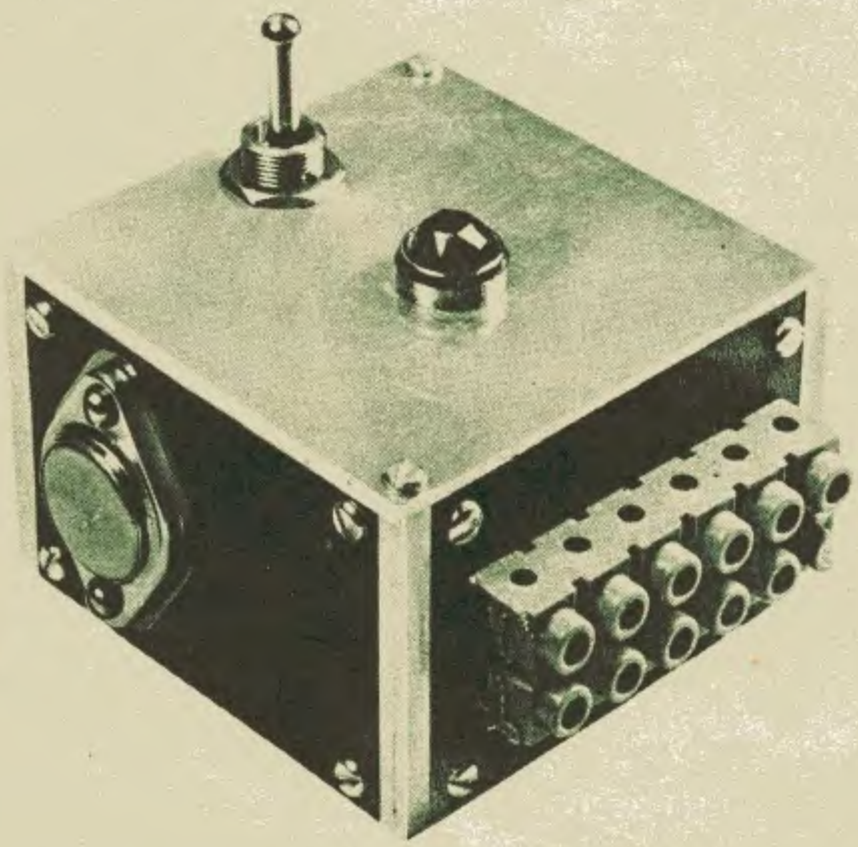
by this voltage, and a current will flow through TR3 emitter and base, TR2 emitter and collector, and the pilot lamp LP1, which lights up. A current is now triggered to flow through TR3 collector lighting the flash lamps. Switch S1 is, of course, already operated to "left" or "right" to start the circuit; most of the battery volts appear across the flash lamps.

As soon as TR2 was switched on, TR1 was cut off, due to C2 having charged up and dropping the base voltage of TR1.

Battery voltage appears across LP1, TR2, and TR3 in such proportions that, when on, there are 6 volts across the pilot lamp.

To complete the cycle, C2 discharges through LP1 and R2 until TR1 base is increased negatively switching this transistor on. The circuit will thus continue to alternate giving an on/off condition through TR2.





DIRECTION INDICATOR

by G.M. HARVEY

NEGATIVE "EARTH" SYSTEM

In essence this particular unit is based on the familiar free running multivibrator circuit (see Fig. 1). The on/off sequential action of TR2 is reflected in TR3 which is capable of carrying a high current to flash the pre-selected lamps. A transistor type NKT403 was selected for TR3, its maximum collector current rating being 8 amperes. There are many alternative types that can be used here so long as the collector current rating is within the bounds of handling the two flash lamps and the collector can operate without overheating when used on a 12 volt d.c. supply.

Let us consider an instant in the running cycle of the multivibrator circuit when the base of TR1 is clamped negatively due to the base current through R2. This transistor is hard on so that its collector is almost at battery positive potential and TR2 is switched off.

Capacitor C1 is charged to the battery voltage. TR2 and TR3 are held off for a time determined by the discharge of C1 through R1 and R3. The potential difference between TR2 base and battery positive will gradually increase negatively until TR2 is switched on

NEAT BOX UNIT

The component housing for the flasher unit is a metal box similar to that used for the parking light (3in × 3in × 2in), but in this case is well filled with components.

Holes are first made in the 3in square plate to take the toggle switch S1 and the pilot lamp LP1. These are $\frac{1}{2}$in diameter and positioned $\frac{5}{8}$in and $1\frac{3}{4}$in respectively from one edge of this plate along the centre line.

Drilling for the power transistor should be done carefully in one side, taking the dimensions from the mica insulating washer provided with the transistor. Notice that the two pins are offset and are not centrally positioned between the fixing screws. This aids identification of the connections, which are shown in the "opened" drawing in Fig. 2.

The case of the transistor should be electrically insulated from the metal box with the mica washer and nylon bushes. Good thermal contact should be maintained by using silicon grease under the transistor case. The base and emitter connecting pins must not touch the metal box.

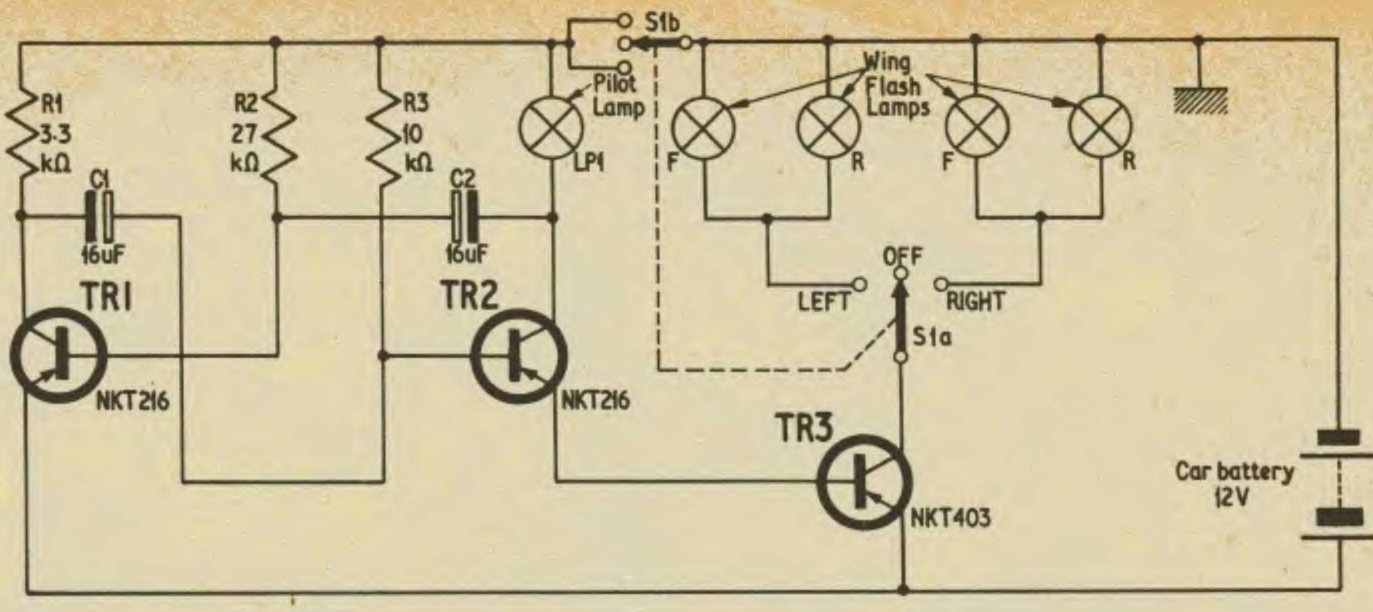


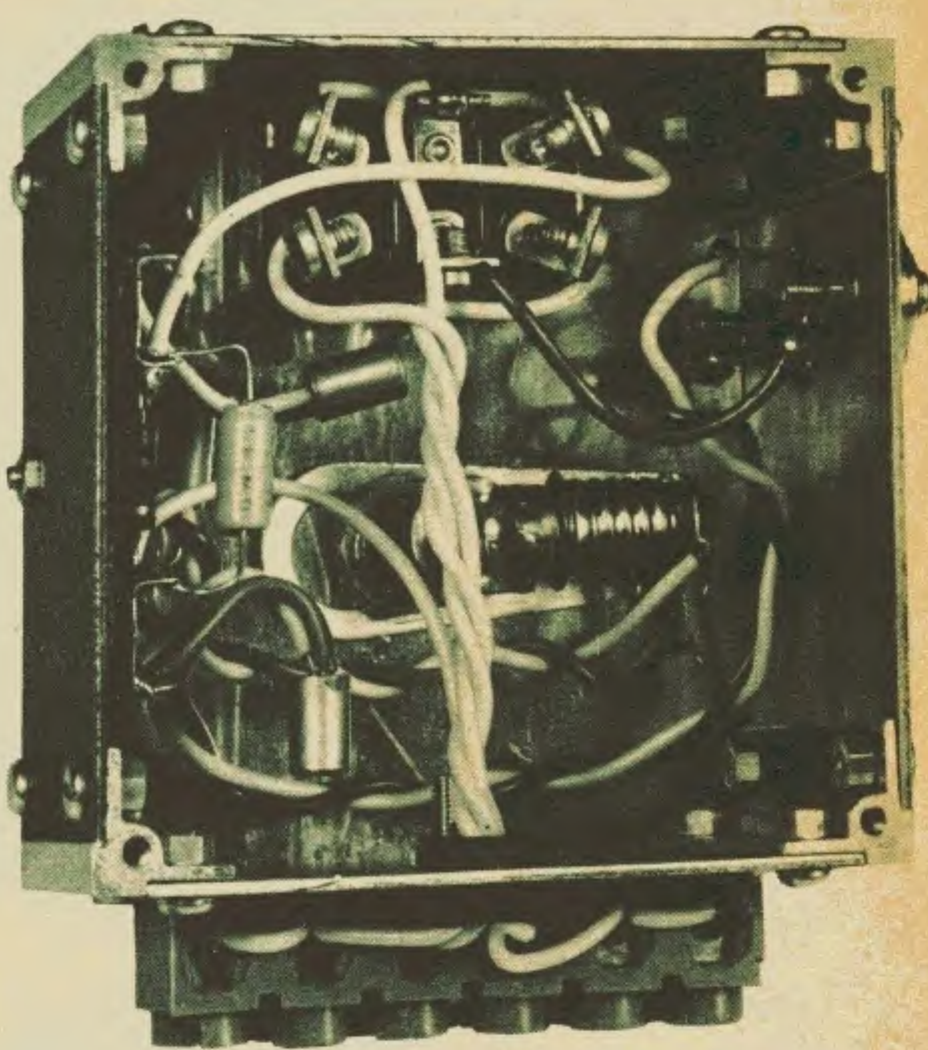
Fig. 1. Circuit diagram of a direction indicator suitable for 12 volt negative "earthed" car electrical systems only

Wires for connection to the screw terminal strip are taken through a grommetted hole in an adjacent side plate. The component tag board is mounted on the side opposite to the power transistor by fixing with a 6 B.A. nut and bolt; an insulating backing plate is used under the tag board.

It is most important that all holes drilled in the box must be clean, smooth and free from burrs, especially with regard to TR3 holes, where a puncture in the mica washer could easily cause a breakdown in the insulation.

Wiring is best carried out on the tag board before finally fitting it into the box. The prototype has seven pairs of tags and is wired according to the drawing in Fig. 2. It is advisable to keep the wires of TR1 and TR2 fairly short, then position them away from the pilot lamp when installed to avoid undue damage due to the heat from the lamp.

Flying lead connections to S1 and LP1 should be soldered in position on the tag board before it is fitted to the box, since wiring *in situ* is difficult with the limited space available. The best order in which to assemble the parts in the box is: power transistor TR3, pilot lampholder and bulb, switch, then tag board assembly.



Finished model of the direction indicator for negative "earth" systems

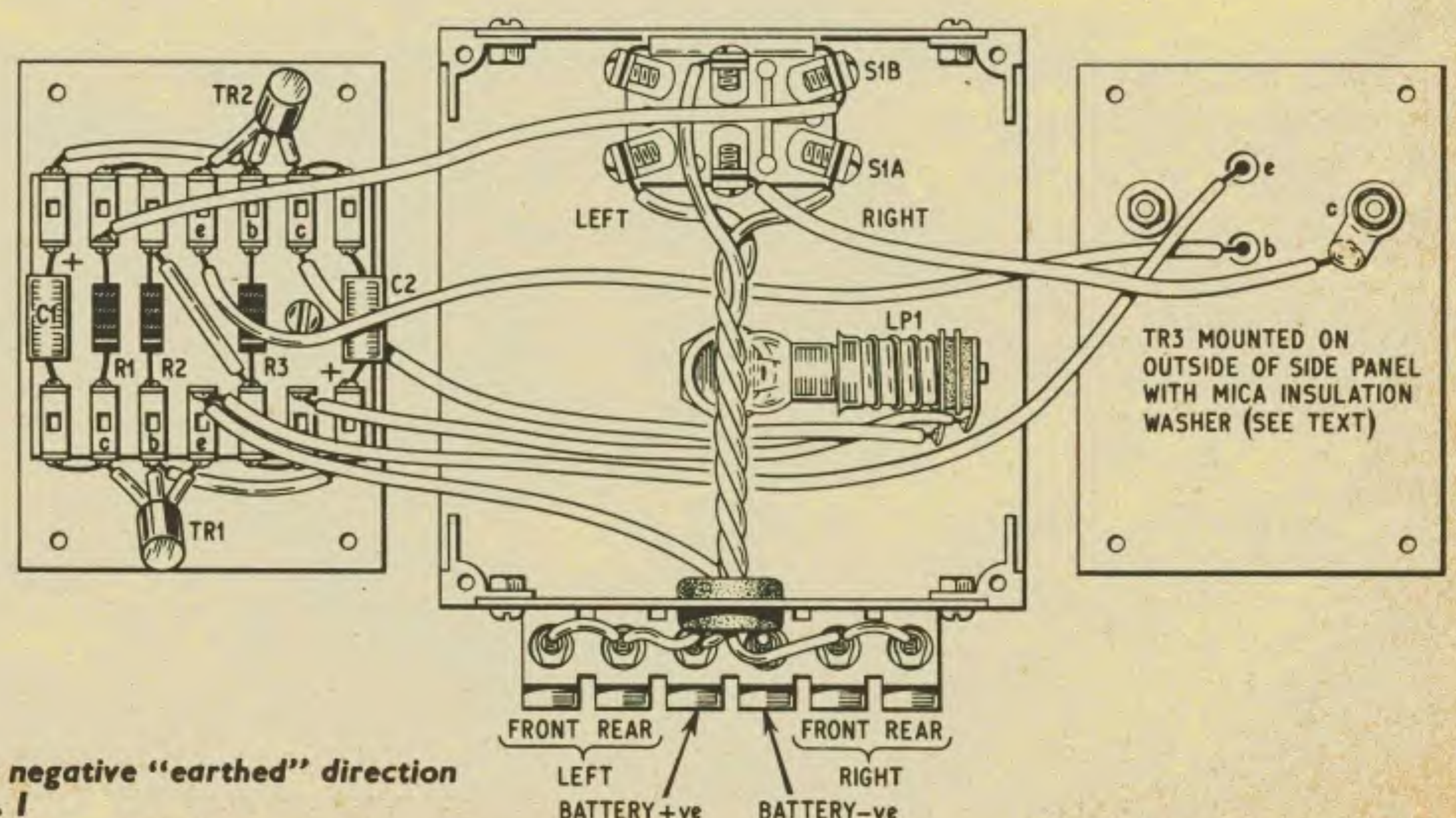


Fig. 2. Layout of the negative "earthed" direction indicator shown in Fig. I

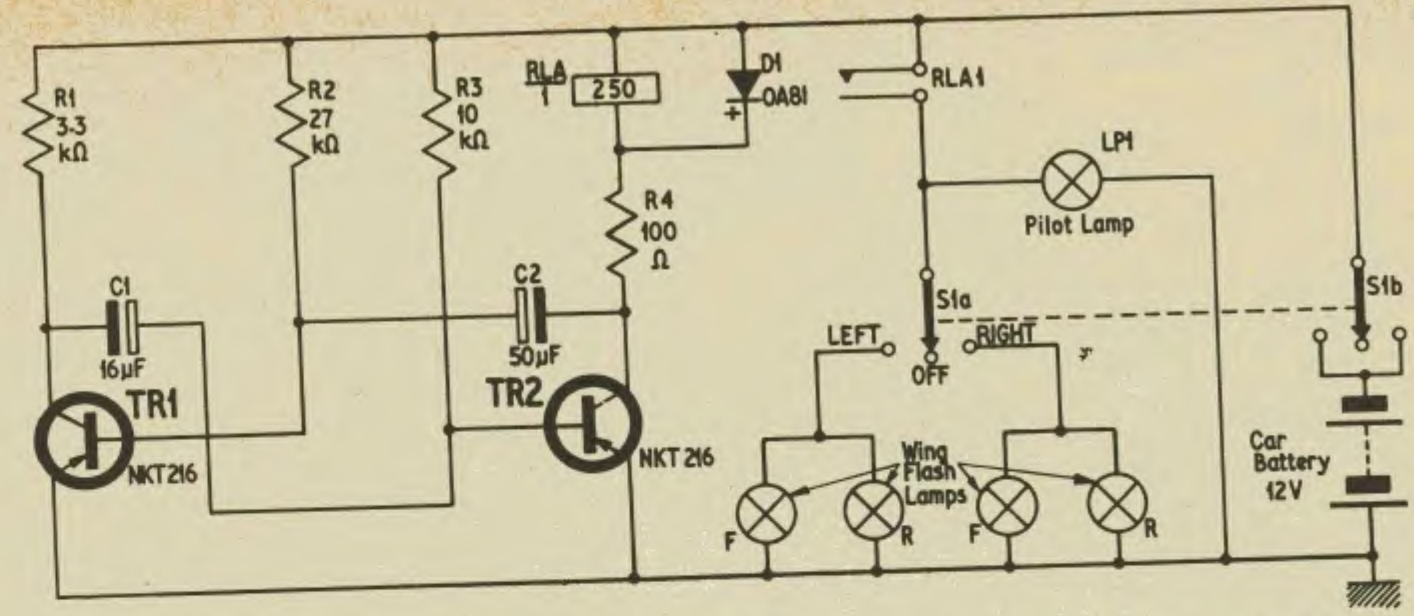


Fig. 3. Circuit diagram of a direction indicator for 12 volt positive "earthed" car electrical systems only

COMPONENTS . . .

NEGATIVE "EARTH" VERSION

Resistors
R1 3·3kΩ, R2 27kΩ, R3 10kΩ — All 10% ½watt carbon

Capacitors
C1 16μF elect. 15V
C2 16μF elect. 15V

Transistors
TR1 NKT216, TR2 NKT216, TR3 NKT403 — (Newmarket)

Switch
S1a and S1b Double pole, changeover with a centre "off" position (Radiospares)

Lamps
LP1 Pilot lamp 6V 0·04 amp with panel mounting holder and red lens
Flasher lamps as required 21 watt (4 off)

Miscellaneous
Metal box 3in × 3in × 2in pressed steel type (Home Radio (Mitcham) Ltd.)
Component tag board (7 pairs of tags) and insulating backing plate
Mica washer and nylon bushes for NKT403
Screw terminal strip, insulated, 5 amp rating
P.V.C. connecting wire
Heavy duty automobile wire for flash lamps

POSITIVE "EARTH" SYSTEM

Components as above except:
Delete TR3 and mica washer

Add **Relay**
RLA 250Ω miniature S.T.C. type with one pair of heavy duty contacts (Henry's Radio Ltd.)

Resistor
R4 100Ω 10% ½ watt carbon
See text for circuit modification

POSITIVE "EARTH" SYSTEM

It is appreciated that some readers have cars with a 12 volt positive "earthed" electrical system. It is emphasised that in this case this unit is unsatisfactory unless certain precautions or modifications are carried out. If you try the unit, as it stands on such a system, you could damage the transistors and possibly the battery.

In order to get round this problem, the simplest way is probably to isolate the lamp wiring from the car body completely. This may mean insulating the lamp housings from the car, since one connection is often made through the case and reflector.

Alternatively, the power transistor TR3 could be dispensed with altogether and the lamps connected to a relay contact assembly, which is operated by connecting the relay in place of LP1 with a series resistor of 100 ohms. The relay coil should be not less than 250 ohms d.c. resistance. It may be necessary to alter the values of C2, to achieve the correct timing, to a higher value, say 50μF.

This alternative circuit is shown in Fig. 3. The metal box should be insulated from all internal wiring so that crossed "earth" connections do not occur when fitted to the car. The relay used here has heavy duty contacts rated at 10 amperes which should handle the current required by two 21 watt flashers and a small pilot lamp. It should be capable of operating at 9 volts.

Since the circuit for this version is different from that shown in Fig. 1, the layout diagram in Fig. 2 will need to be altered to suit.

The series resistor R4 prevents the transistor drawing to much current and getting too warm. If the circuit should fail to start the value of R4 can be reduced a little, but the lower this value becomes the shorter will be the "off" period of the flash. If this is too short increase the value of C2; if too long decrease C2. ★

TRANSISTOR TESTER

By B. F. Pamplin

AMONGST the many projects undertaken by the home constructor, few are as rewarding, in the long term, as the construction of test gear. Commercial test equipment is usually an expensive item and whilst construction of elaborate instruments is beyond all but the most experienced amateurs, there are some types of instrument which can be built by the beginner providing that he is sufficiently interested and has mastered the art of soldering.

The transistor tester described here is such an item. It was originally built by the author to enable him to select transistors from a "bargain assortment" purchased at an auction, and since that time it has been used almost continually by both the author and his friends. When the set was originally built it was designed with the following criteria in mind.

1. The cost had to be a minimum consistent with reasonable performance.

2. The design had to be such that incorrect insertion of the transistor or wrong positioning of the controls could not damage either the transistor or the test set.

3. It had to be able to measure leakage and gain on both low power and high power transistors and be able to deal with either *pnp* or *npn* types.

4. Whilst not intended as a laboratory instrument it had to be arranged so that the calibration could be checked before use in order that consistent results were obtainable.

THE CIRCUIT

The circuit diagram is shown in Fig. 1. It can be divided into three separate sections.

1. The test sockets and associated test selector switches S1a–S1c which apply the appropriate connections to the transistor.
2. The battery and polarity reversal selector switches S2c and S2d which power the test circuits and enable both *pnp* and *npn* types to be tested.
3. The meter M1, together with its shunt network and polarity reversal selector switch S2a and S2b.

For the purposes of explaining the circuit we will assume that the polarity selector switch S2 is in the "NPN" position as shown in Fig. 1. With the test selector switch S1 in position "1", as shown, the emitter of the transistor under test is open-circuited, the base is connected directly to the negative pole of the battery BY1 and the collector is connected via a 390 ohm limiting resistor R3, the meter circuit and the TEST push PB2 to the positive side of the battery. Under these conditions closure of the TEST push PB2 will cause the meter M1 to read I_{CBO} (d.c. collector current with collector junction reverse biased and emitter open circuit).

Moving switch S1 to position "2" connects the emitter to the battery negative, open-circuits the base, and leaves the collector connected as before. Closure of the TEST push PB2 will now enable the meter to register the value of I_{CEO} (d.c. collector current with collector junction reverse biased and base open circuited).

Moving S1 to position "3" leaves the emitter and collector connected as before but connects the base to positive via 270 kilohms R1 and PB2. This allows a base current of 20 microamps to flow, whilst the meter M1 will read the collector current caused by this base input. In position "4" the circuit remains unchanged except that the base feed resistor is reduced to 56 kilohms (R2) thereby increasing the base current to 100 microamps.

METER SCALE COMPRESSION

One feature of the circuit which may puzzle the reader is the arrangement of components around the meter. When the unit was originally built it was necessary to use switched shunts across the meter, because when checking leakage currents the values involved were a few microamps, whereas when measuring gain several milliamps had to be measured. To avoid the use of switched shunts meant devising a meter which,

1. Would measure accurately from zero to 20 or 30 microamps, for leakage tests.
2. Would compress the scale from 30 microamps to about 1mA.
3. Would measure accurately from 1mA to 10mA, for gain tests.

The choice of an upper limit of 10mA was arrived at by multiplying the gain of typical transistors by either 20 or 100 microamps. It will be appreciated that since the upper limit of leakage current is of the order of 20 microamps and the lower limit of collector current, with either 100 or 20 microamps base drive, is around 1mA, the portion of the meter scale from 20 microamps to 1 milliamp will never be used and the fact that it is compressed and non-linear is of no importance.

The meter network shown achieves the required scale compression in a very simple manner. The collector current is passed through a silicon diode D1 and series resistor, whilst the microammeter is used with a series resistor (making it in effect a voltmeter) to measure the potential drop across these components. Fig. 2 shows the current versus voltage curve of a silicon diode. It will be seen that until a certain voltage is reached the diode does not conduct at all; as the voltage is increased the diode conducts more and more readily over the curved portion of the curve and finally as the curve straightens out the current increases at the same rate as the voltage.

When a small leakage current is flowing through the transistor under test the voltage dropped across the meter and its series resistor R5 will be too small to

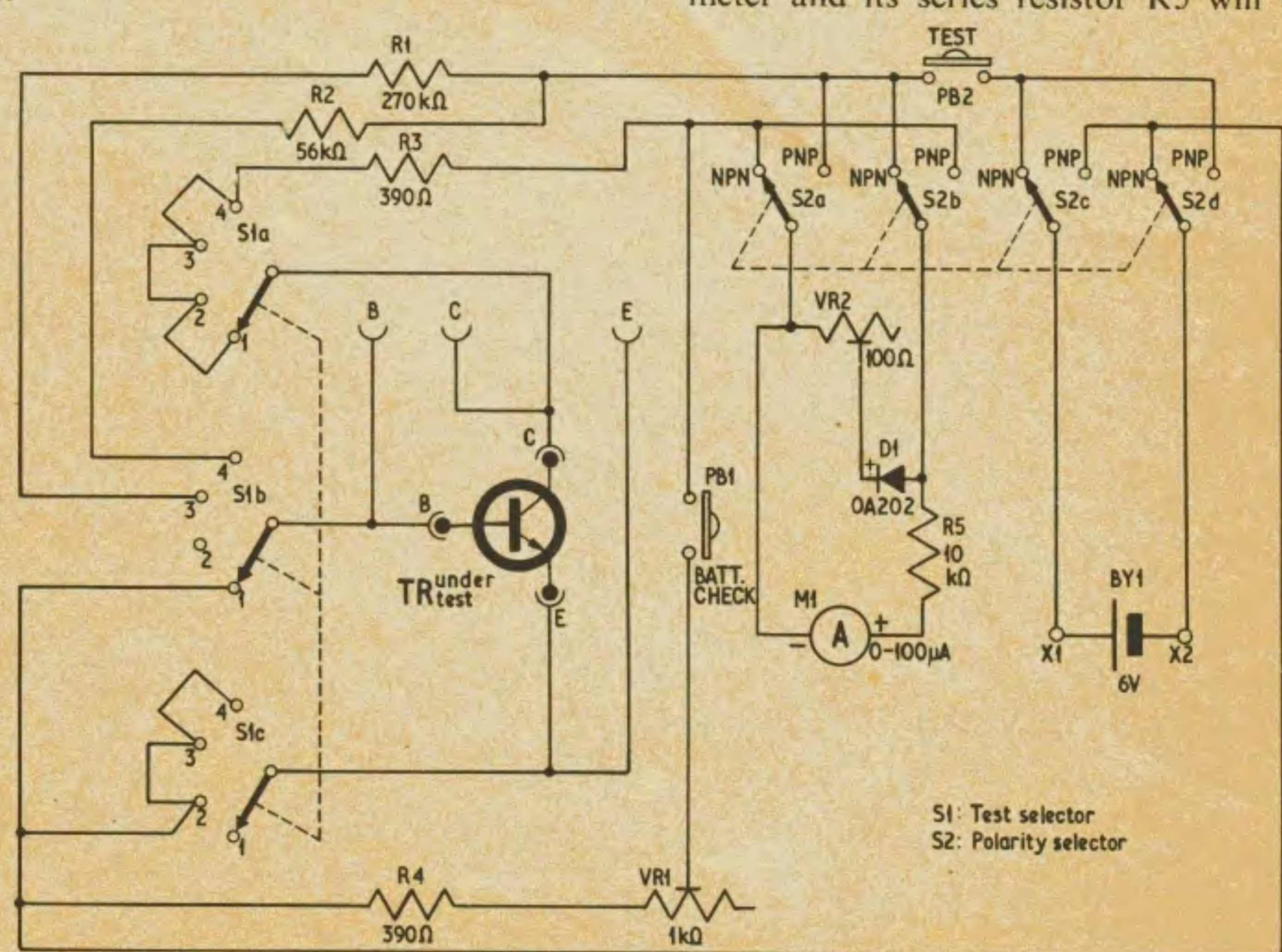


Fig. 1. Circuit diagram of the transistor tester

enable the diode to conduct. The meter therefore will act as though the diode were not there and its indicated reading will be the actual transistor collector current. As the current increases however so does the potential dropped across the meter and in consequence the diode starts conducting and shunts some of the current away from the meter. Whilst the diode is working in the curved region of its characteristic the meter reading will be compressed (i.e. there will only be a small change in pointer position for a large change in current) but once it has reached the straight portion the meter indication becomes linear again.

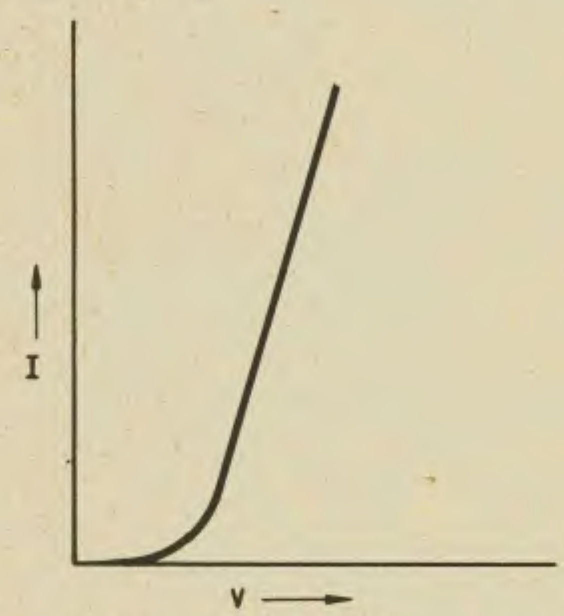


Fig. 2. The typical current vs voltage characteristic of a silicon diode

So much for the theory. The practical problem is to ensure that the compressed portion of the scale occurs over that current range which is not of interest. For the diode specified the component values shown have been found to be satisfactory, there is however scope for experiment here as will be explained later. One point to note is that if tests are made using a germanium diode instead of a silicon one it will be necessary to reduce the meter series resistance R5 because the voltage at which germanium diodes start to conduct is approximately half the value applicable to silicon devices.

Before passing onto the construction details it will be noticed that there is no on/off switch; this is because until a transistor is inserted in the TEST socket no power can be consumed from the battery, and to fit a switch would therefore be superfluous. The components R4 and VR1 are used in conjunction with the BATTERY CHECK push PB1 to enable the battery voltage to be checked before making tests. Under normal conditions of use the battery life will be virtually the same as its shelf life.

CONSTRUCTION

The choice of housing and presentation depends principally upon what the reader has available, the wiring and disposition of components being non-critical. The circuit is straightforward and the only points which require particular attention are to ensure that the meter and diode are connected with the correct polarity and that the wiring of S2 is in accordance with the diagram. If any error is made in the wiring of S2

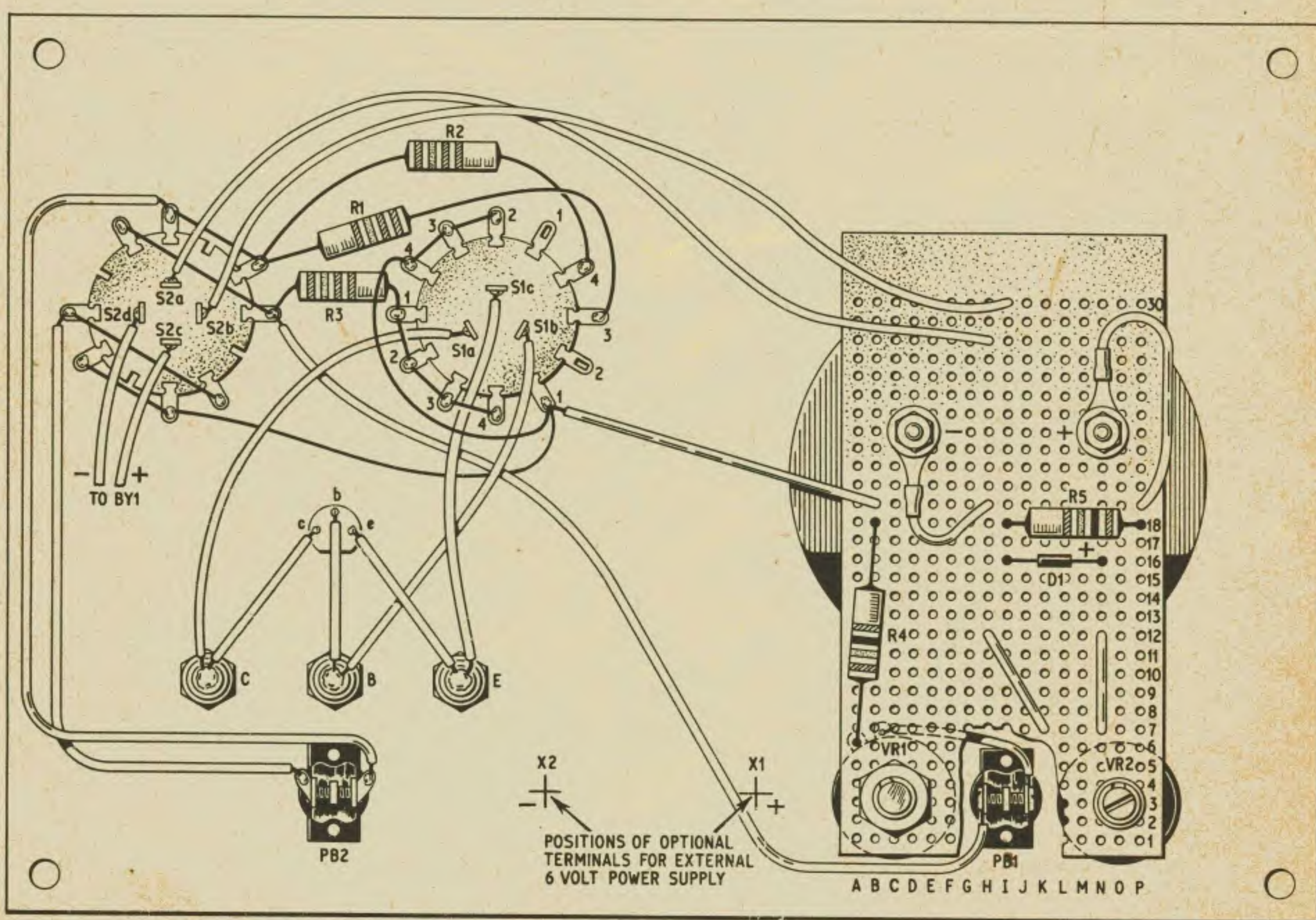


Fig. 3. Rear view of the assembled instrument showing the wiring of the front panel

no harm will result and the effect will be either that the meter reads backwards or that in the leakage test position the meter reads full scale, indicating that the potential on the transistor is reversed.

The most expensive item is the meter, but since this can be rescaled as explained under the calibration section, any ex-Government unit having a f.s.d. of 100 microamps will be satisfactory. All other components are standard items which, if not available from the "junk box", can easily be obtained from the usual retail sources.

Although appearance often takes second place to utility in "shack instrumentation" the arrangement adopted by the author of mounting all components on a black plastics panel and using *Letraset* for marking produces at low cost a very pleasing result. The arrangement of the components and wiring is clearly shown in Fig. 3. The assembled unit can be housed in a wooden cabinet as shown in the photograph.

First, prepare the front panel from a piece of ⅛in thick laminated plastics (Bakelite or Paxolin, etc.). Mount the meter, switches and sockets.

The two preset potentiometers, the diode and three resistors are mounted on a piece of Veroboard 5in × 2½in (see Fig. 4). This panel is then secured to the meter terminals. Wiring up should now be completed, including the fitting of the three resistors to the rotary switches.

The two terminals X1, X2, are only required if the tester is to be powered from an external source (see below).

For battery operation, the two leads (9 to 12 inches long) should be terminated in the appropriate snap fasteners.

A shallow wooden box should be built to house the front panel assembly and the battery. An internal depth of 3in should be adequate.

MAINS POWER UNIT

The prototype was powered from a 6V battery but there is no reason why the tester should not be mains powered via a suitable supply unit. For constructors who prefer this system Fig. 5 shows the circuit of a suitable unit. A standard 6·3V filament transformer is used, feeding into a voltage doubler circuit, the output of which is stabilised by a 6·2V reference diode D4. The two terminals seen on the front of the author's test set are for feeding such an external supply into the instrument (see cover picture).

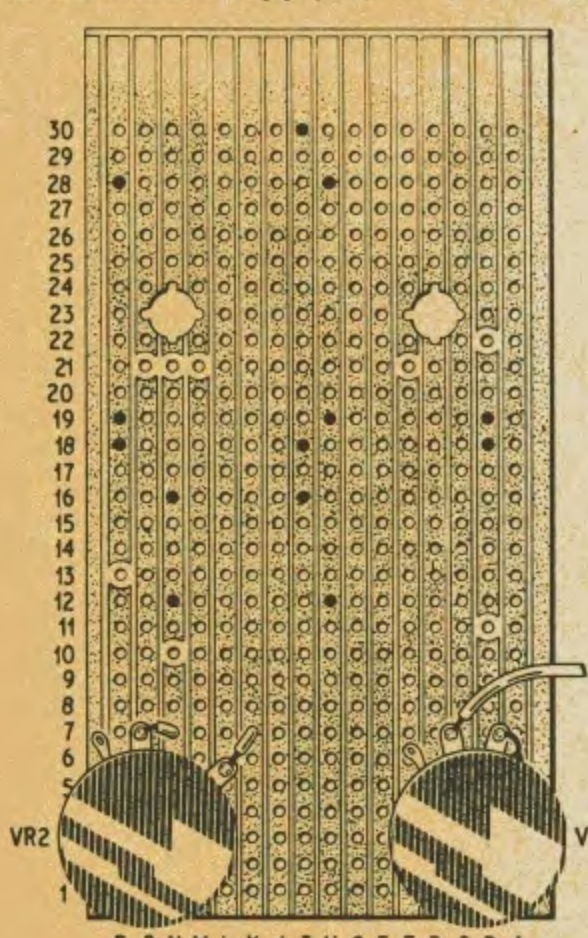


Fig. 4. The reverse (copper-strip side) of the Veroboard sub-assembly. Breaks in the copper strips must be made where shown

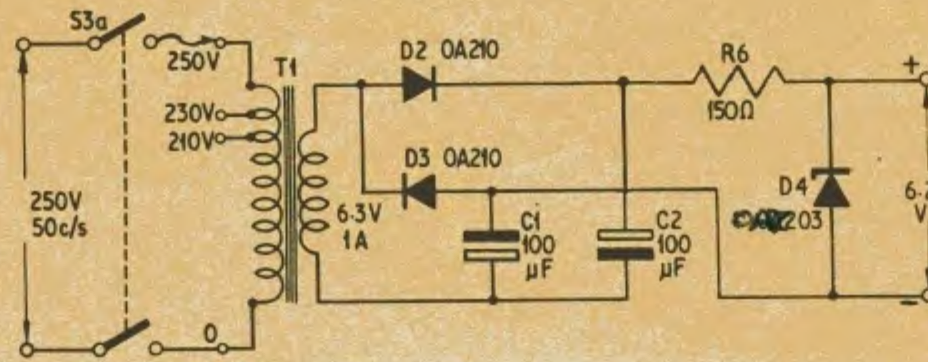


Fig. 5. Circuit of a mains power supply unit

COMPONENTS . . .

Resistors
R1 270kΩ 5% ½W
R2 56kΩ 5% ½W
R3 390Ω 10% ½W
R4 390Ω 10% ½W
R5 10kΩ 10% ½W

Potentiometers
VR1 1,000Ω linear, carbon or wire wound preset
VR2 100Ω linear, carbon or wire wound preset

Switches
S1 Rotary switch, 3 pole, 4 way, break before make
S2 Rotary switch, 4 pole, 2 position, break before make
PB1 Push-button switch, single pole, black button (Arcolectric)
PB2 Push-button switch, single pole, white button (Arcolectric)

Sockets
SK1, 2, 3 Panel mounting socket (3 off—green, yellow, blue)
SK4 Transistor holder
Plastics panel ⅛in × 10in × 7in. Piece of Veroboard 5in × 2½in. Material for case. Wire and crocodile clips. Two terminals (for external power supply—if desired)

Miscellaneous
BY1 6V battery. Ever Ready PP1 or equivalent
D1 OA202 silicon diode
M1 100μA moving coil meter, 3½in scale (or as preferred)

POWER SUPPLY UNIT

Resistor
R6 150Ω 10% 1W

Capacitors
C1 100μF elect. 15V
C2 100μF elect. 15V

Diodes
D2 OA210 Silicon rectifier
D3 OA210 Silicon rectifier
D4 OAZ203 Zener 6·2V

Transformer
T1 Filament transformer: Tapped primary for a.c. mains
Secondary 6·3V 1A

CALIBRATION

Before detailing the calibration procedure it should be pointed out that the meter can either have the scale recalibrated by the constructor or a chart can be prepared with the meter reading, normally 0–100, plotted against the actual values as determined during the calibration.

Before commencing calibration the following items are required.

(*a*) Multirange meter capable of measuring between 0 and 100 microamps and between 0 and 10 milliamps.

(*b*) 1,000 ohm variable resistor, wire wound or carbon (VRx).

(*c*) 500 kilohm variable resistor, wire wound or carbon (VRy).

The first step in the calibration is to set potentiometer VR2 so that the meter reads 10mA at f.s.d. This is performed as follows: Connect the positive lead of the multirange meter to the collector connection, connect the negative lead to one end of the 1,000 ohm resistor VRx; the other end of this resistor connects to the emitter terminal. Set the polarity switch to the "NPN" position and the multirange meter to read 10mA. Set the function switch S1 to position 2 and adjust

USING THE TESTER

The basic uses of the transistor tester are as follows.

1. Determination of whether a transistor is a *pnp* or *npn* type.
2. Measurement of collector leakage, with either base or emitter open circuited.
3. Measurement of gain with base current of either 20mA or 100mA.
4. Detection of intermittent connections in a transistor.
5. Measurement and determination of connections of diodes.

We will now deal with these tests in turn.

PNP or NPN?

1. Insert transistor into test socket.
2. Set switch S2 to "PNP".
3. Set switch S1 to position "2".
4. Push TEST button. If meter reads a few microamps the transistor is a *pnp* type.
5. If meter reads f.s.d., alter selector switch to "NPN" position and repeat test.
6. If meter reads a few microamps the transistor is an *npn*, if it again reads f.s.d. it is neither *pnp* nor *npn*, but a variety known as DUD.

MEASUREMENT OF I_{CBO}

1. Insert transistor into test socket.
2. Set S2 to appropriate position.
3. Set S1 to position "1".
4. Press TEST button and read meter direct in microamps.

MEASUREMENT OF I_{CEO}

As above, but with S1 in position "2".

When measuring the leakage current of a transistor it must be remembered that the actual value depends upon the junction temperature. In most cases the leakage doubles for every 8–10°C rise in temperature. Before measuring leakage, therefore, it is most important to allow the transistor to attain room temperature, especially if it has just been removed from a circuit with a soldering iron.

MEASUREMENT OF GAIN

1. Insert transistor in test socket.
2. Set S2 to appropriate position.
3. Set S1 to position "3".
4. Press TEST button and read meter direct in milliamps.
5. If meter reading is above 1mA multiply the reading by 50 to obtain the gain (h_{FE}) of the transistor.
6. If meter reading is below 1mA move S1 to position "4" and take another reading.
7. To obtain the gain value multiply this reading by 10.

INTERMITTENT CONNECTION

1. Insert transistor in test socket.
2. Set S2 to the "wrong" position, i.e. opposite to the transistor under test.
3. Set S1 to position "3".
4. Press TEST button. Meter will show f.s.d.
5. If the transistor is now tapped or moved, any abrupt changes in the meter reading will confirm an intermittent connection.

DIODE POLARITY TESTS

1. Insert diode into test socket across collector C and emitter E connections.
2. Set S2 switch to "NPN".
3. Set S1 to position "2" and press TEST button.
4. If no reading (silicon diode) or a small reading (germanium diode) is obtained the end connected to the collector point on the test socket is the ANODE.
5. If the meter reads f.s.d. reverse the diode in the test socket, and repeat tests 3 and 4.
6. If the meter again shows f.s.d. the diode is defective.
7. If the diode gives no meter reading when it is connected either way round it is open circuited and of no use.

VRx to maximum resistance and push the TEST switch PB2. If all is in order both the meters will register. Adjust VRx until the multirange meter reads 10mA, then adjust VR2 so that the test set meter M1 is fully deflected. Alteration of VR2 will affect the current so that several consecutive adjustments will be necessary to obtain the required condition of the multirange meter reading 10mA and the internal meter reading f.s.d.

Having set VR2, it should be locked in position and the 1,000 ohm variable resistor VRx replaced with the 500 kilohm unit VRy set to full resistance. Push the TEST switch PB2 and set the multirange meter to read 100 microamps. A reading of a few microamps should be obtained on both meters. Now rotate VRy: as the current increases both meters should track, i.e. give the same reading, until the current reaches 20–30 microamps. At this point (when the shunt diode D1 starts to conduct) it will be found that the rate at which the test meter M1 deflection increases will slow down, but as the current is further increased it starts to move again at the same rate as the multirange meter.

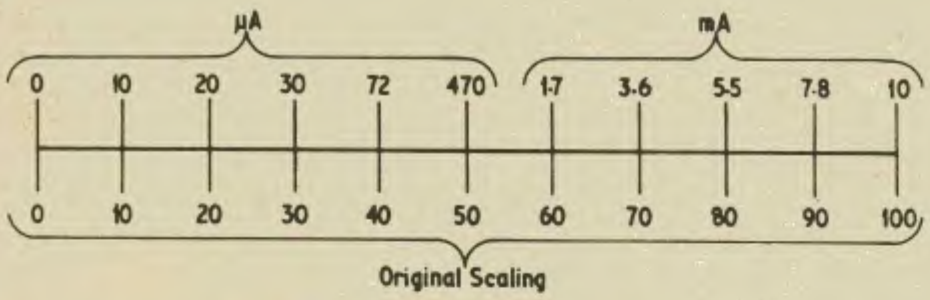


Fig. 6. Meter calibration chart

In order to prepare a calibration chart a line should be drawn as shown in Fig. 6, the bottom being divided into 10 equal divisions to correspond with the markings on the meter. If the meter scale is divided up in some other way this should be used as a basis for dividing the line. Having done this, the top of the line should be marked with the readings obtained from the multirange meter, against the corresponding points below the line, as shown in Fig. 6. This chart can either be used when remarking the meter scale or can be kept with the instrument as a conversion chart.

If a diode other than the one specified has been used it may be found that after the calibration chart has been drawn the scale has been compressed in the wrong place. If the compression starts too soon try reducing the value of R5, if it starts too late try increasing the value of this resistor. Similarly, if the compression extends beyond 1mA, increase the resistor value and vice versa.

The range of current over which compression occurs depends upon the span of voltage over which the diode characteristic is curved; the sharper the curve the more compressed will be the scale over that range.

Having completed the meter calibration it only remains to set VR1. This adjustment must be made with a new battery in circuit. Both the TEST switch PB2 and the BATTERY CHECK switch PB1 are depressed simultaneously and VR1 is set to give a f.s.d. on the meter M1 in the test set. When this adjustment has been made VR1 should be locked in position. To check the battery thereafter it is only necessary to push both switches and ensure that the meter reads f.s.d. If the stabilised power supply is fitted in place of the battery the battery check circuit can be omitted since the reference diode will ensure that the voltage remains constant. ★

Meetings . . .

THE TELEVISION SOCIETY

LONDON

Date: April 15
Title: Domestic Video Recording
W. Silvie, B.Sc., A.M.I.E.E.
(Ampex Great Britain Ltd.)
Time: 7 p.m.
Address: Conference Suite, I.T.A., 70, Brompton Road, London, S.W.3.

Date: April 21
Title: The Fleming Memorial Lecture (admission by ticket only):
"The Implications for Television of Modern Thinking on the Visual Process", by Prof. W. D. Wright, D.Sc., A.R.C.S. (Imperial College)
Time: 7 p.m.
Address: The Royal Institution, 21 Albermarle Street, W.1.

Non-members of the Society are admitted to meetings on presentation of a signed ticket obtainable from the Society's office at 166 Shaftesbury Avenue, W.C.2.

SOCIETY OF ELECTRONIC AND RADIO TECHNICIANS

LONDON

Date: April 14
Title: An Introduction to the Logical Operation of Digital Computers
B. Godfrey (Elliott Bros. Ltd.)
Time: 7 p.m.
Address: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1.

LEEDS

Date: April 20
Title: Television Studio Control Equipment
P. R. Berkley
(A.B.C. Television Ltd.)
Time: 7.30 p.m.
Address: Branch College of Engineering, Cookridge Street, Leeds.

Details of S.E.R.T. meetings obtainable from the Secretary, Society of Electronic and Radio Technicians, 33 Bedford Street, London, W.C.2.

INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

LONDON

Date: April 27
Title: Two papers on the U.K.3 Satellite
"Data Handling and Telemetry Equipment",
W. M. Lovell
"The Satellite and its Ground Checkout Equipment",
F. P. Campbell
Time: 6 p.m.
Address: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1.

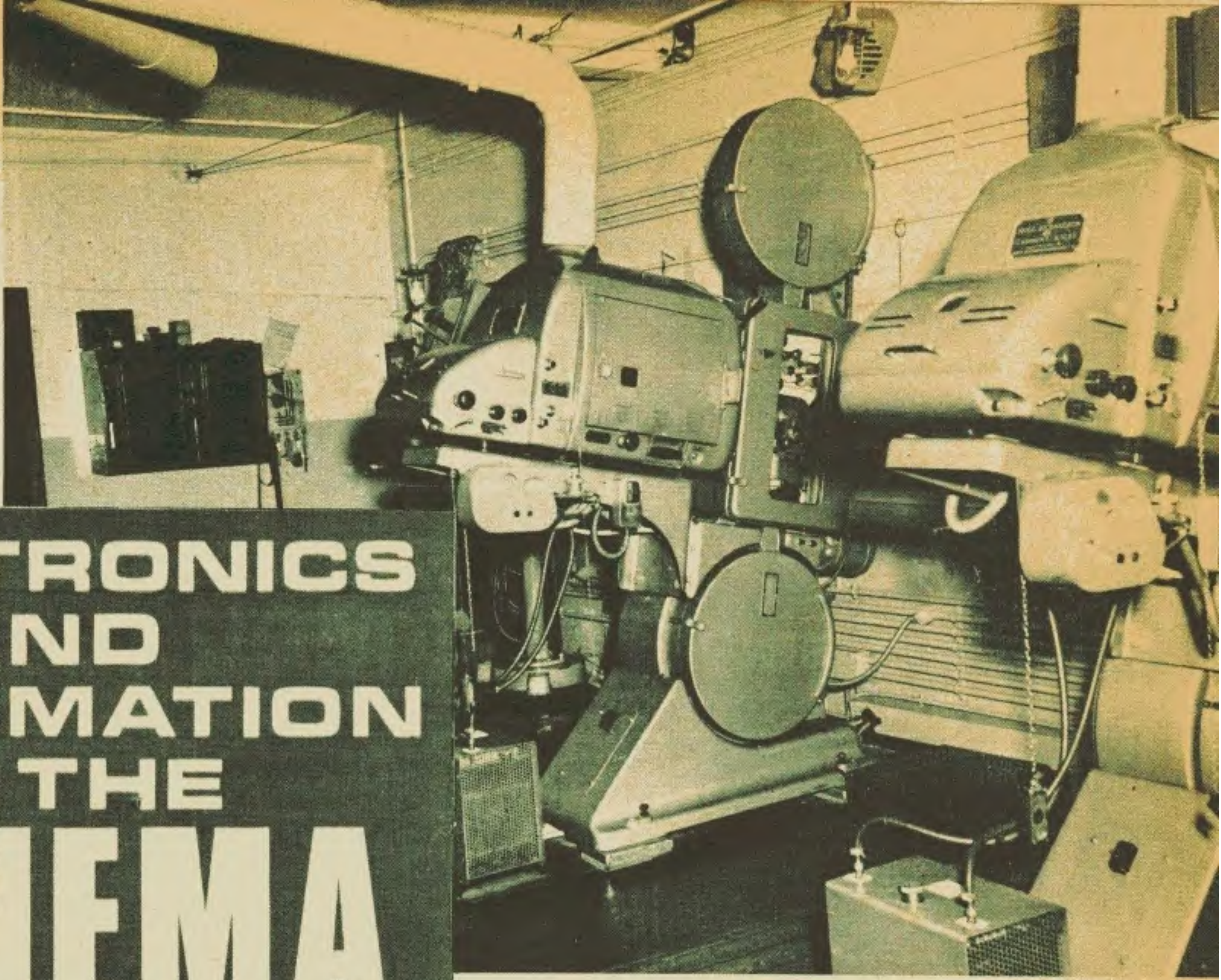
LIVERPOOL

Date: April 20
Title: A.G.M. of the Section followed by
"Colour Television by Wire"
E. J. Gargini, A.M.I.E.R.E.
Time: 6.30 p.m.
Address: Walker Art Gallery, William Brown Street, Liverpool, 3.

OXFORD

Date: April 19
Title: Hybrid Analogue/Digital Computers
C. H. Vincent, Ph.D.
Time: 7.30 p.m.
Address: Clarendon Laboratory, Parks Road, Oxford.

PART TWO



ELECTRONICS AND AUTOMATION IN THE CINEMA

BY S. SIMPSON

THE first part of this article covered the development of sound from its inception up to the time when the cinema trade took a breather and tried to recover the heavy expenditure it had faced. The "talkies" were now firmly established, screens bright—but small, sound very good—but somewhat noisy, the presentation more efficient, and theatres more comfortable.

THE CHALLENGE OF TELEVISION

All seemed well, until BBC television spread throughout the country, closely followed by ITV and, more serious to the cinema, the adoption of 21in tubes to replace the early 9in and 12in television screens.

Soon, the exhibitors sought new ways to bring back the diffident patron, reluctant to leave the comfort of his fireside and his 21in "telly". This was the opportunity long awaited by research engineers to develop radical—but expensive—ideas hitherto shelved. Now, money was flowing quite freely.

The greatest source of annoyance to the cinema patron was the comparatively small screen which, seen from the back of a 2,000-seater, looked like a postcard. To overcome this, new camera lenses were introduced which reduced the picture height, and anamorphic projection lenses which lengthened the picture horizontally; these, on the cinema screen, gave an aspect ratio of 2·5/1; the wide, concave screen had arrived, and now the patron was really in the picture.

The wide screen, however, created another problem. At one edge of a 50ft wide screen, a character might talk—but his disembodied voice arrived from the central area of the screen, 20 or so feet distant from his face; illusion suffered severely. The answer was *stereophony*, so, into the projection suite, on the heels of the new anamorphic lens came multi-channel amplifiers feeding groups of loudspeakers placed across the curvature of the wide screen. (Details of these systems follow shortly.)

MAGNETIC RECORDING

Sound quality then received attention. Some years earlier, the research engineers learned that, in 1945, the invading American Forces in Germany acquired a new method of magnetically recording sound on an iron-oxide-coated plastic tape. The immediacy of the system, its superior frequency range (50c/s to 15kc/s compared with 100c/s to 8kc/s available on film) and its low background noise were investigated; the result was the addition of magnetic tracks to tri-acetate non-flam film carrying the picture—so, on to the projectors, alongside the anamorphic lens assembly, a magnetic reproduction soundhead was fitted.

Cinerama, introduced by the Rockefeller-Times-Reeves Group, was perhaps the most ambitious effort made at that time to recapture patronage but its complications and early troubles deterred the exhibitors. The Group failed, Reeves bought up the company rights—for $1,500!—persevered, and, in 1953, inaugurated the three-projector *Cinerama* system by a showing of *Cinerama Holiday* in New York.

This system is still in use in the so-called "road shows" of big musicals where all of the equipment necessary for projection is hired with the film. It uses three projector booths, each housing one projector and, in the centre booth, the amplifier equipment also. Each projector copes with one-third of the area of the complete picture. A separate follower head, synchronised with the projectors, carries 35mil film on which seven magnetic tracks are recorded. Five tracks carry speech and music, one carries sound effects and the seventh carries cues which bring into use the required amplifiers to provide stereophony. Viewed from even a small distance, the edges of the three sections of picture appear to blend so that the junctions are imperceptible. *Cinerama* is also released on 70mil 6 track film for standard projectors and, of course, is still a wide-screen stereo-sound system.

Similar well-known systems such as *Todd-AO, CinemaScope, Vista-Vision, Perspectasound, Superscope,* all use variants of four fundamental conditions, namely 70mil film, 35mil film, magnetic sound, or optical sound.

It seemed that the cinema had reached the ultimate in perfection, but a peculiar problem remained. Unless the projectionist remained in the auditorium for several minutes, he could not be sure that the stereo system was operating correctly. On the other hand, Home Office regulations (until recently) did not allow complete vacation of the projection suite. How, then, could a lone projectionist check the system? A national shortage of trained projectionists (many having transferred to other employment in recent years) gave added point to the question.

AUTOMATION ARRIVES

Automation answered these problems and has proved so successful that the Home Office regulations have been greatly relaxed. How an automated cinema operates is perhaps best told by describing the *Projectomatic* and *Cinemation* equipments installed in the Dual-Odeon Theatre in Nottingham; this double cinema is operated by the Rank Theatre Division and was commissioned in July 1965.

Projectomatic, an extensible automation system, has been used by the Rank Theatre Division in many of its cinemas for a considerable period. The system can be confined to sounding a warning prior to changeover between projectors, striking the arc (or Xenon lamp, if used), starting the incoming projector, changing over to the picture and sound provided by the incoming projector, then stopping the outgoing projector, all without manual operation of any kind. It can be extended to control opening and closing of proscenium curtains, control of proscenium lighting, starting and ending a non-sync programme, and sounding an alarm at strategic points to recall the projectionist if an emergency arises in any of these services, or in the projection equipment. This limited amount of automatic control was so widely welcomed that extensive research was undertaken by Essoldomatic Ltd. (a company in which the Rank Organisation has an interest) and led to the development of *Cinemation,* a system which places in one console the control of the day by day house functions and programme presentation.

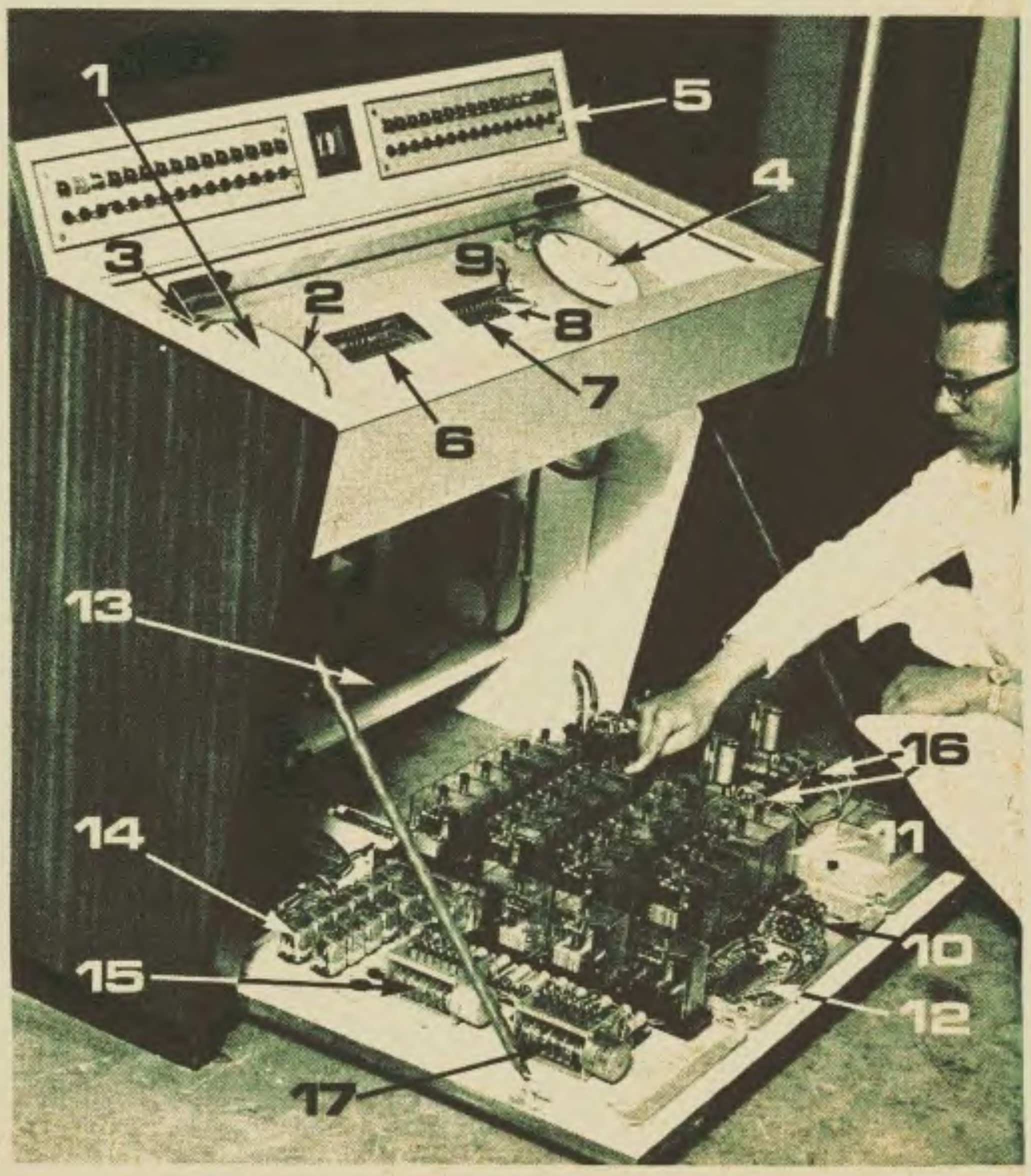
The *Cinemation* console (Figs. 4 and 5), carries two individual timing systems, one controlling the entertainment, the other controlling the house, e.g. interior and exterior lighting, heating, air conditioning. The house facilities are timed by two concentric discs (*1*) in Fig. 4; one controls the theatre on six days, the other (on the right of the console) on the seventh. The larger disc is calibrated in 5 min intervals throughout 24 hours; the smaller in 1 min intervals over one hour for time-correction. Each disc is driven by a synchronous motor in a manner similar to a typical electric clock.

An action, e.g. exterior lighting, is initiated by a trigger (*2*), set into a slot cut into the periphery of the hours disc. The disc carries the trigger under a lever (*3*) which operates a microswitch (not shown). The microswitch causes operation of a 24-way unidirectional rotary switch (*10*) (see Fig. 6), whose contacts pass current to one of two solenoids and to the heavy-duty contacts on one of several latching relays (*11*). (Two solenoids are necessary on a latching relay, one to close its contacts and to mechanically lock the relay so that the contacts remain closed although the solenoid circuit is broken; the other unlocks the relay.) The relay contacts close the circuit to a non-locking contactor or similar equipment which causes the required action.

The programme set up on the six-days disc is repeated until, at a few moments after midnight on day 6, a pin set into the microswitch actuator mechanism lifts the actuator, thus inhibiting switching by the six-days disc and transfers switching operations to the day 7 disc (*4*) previously set up for the required changes in routine.

Versatility is provided by distribution blocks (*12*) carrying the terminations of the latching relay solenoids. The blocks provide simultaneous closing of several circuits, opening of circuits, or opening *and* closing of circuits. For example, one trigger will switch *off* overnight police lights, switch *on* hall-cleaners' floodlights, and start the heating system. Additional flexibility is obtained by bringing the remote equipment terminations to a distribution board (*13*) also in the console; here, a particular timing can be transferred from one operation to another. Any one or more of these operations can be advanced in time, retarded, or inhibited by "centre-off" toggle switches (*5*), placed in a row on the sloping panel of the console; thus, manual control is always available.

Fig. 4. The Cinemation console with front panel lowered for "instant servicing". Principal items of the equipment are identified in the text



HOUSE PROGRAMME

A typical day's programme is in use in the Twin-Odeon Theatre and comprises, police lights off and cleaners' lights on; extractor fan, air-filters and air-washers on; vestibule lights on; hot-water circulator pumps on; accumulator charging plant on; secondary lighting systems on. (About this time, the theatre is ready to begin the day's business.) The programme continues: foyer spotlights on; Projectomatic system power plant on to supply power for amplifiers, etc. in the projection systems controlled by *Cinemation*; neon signs on; canopy lights on. (Shortly after this action, the film programme commences.) Foyer-lighting changes begin (to a continuously-blending, slow-changing colour scheme). No further house actions occur until the evening performance has ended, when interior floodlights are switched on, and a safety check is made in the theatre. The final actions of the day are, first, an overall "search" to release all unrequired actions and then the switching on of police lighting.

Automation of house functions such as these have been welcomed by all grades of theatre personnel, from the manager, who, on a prearranged signal, leaves office business and is present in the foyer when patrons are "mobile", to the cleaners who come into an already-lit hall and find ample hot water for their tasks. Above all perhaps, by the projectionist, now free wholly to attend to presentation of the entertainment.

The second timing system in *Cinemation* deals with such presentation and is set up by the projectionist for each change of programme.

ENTERTAINMENT PROGRAMME

The equipment comprises two drums (*6*), perforated in rows and driven by pulse motors. Pulses to drive the motors are obtained from a transistorised capacitor charge/discharge circuit; each discharge of the capacitor into the motor is initiated by a pulse obtained from the projector as follows.

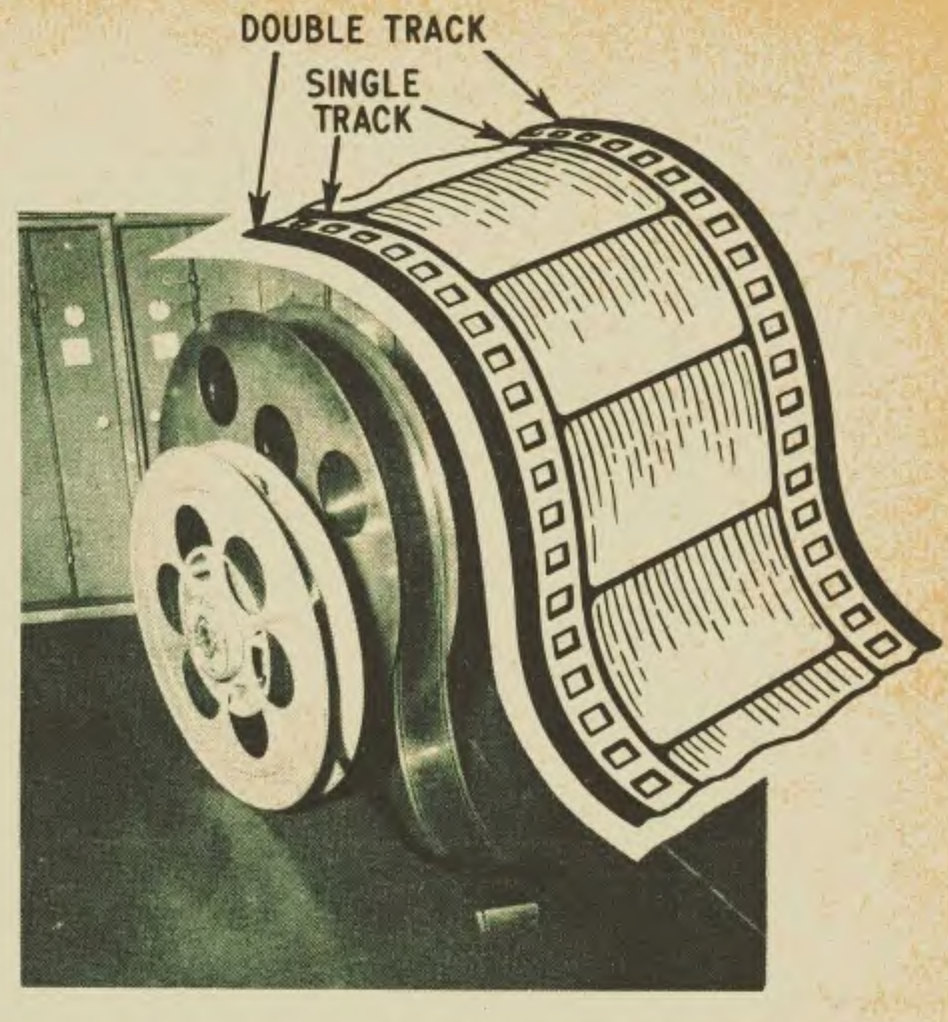


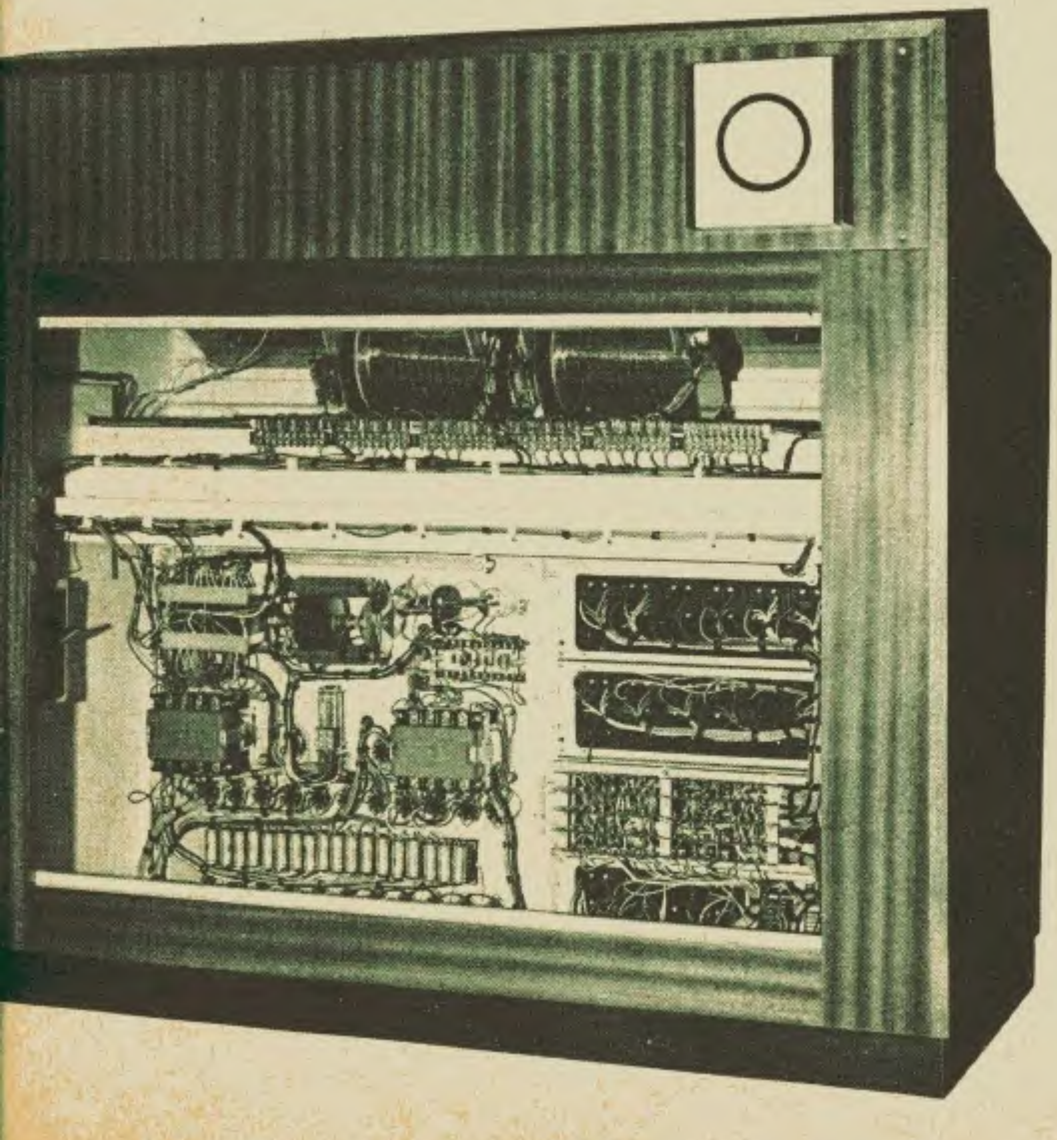
***Fig. 6.** A reel of 35 mil film seen alongside a reel of 70 mil film used in the production "Sound of Music" (Todd-AO). Note the six magnetic tracks as indicated in the accompanying line drawing*

On receipt of the film, the projectionist attaches to the edge of the film, clear of perforations, a number of "triggers"; these are small pieces of adhesive metallic foil. Taking the action of one such trigger, it passes through the projector and eventually in front of a small unit containing a pea lamp and an OCP71 photo-sensitive transistor. The trigger reflects infra-red rays from the pea lamp into the transistor, thus causing a sharp pulse which, although too short to permit operation of the pulse motor system, is stretched by transistorised circuitry for that purpose. (White objects, etc. such as opaque film used in joining subjects cannot operate the pulse unit; only a metallic surface transmits the required light spectrum.)

The drums, having stepped once, carry one of several pins (*8*) inserted into the perforations on its surface under a tongue (*9*) which operates a micro-switch. These microswitches (one to each row of perforations) operate pulse relays (*14*) which electronically close contactors, etc. or buzzers located at remote locations; two microswitches are reserved for motor-driven timers (*15*) which set the projectors in operation. It will be seen, therefore, that the projectionist arranges not only the order of films to be shown, but also the order of triggers to signal personnel, close curtains, light up interval illumination, switch to "non-sync." music (generally on tape).

Contained in the *Cinemation* console circuitry is a self-pulsing system (*16*) whereby the drums can be stepped independently of triggers. The self-pulse function is switched in manually and will drive the step motor for as long as required. This self-pulse function can also be triggered by a series of pins set into a certain row of perforations around the drum, each pin then operating a microswitch in parallel with the manual self-pulse switch. Thus, at the end of the evening, a

***Fig. 5.** Rear view of the Cinemation console. The two drums used for the entertainment programme ("6" in Fig. 4) can be seen more clearly in this photograph*



row of such pins will rotate the drum up to a break in the row. One step more will begin the entire trigger-controlled presentation programme; this step is provided by operation of the manual self-pulse switch.

A TYPICAL ROUTINE

We can conclude this article by watching how the *Cinemation* system operates the projector and, simultaneously, have a look at an ultra-modern projector as used in the Dual-Odeon Theatre. We begin by assuming that the first performance has ended and the projectionist is preparing for the next. Curtains have been closed and floodlit, the non-sync. is providing music to the auditorium and to the foyer; the new audience is entering the auditorium.

In the projection suite the projectionist fits a 6,000ft reel of film into the upper magazine (which can accept 12,000ft) and laces the film through the firetrap. (Fire is a much smaller risk now that tri-acetate non-flam. film has largely replaced highly inflammable nitrate film, but the trap remains as an additional safeguard.)

The film now passes around drive sprockets carrying four rows of teeth, two to drive 70mil film and two, slightly shallower, to drive 35mil stock, then into the magnetic-reproduction head via dashpot-actuated

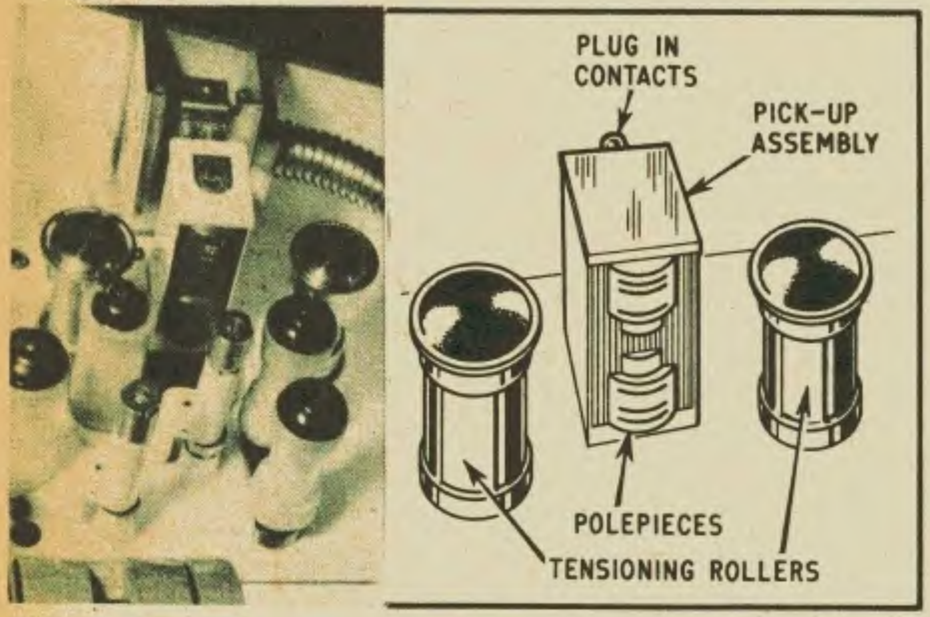


Fig. 7. A view of the magnetic sound head as incorporated in standard projectors for systems such as Cinerama and Todd-AO. The polepieces of the six heads are shown in the detail drawing on the right

tensioning rollers. In the head, the film (assumed *Todd-AO* 6-track magnetic) passes around a drum damped by a spring-loaded, heavy flywheel. The drum holds the recordings in contact with six reproduction heads on one side of a rotatable bracket; the other side carries four heads for use with other, four-track film.

From the magnetic head, the film is passed into the air- and water-cooled projection gate, and the gate is closed against a mask-plate. (The mask-plate has a variable-area aperture to cope with *CinemaScope* and *Todd-AO*. Change of aperture area can be either a manual or an automatic operation; adjusting ("framing") the film in the aperture is also manual, but can be remotely controlled. In the projector under consideration (the Italian *Cinemeccanica*), a second set of gate plates to cope with other frame areas can be substituted in a matter of seconds.) The conjunction of air- and water-cooling in the gate, together with a dichroic mirror plus heat extraction by air-suction in the lamp-house, keeps the gate remarkably cool and well below film-buckle level, even at the end of a long run.

The solenoid-operated shutter, which covers the film aperture until projection is required, is manually closed by the projectionist who then passes the film around the intermittently-operated pull-down sprocket. The next system in line, the optical soundhead, is bypassed and the film proceeds to a "safety" roller. Before considering the safety roller, let us look at the optical soundhead. This comprises a drum of approximately 4in diameter whose body is fixed, but whose flanges, of slightly greater diameter, can rotate and are damped by a heavy, spring-loaded flywheel to give constancy of motion and absence of flutter. Inside the fixed body is a photo-electric cell, and externally fitted, opposing a slit in the body, an exciter lamp in a housing. The path of the film around the drum places the sound track in front of the slit, so causing the necessary modulation of light in the photo-electric cell whose output passes to a pre-amplifier.

FILM-FAULT ALARM

The safety roller immediately preceding the take-up spool is in effect a centrifugally-operated micro-switch which, when the projector has run up to speed, takes over a hold-on circuit maintaining the projector in service. Because the roller is driven only by the film, a break, or a serious slowing down of the projector, causes the microswitch to operate *Cinemation* circuits which shut down the arc and the projector motor and activate a radio transmitter whose "recall" bleep is received by a pocket-pencil radio carried by the projectionist wherever he may be in the theatre; it also rings alarm buzzers at strategic points.

From the safety roller the film passes to the take-up reel and thus completes its path through the projector. At the arc-lamp, the projectionist fits new lengths of copper-clad carbons (which consume 105 amperes at 55 volts) and between the tips of these, a ¾in length of fusible copper sleeve, then adjusts the carbons to grasp it firmly. Finally, the air-cooling, water-cooling and heat extraction systems are started, and the projector is ready for automatic starting by *Cinemation*.

At the *Cinemation* console, at the minute of starting the second performance, the projectionist operates the self-pulse switch once to cause the next pins in the series on the drum to step under the microswitch actuators. One microswitch causes remotely-placed dimmers to extinguish the lighting and the other inserts the self-pulse circuit. The automatic self-pulse circuit continues to step the drum which eventually initiates the "curtains open" sequence and simultaneously, because of horizontal placing of pins, the "projector start" sequence, both of which are completed in a few seconds.

RUNNING-UP THE PROJECTOR

The "projector start" signal sets into operation a motor-driven, cam-operated series of switches (*15*). The first cam closes a hold-on for the switch motor; the second rings a warning gong in the console (quietly!); the third operates a "slow-start" unit controlling the projector motor; the device, by sequential operation of contactors, removes one after another a resistor from each of the three phases of the motor power supply. The effect is to give the projector a very smooth, high-torque start; it also prevents lagging by the large take-up spool which might otherwise allow bellying of the film with subsequent snatching when the spool catches up. The fourth closes contactors for the 3-phase rectifiers feeding the arc, and almost simultaneously, applies the rectifier output to fuse the pellet between the carbons; the pellet falls from between the carbons but leaves the arc flame in operation.

The fifth cam opens the solenoid-controlled light cut-off covering the incoming projector gate and simultaneously closes the light cut-off on the second projector. Also simultaneously, by relay action in the sound changeover unit adjacent to the projectors, the sound output from the incoming machine is connected to the amplifiers. A sixth cam provides a clear-down of all circuits controlling the second projector when it has been in use. Finally, a seventh cam searches all circuits affecting the second projector to ensure that none is still operational. If this is not so, the search relay breaks a master holding circuit which shuts down both projectors and also transmits the radio "recall" and buzzer signals to signal a "fault" condition. The operation of the seventh cam completes the projector start sequence and the programme is now under way.

The "triggers" on the film, towards the end of the run on projector No. 1, will bring into operation No. 2 by the same sequence of actions, but controlled by a second motor-driven timer (*17*). Transfer to No. 2 projector of the safety sprocket alarm circuits is made by a latching relay operated by the same pulse which opens the projector light cut-off on No. 2.

CHANGE OF FILM SYSTEM

Where a change of aperture size and accompanying lens change is required (when, for example, about to run from a wide-screen "short" to a *CinemaScope* "feature"), a trigger on the "short" steps the *Cinemation* drum to three paralleled pins. One closes the solenoid operated light cut-off, one controls the curtains and floodlights as described for intervals and the screen masking; the third operates a circuit which drives a motor forming part of the lens turret housing. The housing slowly rotates through 180 degrees. Just prior to being halted by a mechanically-operated microswitch on the turret assembly, a stub on the rotating housing trips a tongue adjacent to the gate and, by a spring-loaded lever, moves the aperture masking plates to the required position.

The *Cinemation* pulse, put briefly, closes curtains, raises floodlights, changes the screen masking area, and changes to the appropriate lens and area of masking plate. Another "trigger" on the still running film then opens the solenoid operated light cut-off and the programme continues with the differently-shaped picture format.

RADIO CONTROL

Volume level, picture framing, and focusing are manually operated controls at the projector; they can also be controlled from any part of the auditorium by a small radio transmitter carried by the projectionist.

This unit provides focus, framing, volume, and manual shut-down control facilities by push-buttons. Each button controls an individual tone which is picked up by a receiver located in the projection suite; filtering directs the tone into the relevant "action" circuit. The lens adjustment is motorised to operate in two directions, as also the framing movement; the volume control is similarly driven. The manual shut-down releases the projector holding-circuits within the console. Receiver and transmitter are transistorised and, since the transmitter is driven by a rechargeable battery, it is "stowed" when not in use in a wall stand carrying two contacts which automatically feed a trickle charge to the battery. The receiver is mains driven.

Correction

In Part 1 of the article (see page 247) the output of the amplifier used in the early days was quoted as 500W. The figure should be 50W.

In the caption to the illustration on this same page the projector was described as a Western Electric assembly; it is, in fact a Kalee projector mounted on a B.T.H. base. The principles of operation in either equipment is similar.

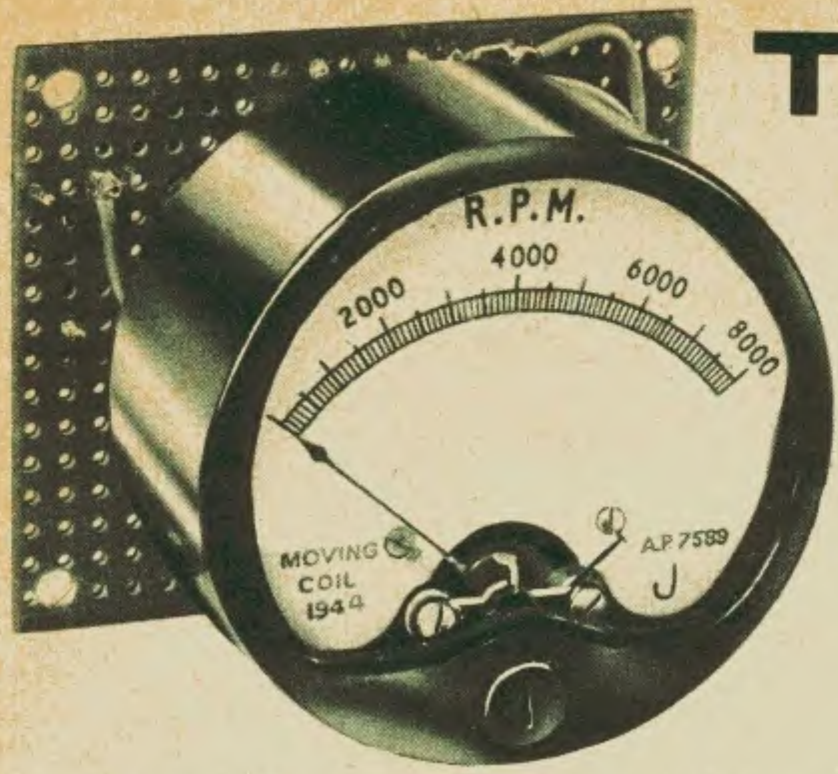
ACKNOWLEDGEMENTS

Because of space requirements, much information has been left unsaid, but it is hoped that a general picture has been presented. It should be noted that the first part of this article is based on American sources of information. This will probably explain minor differences obvious to those possessing prior knowledge of the cinema. Finally, the author gratefully acknowledges the help and facilities provided by Rank Theatre Division; Essoldomatic Ltd.; Palace Cinema, Leith; and Odeon Cinema, Edinburgh, in the preparation of this article. ★

INDEX

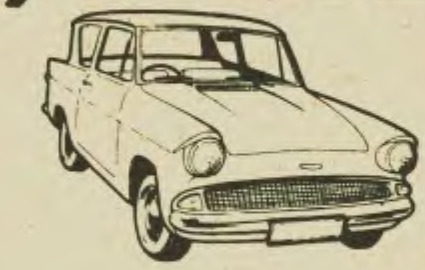
An index for volume one (November 1964 to December 1965) is now available price 1s 6d inclusive of postage.

Orders for copies of the Index should be addressed to the Post Sales Department, George Newnes Ltd., Tower House, Southampton Street, London, W.C.2.



TACHOMETER

by P. G. SELWOOD



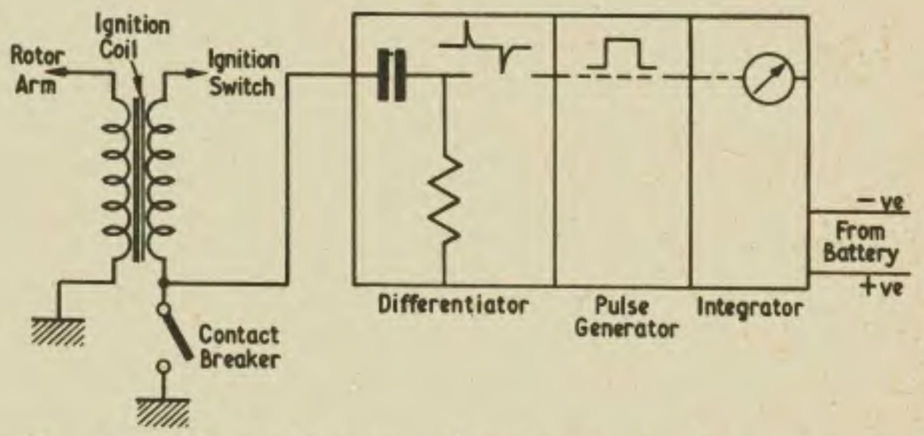


Fig. 2. Block diagram showing how the tachometer operates from the ignition coil

An increasingly popular requirement of almost any motor car is a facility for monitoring the speed of the engine. Some modern cars are fitted with such a facility in the form of a revolution counter or tachometer. This can be either a mechanical device or the more reliable electronic device such as that described in this article.

It has been designed for use with a 12 volt car battery with positive connected to the car body.

CIRCUIT

The circuit diagram is shown in Fig. 1, but for discussion purposes it can be seen best in block form (Fig. 2). The input to the tachometer is taken from the contact breaker side of the ignition coil. An almost square waveform is produced by the contact breakers; the frequency is the number of times the contact breaker makes and breaks per second, which is governed by the speed of the engine.

This square wave is differentiated by a resistance capacitance network made up from C1 and the input impedance of TR1. The "spiky" pulse obtained ensures reliable triggering of the pulse generator circuit which is a monostable multivibrator. Although a differentiated square wave gives one positive and one negative spike per cycle, the pulse generator is only triggered by the positive spike. A square output pulse is obtained from the multivibrator but its amplitude and duration depend only on the time constants within the circuit.

The meter performs the action of a pulse integrator and shows the average current passing through the collector of TR2. This average current is proportional to the output pulse repetition rate. If this rate doubles then the current through the meter will double.

CONSTRUCTION

As the circuit uses relatively few components it can be constructed quite easily on a small component assembly board. The meter can be any shape or size to suit the constructor, but in the prototype a 2½in diameter circular meter was used and the tag board was fixed to the meter terminals (see photograph and Fig. 3). The physical size of the meter is not important, but when purchasing one the current rating (500μA moving coil) must be quoted. The complete tachometer is then made up into one unit which is easily fitted to the dashboard.

Before the components are wired up a new scale must be marked on the meter to indicate revolutions per minute. Care must be exercised when doing this to avoid undue damage. This is accomplished by removing the

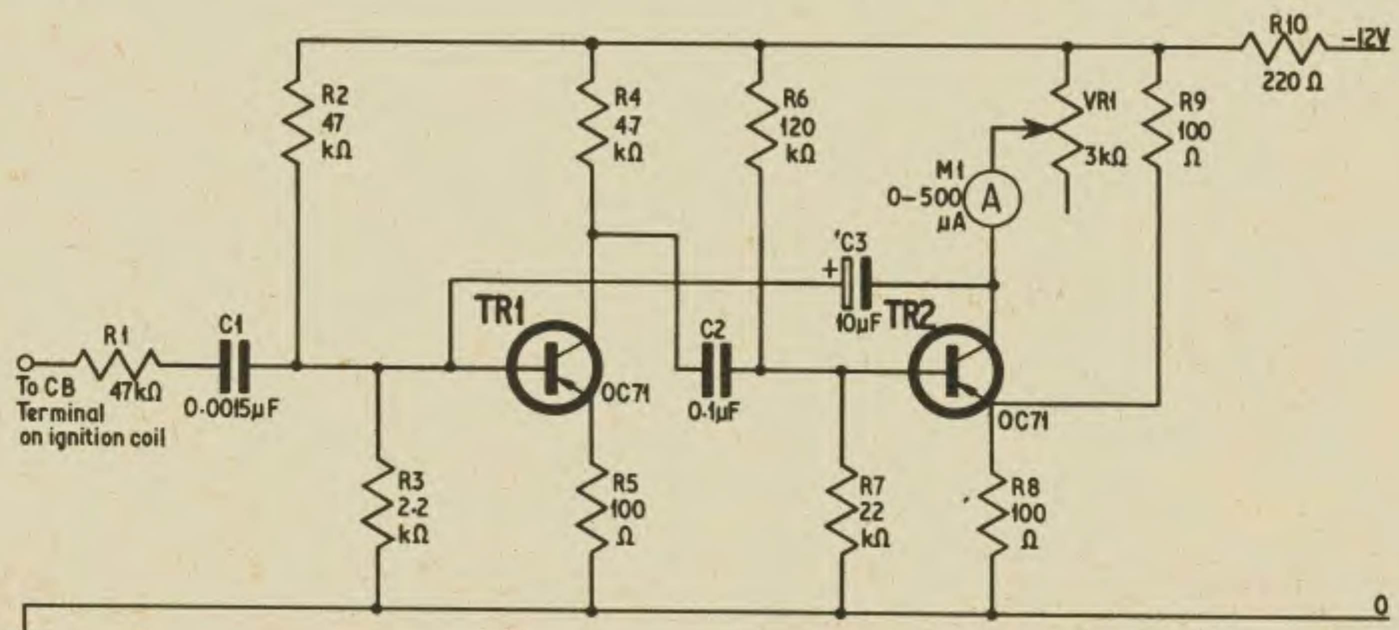


Fig. 1. Circuit diagram of the tachometer unit for 12 volt positive "earth" car electrical systems

small screws which hold the case on and pulling the case, complete with glass, off the meter body. The new scale is a linear one, a useful range being 0 to 8,000 revs/minute. Probably the best way to make it is to draw it on a piece of paper so that it occupies the same area as the existing scale, then glue it in place. Coloured lines to show normal and maximum revolutions can be painted on the new scale at the same time if desired. These limits will depend on the car and should be determined from the manufacturer's data.

The wiring diagrams (Fig. 3) are self-explanatory. Peg board was used to mount the components. Interconnections and soldering were done on the reverse side (Fig. 3a).

The unit can be fixed in any convenient position in the car, either a suitable sized hole can be cut in the dash panel or a special bracket can be made. The circuit relies on a connection through the car's "earth" system for its positive supply and also for the second input lead, so if the unit is not bolted to the metal of the car then a separate wire must be run to a convenient "earthing" point. This applies to cars with the positive terminal of the battery connected to the car body. Otherwise be careful of connections and make sure the polarity of the car electrical system corresponds with that of the tachometer.

If the negative terminal of the car battery is connected to "earth" then the unit must be insulated from any metal parts of the car. The battery negative line would then be connected to the earth system and the positive line taken to battery positive.

The complete circuit draws only 30mA so it can be connected directly to the battery without any fear of it running the battery down. It is probably best to have it connected so that it is controlled by the ignition switch; alternatively an extra switch must be fitted to enable the driver to disconnect the unit from the battery supply when leaving the car unattended.

CALIBRATION

In a four-stroke four-cylinder engine each cylinder fires once every two revolutions, so there are two input signals to the tachometer for each revolution of the engine. For a six-cylinder engine there are three input signals to each engine revolution.

COMPONENTS . . .

Resistors

R1	47kΩ	R6	120kΩ
R2	47kΩ	R7	22kΩ
R3	2·2kΩ	R8	100Ω
R4	4·7kΩ	R9	100Ω
R5	100Ω	R10	220Ω

All 10% $\frac{1}{2}$ watt carbon

Potentiometer
VR1 3kΩ 3 watt preset (Radiospares)

Capacitors
C1 0·0015μF paper 150V
C2 0·1μF plastics 30V
C3 10μF elect. 12V

Transistors
TR1, TR2 OC71 (2 off)

Meter
M1 500μA moving coil, 2½in dia.

Miscellaneous
Eyelet board. P.V.C. wire

If a square wave signal generator is available, connect it to the input and set to a convenient frequency, e.g. 100c/s, this is equivalent to 6,000 cycles per minute which on a four-cylinder engine is equivalent to 3,000 revs/minute (2,000 revs/minute on a six-cylinder engine). VR1 is then adjusted to give a corresponding reading on the meter.

If a square wave generator is not available then the unit can be installed in the car. Check to make sure it is working then take the car to a garage which has a stroboscope for engine tuning. The stroboscope will also give the speed of the engine, the tachometer can be adjusted by direct comparison.

This tachometer is temperature sensitive, but as the interior of a car is normally around room temperature this temperature dependence is evident only for a few moments when starting up on a very cold morning. ★

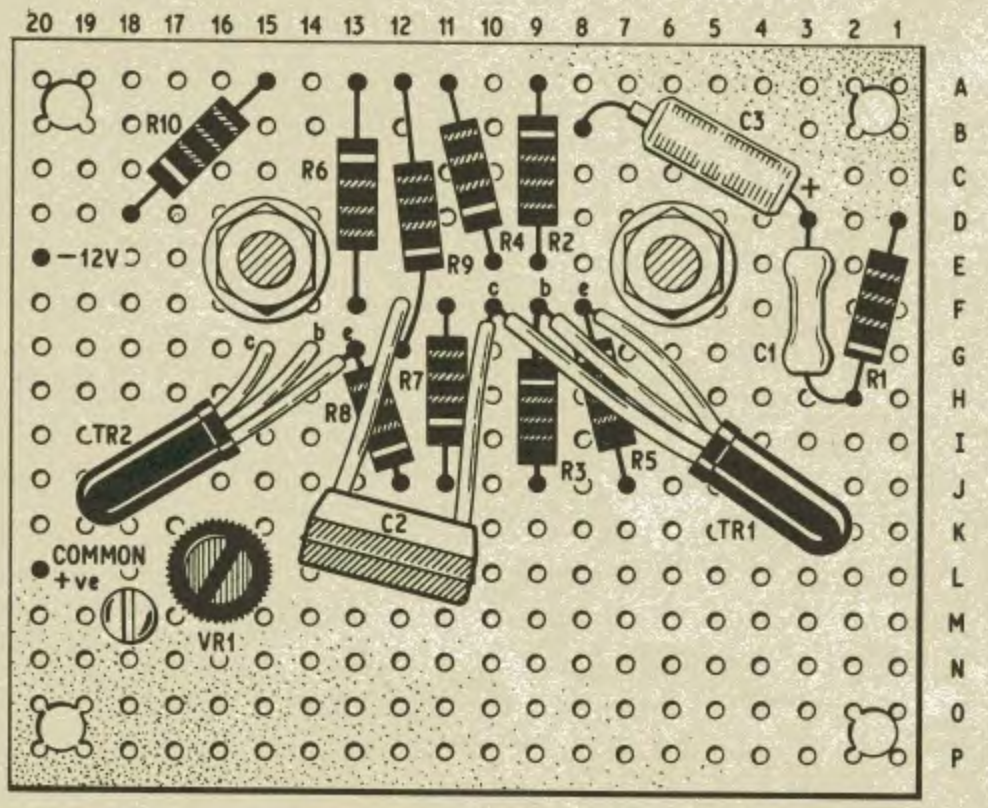


Fig. 3a. Layout of components on a piece of peg board. The collector wires are those nearest the spots on TR1 and TR2

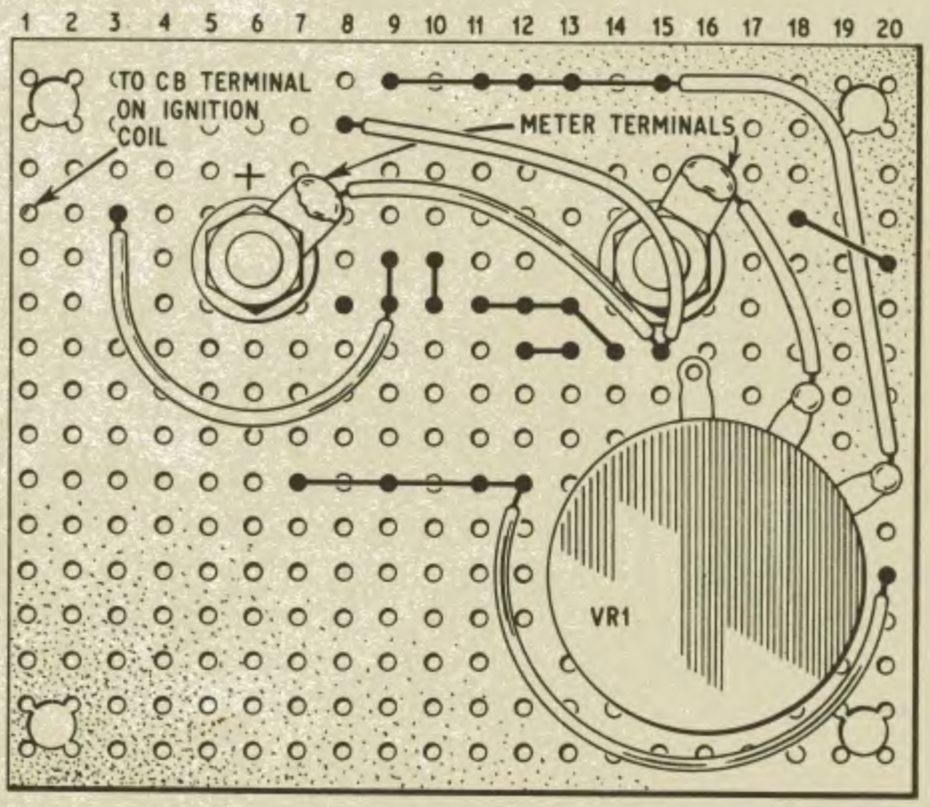


Fig. 3b. The minimum of wiring on the reverse side of the board is apparent here. Observe the polarity of connections to the meter and battery

Impedance and Negative Feedback

BY G. D. HOWAT

THE terms "impedance" and "feedback" have a habit of turning up in radio and electronic literature in a number of different contexts and with several apparently different meanings. There is a tendency to think of both as highly complex mathematical topics. While it is true that there is a fair amount of mathematics involved in both, the general outlines are not at all difficult to understand and it is the aim of this article to demonstrate this. We shall start off with impedance and go on to feedback later.

IMPEDANCE

D.C. theory is reasonably easy; the relationship between current and voltage in a resistor is given by Ohm's Law: $V/I = R$ where R is constant for a given resistor at a given temperature. Now by definition an alternating current is one which is not constant but varies in a regular fashion with time, the voltage also varying of course. For the benefit of mathematicians we can write $I = f(t)$ which means that the current I is a function of the time t, that is, it varies with t in a regular pattern. For a.c. flowing in a pure resistance with a sine waveform, the relation is: $I = I_{max} \sin \omega t$ where I is the instantaneous current at time t, I_{max} is the maximum current, $\omega = 2\pi f$, f being the frequency of alternation of the a.c. For the same resistor the voltage also rises and falls in a similar fashion:

$$V = V_{max} \sin \omega t$$

The ratio between these turns out to be constant, i.e.

$$\frac{V_{max} \sin \omega t}{I_{max} \sin \omega t} = \text{constant}$$

$$\therefore \frac{V_{max}}{I_{max}} = \text{constant}$$

This constant is called the impedance of the system and is given the symbol Z. This equation looks remarkably like Ohm's Law, the d.c. equivalent, and has led to the rather poor definition of impedance as "the a.c. equivalent of resistance". Certainly there is an apparent similarity but there is also a fundamental difference.

In a d.c. circuit there is obviously no question of "phases" since both current and voltage are constant, however in a.c. circuits it is quite possible that V_{max} and I_{max} will exist at different times, that is, the peak of the voltage swing may well not be coincident with the peak of the current swing. In this case it is still true that $Z = V_{max}/I_{max}$ but in order to specify Z in another way it is necessary to draw a vector diagram in which Z appears as the resultant of two components. One is the real number R representing the resistance component, analogous to the d.c. resistance, and the other is an imaginary number which includes the reactive part of the circuit. It is this reactive part which produces such phase difference as there may be. Z is thus seen to be not a simple number, but a complex one and has a direction as well as a numerical value.

INTERNAL RESISTANCE

So far we have confined our discussion to what we might call "tangible resistances" represented by physical objects which we wire into circuits and which have coloured bands around them. However there is another kind of resistance, the so-called "internal resistance" or "internal impedance" which is present in power units, microphones, and various other places; phrases like "it has an internal resistance of 2 ohms" or "amplifier input impedance of 1megohm" are found.

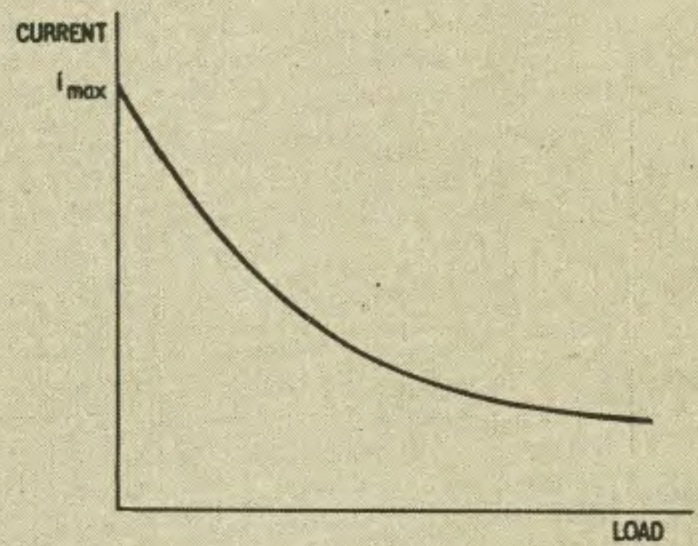


Fig. 1. Typical graph of maximum current (I_{max}) against load resistance for a battery whose internal resistance is R_{int}

It is impedance used in this sense which is more difficult to understand; just because an amplifier has an input impedance of 1 megohm does not necessarily mean that there will be a 1 megohm resistor anywhere in the input circuit. Indeed the input impedance may well not bear any relation to the values of the resistors around the input. Obviously this idea needs to be clarified, but in order to simplify matters it is best to begin with a d.c. example.

Suppose we have a simple battery and we connect various loads to it, then by Ohm's Law the current flowing can be found: $I = V/R$ so for different values of R we get different values of I. Now place a short across the battery so that $R \simeq 0$ but keep a meter in the circuit to measure the current. According to Ohm's Law an extremely high current would then flow, in practice the current remains at a comparatively low value, certainly lower than would be expected from the slight resistance which the ammeter maintains in the circuit. This is shown graphically in Fig. 1.

Even when a dead short is placed across the battery, the current which flows is less than that which is expected, even allowing for the finite resistance of a dead short, the question is: where does the extra resistance come from? The answer, of course, is that the battery has a certain amount of "built-in" resistance of its own. This results from the fact that there is an upper limit to the rate at which the current-producing reactions inside the battery can proceed. In order to take account of this built-in resistance a battery may be represented as in Fig. 2a where X and Y are the actual terminals of the battery and R_{int} represents the internal resistance.

This diagram is useful for demonstrating the properties of a battery, but it can be slightly misleading. It must be realised that R_{int} has no physical existence in the normal sense of the word resistor. There is not, anywhere inside the battery anything which, if measured with an ohmmeter, would give a value of R_{int}. It is merely a property of the materials of which the battery is built. In many ways it would be better to use a different symbol showing R_{int} in between the poles as in Fig. 2b. This is more correct technically, but it necessitates a complication of the traditional symbol for a battery and is therefore unacceptable. It is thus usual to use the idea depicted in Fig. 2a, remembering that the battery and the built-in resistance are inseparable.

The resistance R_{int} is sometimes given the symbol B and assuming its presence, it is possible to explain the known facts and to anticipate new ones. First, it is now clear why the short-circuit current of a battery is lower than the expected value—in any circuit there is always a resistance B which places an upper limit on the current available. Second, the output voltage across X and Y will always be less than the open circuit voltage, called the e.m.f., by an amount IB, I being the current taken. This is not a serious problem in practice since in any type of circuit, the power supply is chosen so that B is very small compared with the load resistance. In this way there is little loss across B and very little voltage is lost. To be strictly accurate, the current taken from a battery should be calculated: $I = E/(R + B)$ where E = e.m.f. and R = load resistance. Since $R \gg B$ in most cases, the equation contracts to $I = E/R$. Third, it is possible to calculate the conditions not for maximum voltage transfer, but for maximum power transfer.

$$\text{Power} = P = I^2R$$

and

$$I = \frac{E}{(R + B)}$$

$$\therefore P = \frac{E^2R}{(R + B)^2}$$

It can be shown by calculus that if

$$\frac{dP}{dR} = E^2\left[\frac{B^2 - R^2}{-(R + B)^4}\right] = 0$$

then $R = B$

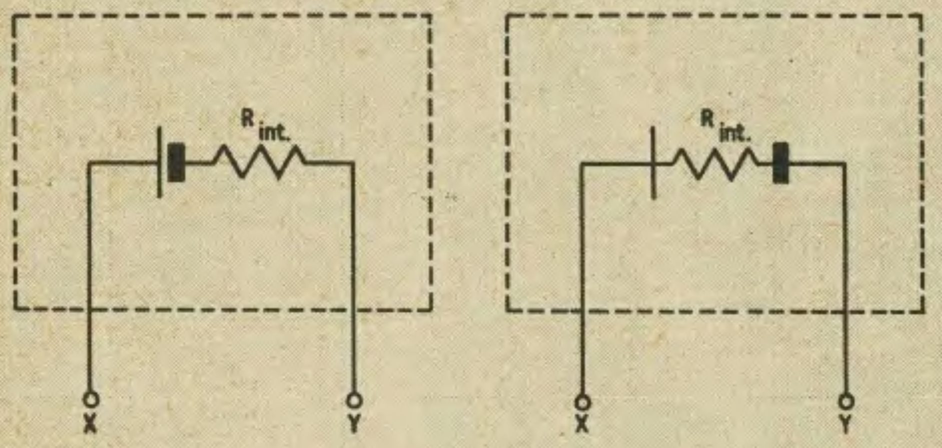
Maximum power is transferred from source to load when the load is equal to the internal resistance of the source. This is known as the "Maximum Power Transfer Theorem".

AMPLIFIER INPUT

We have already seen that for a.c. in purely resistive circuits, the impedance is measured as $V_{\max}/I_{\max}$. Any source of a.c. will have an internal impedance in just the same way that a d.c. source had an internal resistance. Also, a circuit such as an amplifier will exhibit a certain impedance across its input terminals which may not bear any relation to the resistors around the input. Mathematical calculation of the input impedance is difficult and the following practical method may be used:

Suppose we have a linear amplifier, that is, one where the output is in direct proportion to the input, and we feed into it a signal via a variable resistance, at the same time measuring the output level on an a.c. voltmeter, this is shown in Fig. 3. With VR set to zero resistance a certain signal will appear across the output. If VR is increased the output signal will decrease, finally reaching a value exactly half the original. When this happens VR at that setting is the input resistance of the amplifier. This can be shown by modifying Fig. 3 to show the effective input resistor R_{in}; this is shown in Fig. 4. When $VR = R_{\text{in}}$, by simple potential divider theory only half the signal appears across R_{in} so we get half the original output.

It can be said that the input impedance is $V_{\max}/I_{\max}$ as "seen" by an a.c. generator which is "looking into" the input terminals. If we varied the output of the generator, simultaneously noting the current flowing into the input, the $V_{\max}/I_{\max}$ ratio would be equal to Z. This idea of "looking into" the terminals of an amplifier in the way we have described is not so puerile as it might



(a) (b)

Fig. 2. A battery has internal resistance which is normally represented by the symbol shown in (a), although the actual resistance is between the plate terminals as shown in (b)

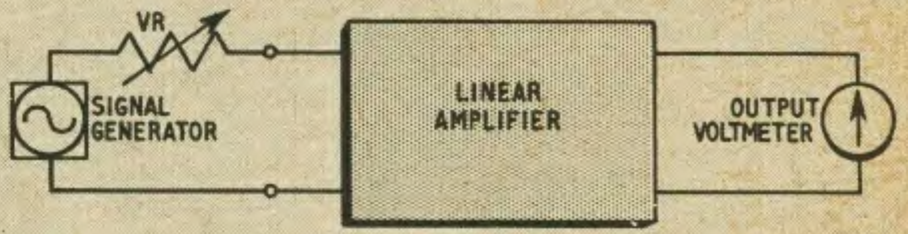


Fig. 3. Measuring the output of an amplifier to determine the 6dB voltage drop by adjusting the variable resistor VR

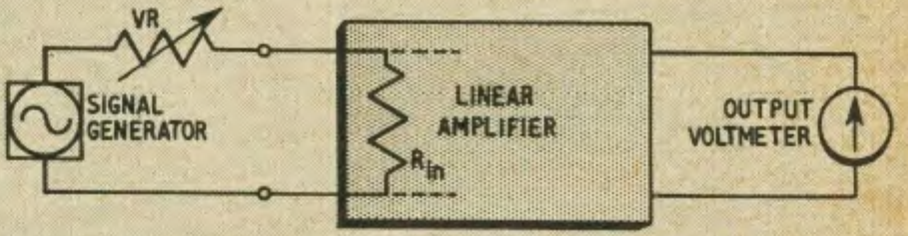


Fig. 4. The setting of VR found from the set-up in Fig. 3 is equal to the input resistance R_{in} of the amplifier

at first seem. It is very difficult to appreciate what happens to a signal as it enters an amplifier apart from considering the voltage and current relationships at the junction, and after all, this is what the generator "sees".

SOURCE IMPEDANCE

After examining the question of internal resistance in a battery it was shown how the output voltage was always lower than the e.m.f. by an amount IB, B being the internal resistance of the battery. The most obvious way of finding the internal impedance of a power source is to measure the fall in output voltage when varying currents are taken from it. Here again we have to consider how the source "appears" to a load working from it.

The term "regulation" has been used to describe the constancy or otherwise of the output voltage from a power unit when different currents are taken from it; what regulation really measures is the internal resistance of the source. The lower this is the better the regulation. As an example a 300 volt power supply with a source resistance of 1 ohm would supply 299·9 volts when 100mA was taken from it. In practice only a special voltage stabiliser would do this. A simple power unit with no stabilisation might have B as high as 500 ohms in which case the output would fall to 250 volts at the same current.

In the section on d.c. theory we showed that maximum power was transferred from source to load when the internal resistance of the source was equal to the load. By substituting V_{max} for E and I_{max} for I an analogous equation can be found for a.c. with precisely the same result. This has practical importance in impedance matching. If we want to transfer a signal from a pick-up head to an amplifier the maximum power will be transferred when the output impedance of the head equals the input impedance of the amplifier; if the two impedances are the same they are said to be matched to each other.

If impedance were independent of frequency, then mismatching a source and its load would have no effect apart from reducing gain. Unfortunately this is rarely true in practice, and impedance is found to vary with frequency. In these cases a mismatch will result in a loss of fidelity since one band of frequencies will be attenuated or amplified more than another. A classic example of this is the crystal microphone, many varieties of which have a very high source impedance and also a high internal capacitance. The alteration of the impedance of the capacitance with frequency leads to a drastic reduction in output impedance as the frequency is raised; such a system must be fed into a very high impedance if serious loss of bass is not to occur. The equivalent circuit of such a microphone is shown in Fig. 5, and Fig. 6 shows the bass attenuation which can occur when such a microphone is fed into an impedance of 100 kilohms. This emphasises the importance of matching the units in an a.f. chain of equipment, especially if the inputs and outputs are not purely resistive, as is usually the case.

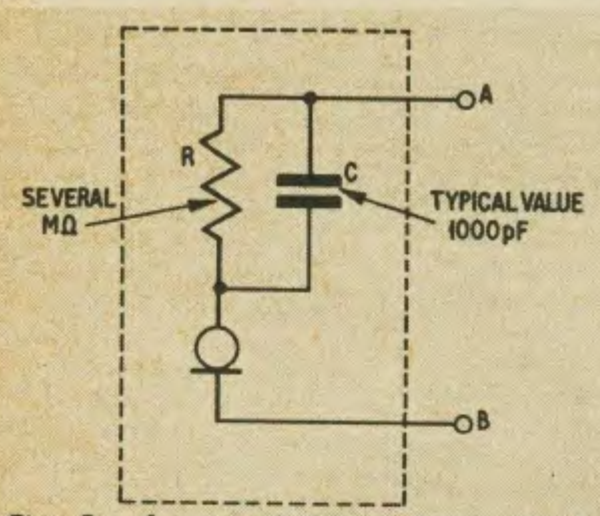


Fig. 5. A crystal microphone can be represented by a circuit of its component properties, namely its internal resistance R and internal capacitance C in series with the microphone itself

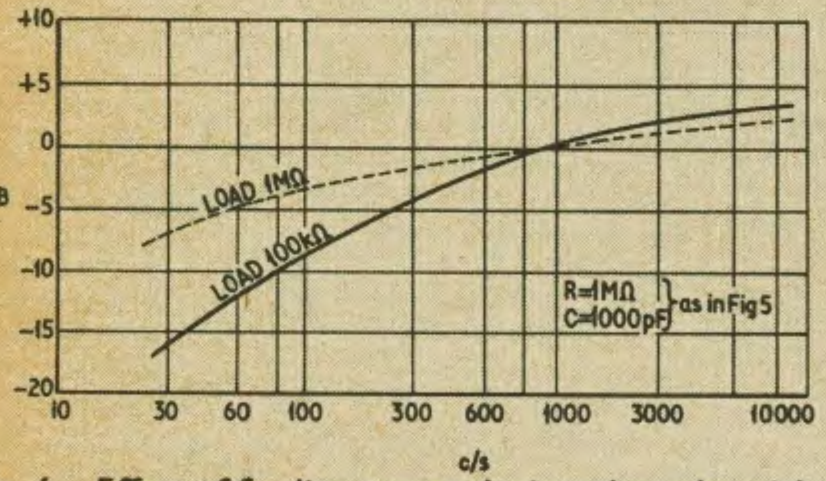


Fig. 6. Effect of feeding a crystal microphone (or pick-up) into too low an impedance amplifier; the bass is reduced

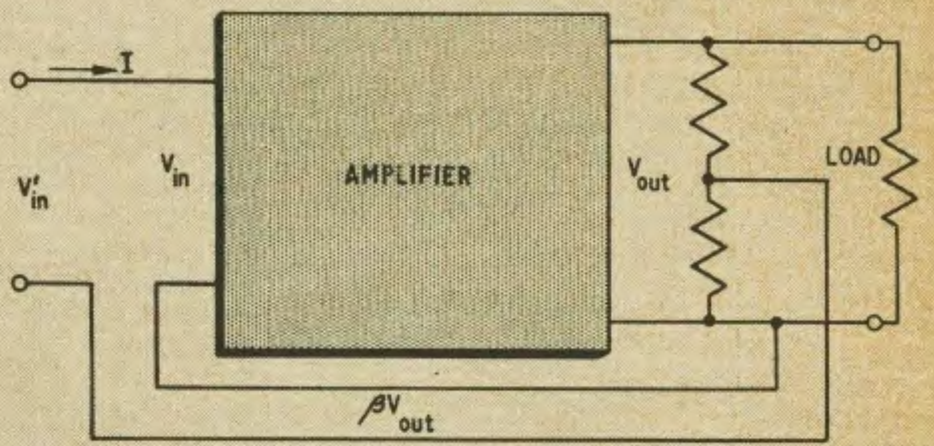


Fig. 7a. Series voltage feedback from the output to the to the input

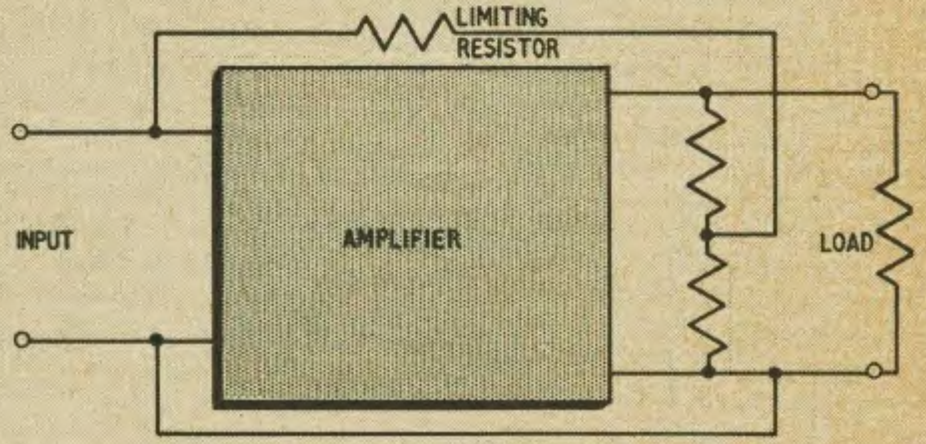


Fig. 7b. Parallel voltage feedback from the output to the input

FEEDBACK

The second topic to be discussed in this article is feedback as applied to amplifying equipment.

As the name implies, feedback is the process of applying some of the output of an amplifier back to the input so that it goes through the amplifier a second time. The process can be applied to any amplifier whether working at audio or radio frequencies, and there are two forms of feedback: negative and positive, depending on the relative phasing of the signal which is being fed back. Also there are two ways of applying the feedback signal, in series with the signal input, or in parallel with it. These two ways are shown in Fig. 7.

In order to be strictly correct it should be added that there are two methods of determining the feedback: voltage or current feedback. In the former case the feedback signal is proportional to the voltage output of the amplifier, in the latter case it is proportional to the current flowing in the output circuit. Voltage feedback signals are tapped off across a resistor in parallel with the load as in Fig. 8a. In order to prevent mis-matching, the sum of R1 + R2 must be very much greater than the load. Current feedback signals are developed across a resistor in series with the load as in

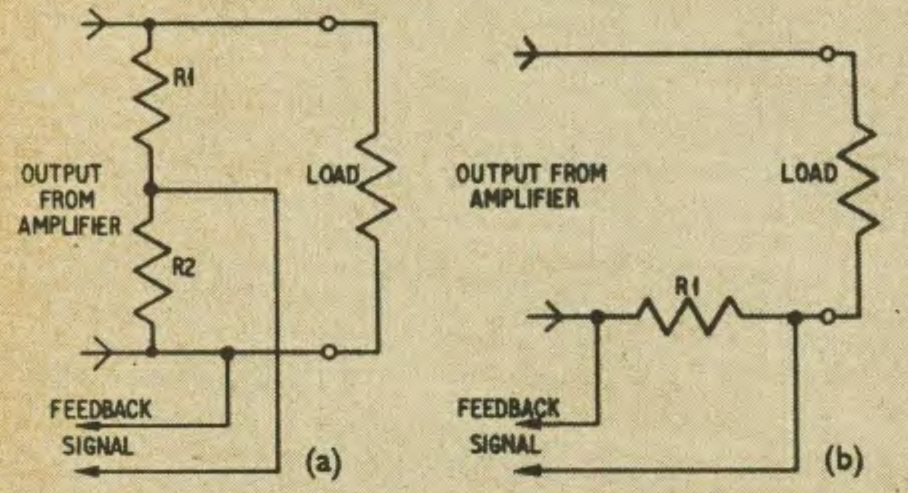


Fig. 8. Tapping the output for (a) voltage feedback, (b) current feedback

Fig. 9. An amplifier with positive feedback, i.e. output in phase with the input

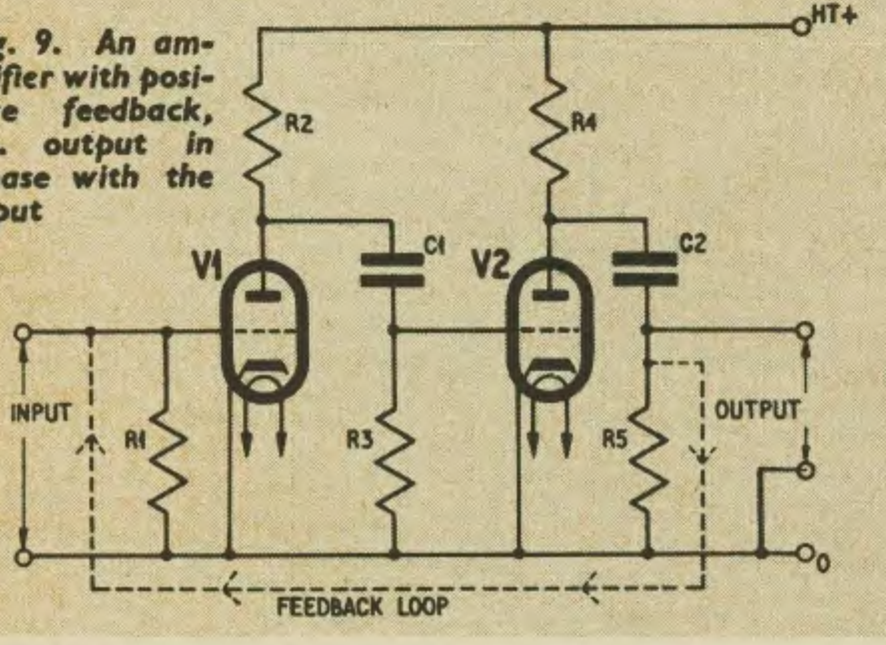


Fig. 8b, in this case the value of R1 must be small compared with the load. In this article we concentrate on the most frequently used forms of feedback: series voltage feedback, negative and positive. Fig. 7a shows an amplifier with series voltage feedback, the instantaneous voltages and currents being shown.

V'_{in} is the signal voltage across the input terminals of the amplifier;

V_{in} is the voltage which actually appears across the input circuit after application of feedback;

I is the instantaneous current flowing into the input;

V_{out} is the output voltage and

β is the fraction of the output signal being fed back; the actual feedback signal is therefore βV_{out}.

Clearly $V'_{in} = V_{in} \pm \beta V_{out}$, the $\pm$ sign allowing us to reverse the polarity of the feedback; this will be mentioned shortly.

With no feedback $\beta = 0$, so the amplification is

$$A = \frac{V_{out}}{V_{in}}$$

With feedback, amplification now is

$$A' = \frac{V_{out}}{V'_{in}}$$

Since $$V'_{in} = V_{in} \pm \beta V_{out}$$

$$A' = \frac{V_{out}}{V_{in} \pm \beta V_{out}}$$

POSITIVE FEEDBACK

Before going on to discuss the conclusions to be drawn from the last equation, the polarity of the feedback must be explained. The symbol $\pm$ was used

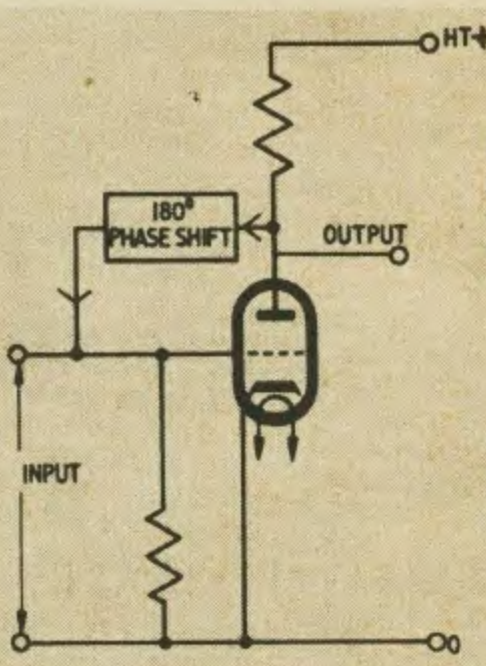
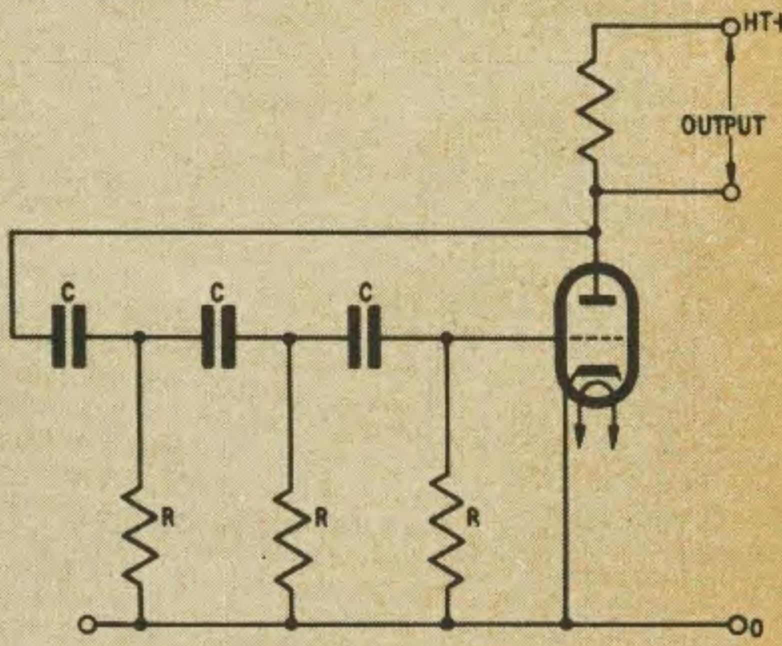


Fig. 10a (left). Positive feedback obtained by using a phase shift network from anode to grid

Fig. 10b (below). Positive feedback by using an RC phase shift network



in the equation $V'_{in} = V_{in} \pm \beta V_{out}$ to show that the feedback signal βV_{out} could either be added to or subtracted from the signal applied to the amplifier input. If the signals are added, the effect is to increase the output, this being positive feedback. Conversely if βV_{out} is 180 degrees out of phase with V'_{in} it will effectively cancel out a part of the input signal, reducing the overall gain; this is negative feedback.

Positive feedback is a cumulative process, and an amplifier with this becomes an oscillator. Fig. 9 shows a typical two-stage resistance-capacitance coupled valve amplifier. Suppose we feed a portion of the output signal across R5 back to the input; what happens? Suppose that at one instant V1 grid is going more negative, then V1 is passing less current, the anode voltage rises and the potential on V2 grid also rises due to the coupling capacitor C1. As the valve conducts to a greater extent the anode voltage falls and so the output across R5 also falls, that is, becomes more negative. It is the output across R5 which is fed back to V1. As the input falls, the feedback signal also falls. In other words this is a case where input and feedback signals are in phase, hence it is positive feedback.

The feedback will continue to drive V1 grid into cut-off and it will remain thus until C2 has discharged. When this happens V1 begins to conduct and the reverse of the above process takes place, this time the feedback causes V1 grid to keep going positive and finally to cut off V2 by the coupling action of C1. After C1 has discharged the cycle is repeated.

Most readers will have realised by now that the circuit in Fig. 9 is simply a multivibrator, usually drawn slightly differently but, with R1 and R5 combined, still the same thing. The multivibrator is effectively a two-stage amplifier with a large amount of positive feedback.

It is not so easy to arrange positive feedback in a single valve as the waveform at the anode will always be 180 degrees out of phase with that at the grid. In order to make a single valve oscillate using positive feedback, a phase-shift network would be required as in Fig. 10a. It is possible to do this by making use of the property of an RC combination to partially differentiate a waveform. In the case of a sine wave this is equivalent to giving it a certain amount of phase shift.

In the most common versions three RC combinations connected between anode and grid, as in Fig. 10b, will provide a phase shift of 180 degrees at one frequency only, this frequency depending on the values of the resistors and capacitors used. Such a circuit as is shown in Fig. 10b is known as a phase-shift oscillator and has a wide variety of uses since the output is nearly a pure sine wave and also, as no current flows in the phase-shifting components, there is very little frequency drift.

NEGATIVE FEEDBACK

By definition, negative feedback applied to an amplifier will reduce the gain to a greater or lesser extent so one might ask: why put it into an amplifier at all? The answer can be found by applying the formula we previously derived for the amplification of an amplifier with and without negative feedback, but first we must find the actual reduction in gain. Since the feedback is negative the equation becomes:

$$A = \frac{V_{out}}{V_{in}} \text{ with no feedback}$$

$$A' = \frac{V_{out}}{V_{in} - \beta V_{out}} \text{ with feedback.}$$

The ratio between these is:

$$\frac{A}{A'} = \frac{V_{out}}{V_{in}} \times \frac{V_{in} - \beta V_{out})}{V_{out}}$$

$$\therefore \frac{A}{A'} = \frac{(V_{in} - \beta V_{out})}{V_{in}}$$

$$= 1 - \beta \frac{V_{out}}{V_{in}} = 1 - \beta A$$

i.e. $$\frac{A}{A'} = (1 - \beta A)$$

This factor $(1 - \beta A)$ is called the feedback factor and gives the reduction in gain in terms of the original amplification and β. The reduction in gain, expressed in decibels is also used as a measure of the degree of feedback. Thus in an amplifier quoted as having "15 dB of negative feedback" this means that the gain is reduced by 15 dB when the feedback circuit is working.

In an earlier section on impedance it was shown how, when using many types of signal source, it is necessary to provide a high input impedance in the amplifier into which they are being fed. The input impedance of an amplifier without feedback (Fig. 7a with $\beta = 0$) is $R_{in} = V'_{in}/I = V_{in}/I$. When negative feedback is applied, the gain control must be turned up in order to obtain the same output. The signal current I will remain the same, but the input voltage $V'_{in} = V_{in}(1 - \beta A)$ so the input impedance now is

$$R'_{in} = \frac{V_{in}(1 - \beta A)}{I}$$

and the ratio

$$\frac{R_{in}}{R'_{in}} = \frac{V_{in}}{I} \times \frac{I}{V_{in}(1 - \beta A)}$$

$$\frac{R_{in}}{R'_{in}} = \frac{1}{(1 - \beta A)}$$

or

$$R'_{in} = R_{in}(1 - \beta A)$$

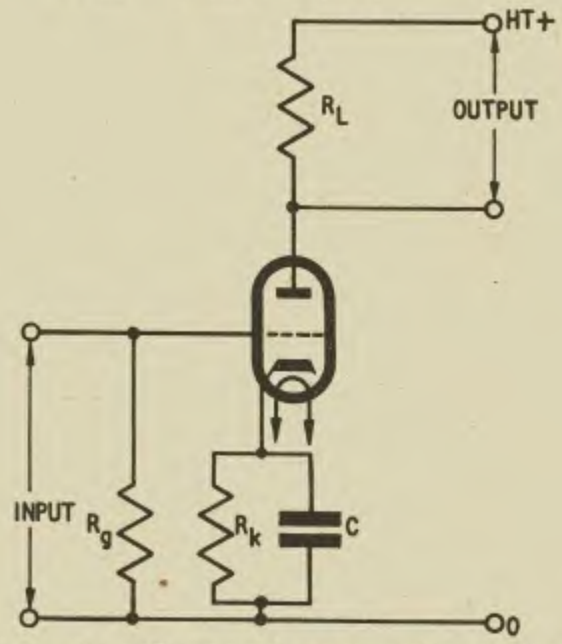


Fig. 11. Capacitor C smooths out voltage changes due to anode current changes. The absence of C effectively incurs a large degree of negative feedback

The input impedance is now higher by an amount $(1 - \beta A)$. This is then the first reason for adding negative feedback, although the gain decreases, the input impedance increases by the same amount, i.e. $(1 - \beta A)$. This is useful in the design of amplifiers with a high input impedance.

CURRENT FEEDBACK

Most valves used today are indirectly heated types and are used in circuits where the grid bias voltage is obtained from the voltage drop across the cathode resistor. In Fig. 11 it is clear that the cathode of the valve will be maintained a few volts positive with respect to earth by the anode current flowing in it. The capacitor C acts as a buffer, smoothing out changes in voltage due to variations in anode current, the larger the capacitance of C, the more constant is the grid bias. On the other hand the more current taken by a valve, the less effective a given capacitor will be.

If C is omitted entirely then the regulation of the bias is at a minimum (assuming that there are no stray capacitances, true at low frequencies only) and the

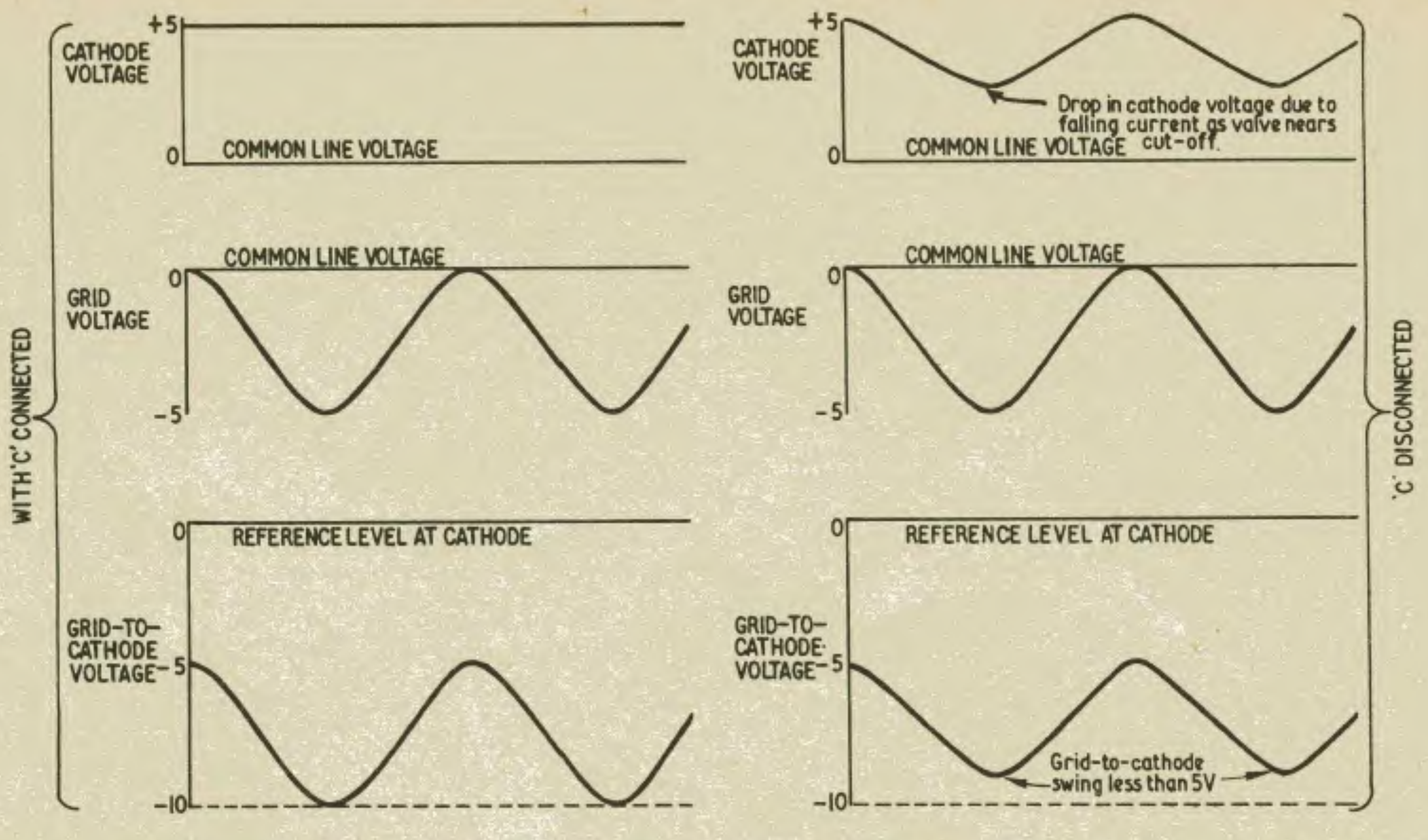


Fig. 12. Comparison of cathode and grid voltages with the cathode bypass capacitor in circuit and disconnected

effect is to add a large degree of negative feedback. Unlike the cases we have been discussing, however, this is an example of negative *current* feedback. Although we are primarily interested in voltage feedback, a brief explanation of this type of current feedback will be given as in this case it is easy to appreciate the mode of operation.

With a fairly large capacitor C in position the bias is virtually constant and the grid-to-cathode voltage swing is the same as the input swing across R_g. In the absence of C things are rather different. As the grid swings more negative the anode current decreases so the voltage across R_k falls bringing the cathode nearer to earth potential. The bias voltage across R_k is effectively in series with the input signal across R_g, and since both alter in value the net effect is to partially cancel each other out, and the grid-to-cathode voltage swing is less than the swing across R_g. This is clearly a case of current feedback as the signal acting as the feedback, i.e. the signal developed across R_k, is proportional to the current flowing in R_k. By by-passing a portion of R_k with a capacitor, varying degrees of feedback can be obtained. Fig. 12 summarises these points graphically.

POWER AMPLIFIER FEEDBACK

As far as power amplifiers are concerned the most characteristic mode of application of feedback is from the secondary of the output transformer to the preceeding stage, i.e. the driver stage. Two methods of doing this are shown in Fig. 13. In Fig. 13a a certain fraction of the voltage developed across the secondary of the transformer is selected by Rx and Ry and applied via R_f to the grid of the driver stage. It is important to phase up the connections correctly otherwise the feedback will be positive and oscillations will result.

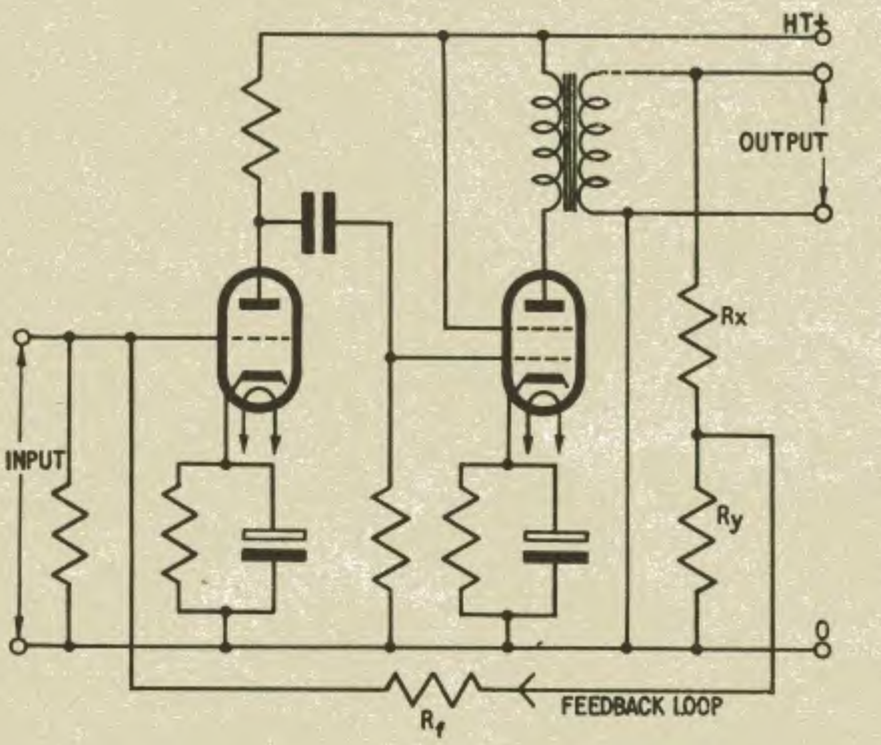


Fig. 13a. Method of applying negative feedback in class A power amplifer

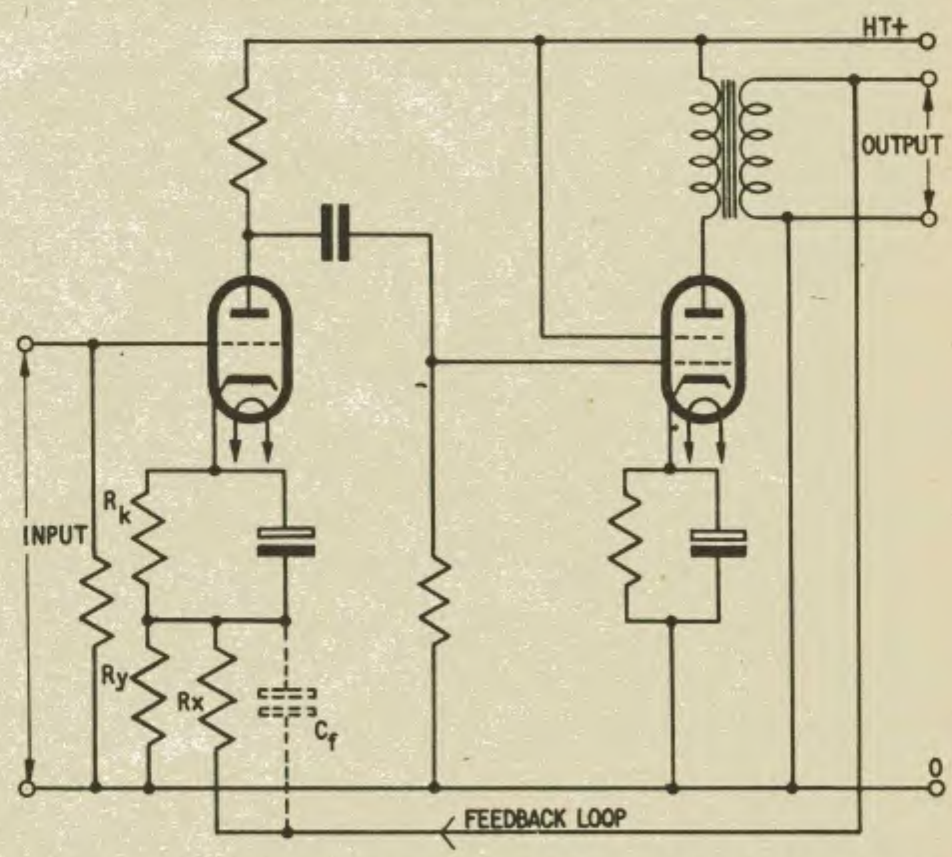


Fig. 13b. Feedback applied to the cathode of the driver stage

A more common procedure is shown in Fig. 13b where the feedback is applied to the cathode of the driver stage. In this case Ry is still half of the potential divider but is also part of the cathode resistor of the driver. The other half of the divider Rx, now doubles as the equivalent of R_f in Fig. 13a. If the feedback resistor R_f (R_f in Fig. 13a, Rx in Fig. 13b) is partially or entirely shunted by a capacitor, then the feedback is frequency selective. The impedance of C_f falls with increasing frequency so allowing an increasing amount of feedback. This compensates for bass deficiency in the amplifier.

As in the previous case it is important to ensure that the feedback is in the correct phase relationship with the input signal. It could be argued that, in Fig. 13b, there is negative current feedback due to part of the cathode resistor being unbypassed. While this is quite true, the value of Ry is always made much less than the bypassed R_k so the effect is minimised.

DISTORTION

Any amplifier will introduce a certain amount of distortion into the signal it is amplifying. There are various forms of distortion, one being the introduction of certain frequencies which are harmonics of the input signal but which were not originally in it, or only in it to a lesser extent. This is called harmonic distortion and is due to slight curvature of the input/output characteristic of the amplifier, mainly as a result of the slight curvature of the transfer characteristic of the valves.

It is possible to show that the addition of negative feedback reduces the harmonic distortion. This is a somewhat complex proof since it is necessary to express all the signals in terms of time, V_{in} must be written as $V_{in}\cos\omega t$. The result of the calculation is to show that the magnitudes of all the spurious harmonics, and hence the harmonic distortion, are reduced by the factor $(1 - \beta A)$. In a similar way it is possible to show that hum, hiss, and other forms of noise introduced by the amplifier can also be reduced by feedback, as might be expected; the reduction in noise is found to be $(1 - \beta A)$.

So far we have considered amplifiers in which the feedback loop was operative at all frequencies. There is no reason why this should always be so, and in many cases it is possible to improve the frequency response of an amplifier by selectively feeding back an excess of the signals which are over-emphasised.

In a normal amplifier a certain amount of bass cut is introduced by the coupling components between the valves. It is possible to feed back slightly more signal in the middle and upper ranges than in the bass and since the feedback is negative the output power will be reduced less in the bass than elsewhere. This has the apparent effect of improving bass performance though it is necessary to remember that what really occurs is an attenuation of everything else. ★

INDEX

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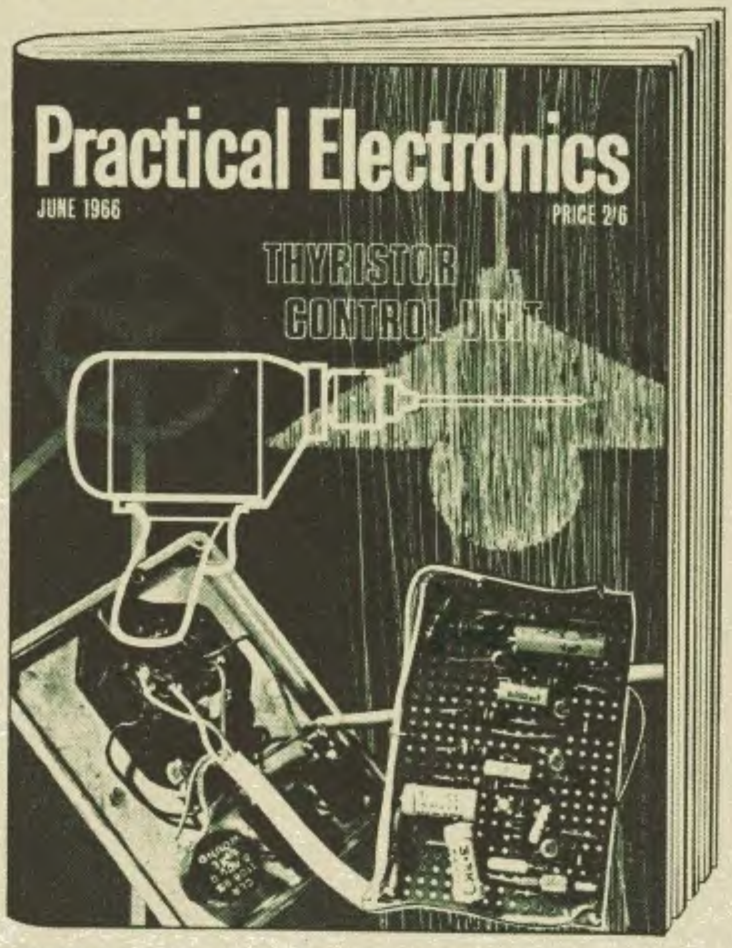

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ANY complete radio system must employ a combination of transmitter, receiver and actuator. The latter translates the electronic signal or control into "muscle power".

The actuator is a critical device and is not generally a suitable subject for home construction in miniature form. However, an understanding of how actuators work and the various ways in which they can be made to perform "compound" duties is an essential part of practical radio control. For heavy duty mechanical outputs an electric motor may have to be employed, adapted to actuator-type switching for control. In general, however, the majority of radio control applications can be met by choice of a suitable actuator from the many different commercial types produced specifically for model radio controls. This section deals specifically with simple single-channel actuators, as employed with straightforward "on-off" receiver working.

The response provided by any single-channel receiver controlled by a conventional on-off transmitter signal is a simple on-off switching action. In the case of a relay type receiver this is initiated by relay armature movement and thus a change in mechanical switching conditions as far as the relay contacts are concerned. With a relayless receiver a low voltage d.c. output is triggered "on" and "off" in the final (output) stage of the receiver. In both cases the receiver must be coupled to an electro-mechanical device called an actuator to translate the switching action in terms of mechanical output.

The main difference between the two types of receiver is that when the switching element is a relay, the actuator circuit becomes entirely independent of the receiver circuit (Fig. 4.1.). Thus the actuator can be of any size and type with its independent battery or power supply arranged accordingly; it is only necessary that the receiver relay contacts be of suitable rating to handle the actuator circuit voltage and current involved. When the receiver has a relayless output the actuator is connected directly to the receiver and draws its voltage from the receiver circuit (see Fig. 4.2.). Satisfactory performance is dependent on the actuator, providing an output load consistent with the receiver design output and the operating current requirements of the actuator itself. This demands the use of a matched actuator and considerably limits the choice of type and scope of actuator performance.

ACTUATOR PRINCIPLE

The simplest possible type of actuator comprises nothing more than a basic galvanometer movement, the coil being wound on a suitably pivoted rotor mounted between the poles of a permanent magnet. The "motor" force derived when the coil is energised then provides the mechanical output. This has distinct limitations as a practical system, although the "magnetic actuator", as it is called, does have applications in specific instances, for example, where only very low unidirectional mechanical output is required.

The simplest practical form (and at one time standard) single-channel actuator is based on a coil and armature controlling an escapement movement as in Fig. 4.1. This is, in fact, normally called an escapement and has the advantage of being a simple device which can be made light and compact. Mechanical power has to be applied to the escapement shaft to provide a mechanical output, which can take the form of a light rubber strip drive (usually) or a clockwork motor.

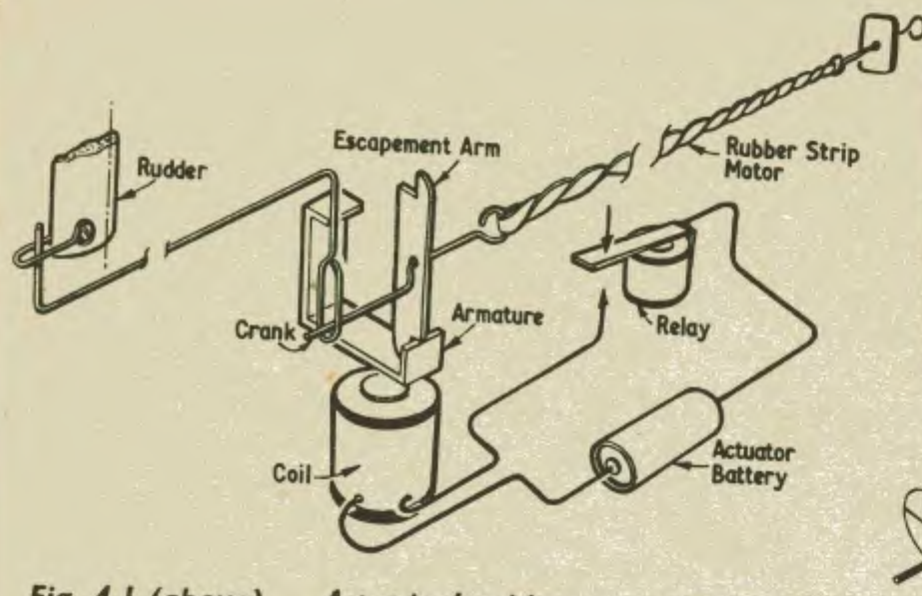
Depending on the electro-magnetic efficiency of the coil circuit and the mechanical efficiency of the escapement action, such escapements are capable of working with coil currents in the range 200 to 500 milliamps, coil resistance being designed accordingly. Typically, for an operating voltage of around 3 volts the coil resistance is 8 ohms; and for 4·5 volt operation 12 ohms, corresponding to a nominal operating current of 375 milliamps. This is well within the load capabilities of small light duty batteries (as for relay receivers), or the typical output of simple relayless receivers. In the latter case receiver voltage is commonly of the order of 4 to 4·5 volts, of which about half a volt or slightly more is dropped in the output stage. Thus an 8 ohm coil is a typical matching actuator resistance for a relayless receiver. Some receivers of this type, however, may be specifically designed to accept slightly higher actuator coil resistances, in which case the receiver battery voltage, and thus output voltage, is usually higher.

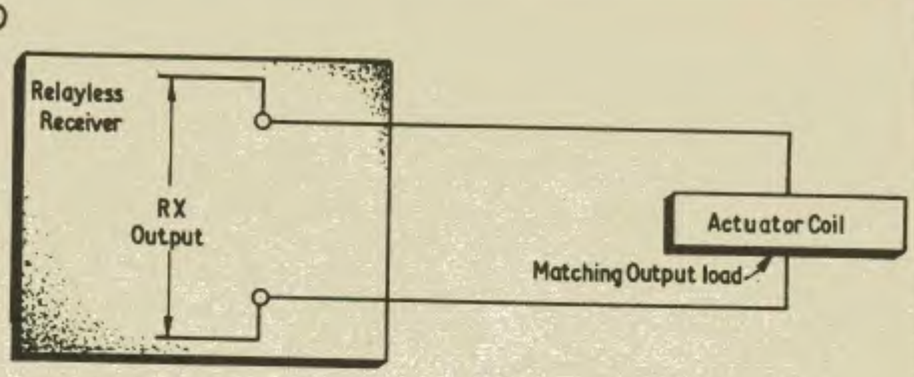
Radio Control of Models

Part Four...

ACTUATORS

By R. H. WARRING





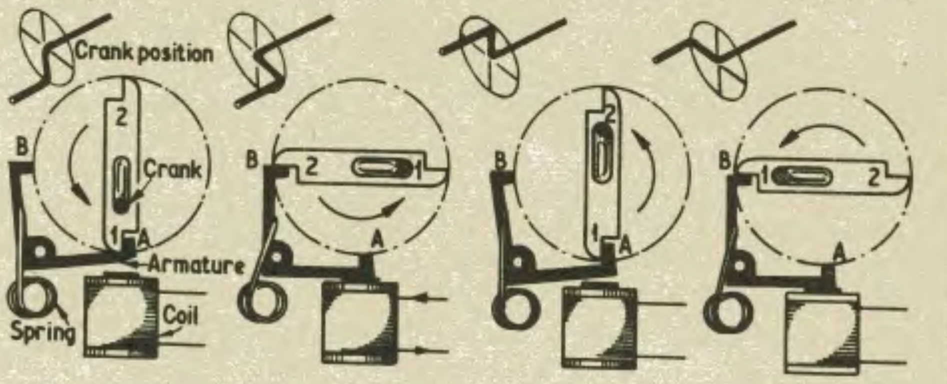


Fig. 4.1 (above). A typical rubber motor driven escapement with actuator coil and relay

Fig. 4.2 (above right). Actuator connected directly to the output of a relayless receiver

Fig. 4.3 (right). Sequential operation of a simple escapement actuator

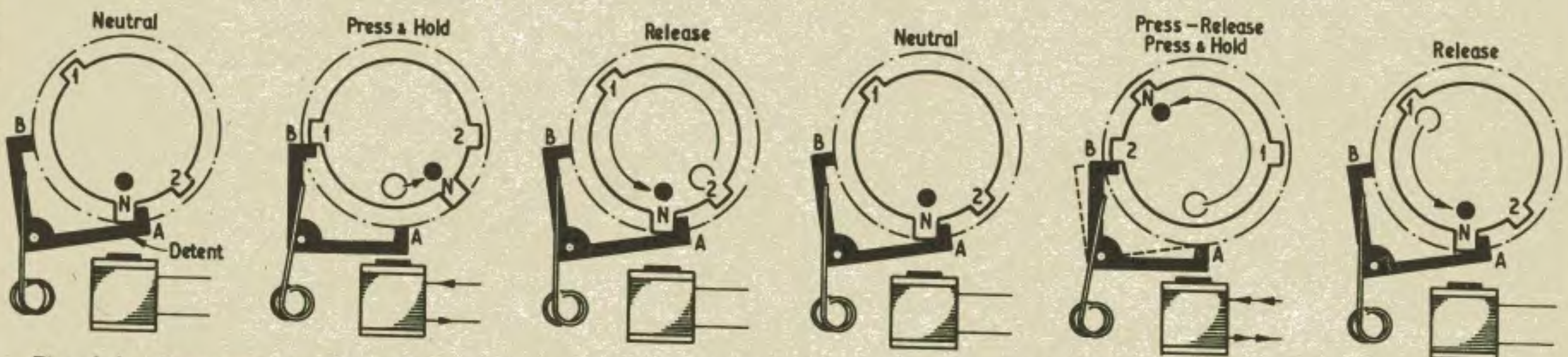


Fig. 4.4. Sequential operation of a compound escapement using a circular disc with teeth to brake at pre-determined positions

The basic action of a simple escapement-type actuator can be followed from Fig. 4.3. Mechanical output is provided by the rotary movement of the crank or extension of the escapement spindle powered by a rubber strip motor (or clock-type spring), interrupted by movement of the pivoted armature.

In the normal or "neutral" position, corresponding to "signal off", the escapement arm and crank are held by armature detent "A". When the receiver responds to a signal that is held on, the armature is pulled in by the actuator coil becoming energised, allowing the escapement arm to rotate one-quarter turn until stopped by coming against detent "B" of the armature. On release of the signal the escapement arm is free to rotate another quarter-turn, back to what corresponds to "neutral" position for the crank. On receipt of the next signal the escapement arm rotates a further quarter-turn; and back again to neutral on release of the signal.

The majority of modern escapements of this basic type employ a four-arm rotor when only one detent need be used on the armature. Two of the rotor arms are long and two short, to provide clearance for the self-neutralising action and two positive stop positions. Specified by duty, such actuators are 2PN type (i.e. two-position, self-neutralising). If a four-arm rotor is used with all the arms equal in length the duty provided is a simple quarter-turn progression or 4P.

A development of the basic action is the *compound* escapement which normally employs a toothed or pegged wheel in place of an escapement arm. Neutral position is always held by one particular tooth, which is larger than the others, and stopped by detent "A" when the armature is not pulled in (see Fig. 4.4.). This provides *selective* switching of a "hold" position, the selecting signal in terms of transmitter keying being either "press and hold" or "press-release-press and hold". The complete sequence operation is shown in Fig. 4.4. In order to achieve correct timing the speed of the rotor when released is controlled by a ratchet type brake (usually a simple pawl running on a fully toothed wheel).

Table 4.1: RECEIVER-ACTUATOR MATCHING

Receiver type	Escape-ments or solenoids	Single channel motorised actuator	Small electric motors	Larger electric motors
Relay	†Any	†Any	†Yes	†*Yes
Relayless	Matching resistance	†*Yes	†*Yes	†*Yes

† Servo circuit battery selected to suit
* Coupling through slave relay

ELECTRICAL SWITCHING

An escapement can also be designed to provide electrical switching for a further (or secondary) actuator, thus increasing the scope of the services required. The two basic methods of achieving this are shown in Fig. 4.5. In Fig. 4.5a a third "hold" position is provided on the rotor movement, this position closing a pair of electrical contacts connected to a separate secondary actuator circuit. In Fig. 4.5b a pair of contacts controlling the external (secondary actuator) circuit are simply momentarily closed when traversed by a peg on the rotor (e.g. an elongated "neutral" tooth).

The main difference between the two systems is that in the first case the secondary circuit contacts can be *held* closed for any length of time required and thus are suitable for switching a motor circuit or selecting a further "hold" position on a secondary actuator. In the second case, however, the external circuit contacts are closed only momentarily, and can only be used to trip a secondary actuator of the non-neutralising type to provide a changeover action.

In both cases the auxiliary contacts will always be closed momentarily every time the main actuator is released from neutral and completes a revolution of its rotor. To avoid giving spurious pulse signals in the secondary actuator circuit in the case of third-position switching, it is necessary either to provide a delay element in the secondary circuit or to wire the auxiliary contacts back through the receiver relay contacts, as in Fig. 4.6. The latter is by far the simplest solution and ensures that the secondary actuator circuit will be closed only when the switching "third" position is signalled and held. At all other times when the auxiliary contacts are closed momentarily by the rotation of the rotor the receiver relay armature will be in the "out" position breaking the secondary actuator circuit. Note, however, that this description refers to a "current rise" receiver where the relay is pulled in on receipt of signal. With a "current fall" receiver the secondary circuit is wired through the normally unused receiver relay contact (i.e. the "normal open" contact in each case).

With "quick-blip" switching the auxiliary contacts are again wired back to the secondary actuator circuit through the "normal closed" (or back contact) of the receiver relay, as in Fig. 4.7. Thus when the receiver relay is pulled in to give a "hold" signal to the actuator the secondary actuator circuit remains broken. If just a "quick blip" signal is given, however, the receiver relay armature will have dropped out immediately after releasing the rotor from its neutral position. Thus, when the auxiliary contacts are momentarily closed by the action of the rotor tooth or peg the secondary actuator circuit is complete. The principle advantage of this system is that the secondary actuator circuit switching signal is a very simple one—just a quick blip on the transmitter button.

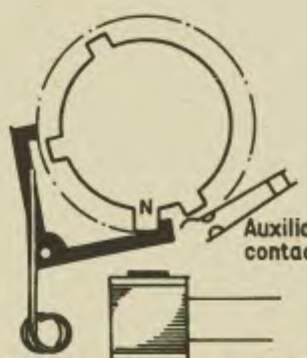
Both systems can only be applied directly to relay type receivers. However, in practice the actual switching contacts involved are usually brushes sweeping a copper strip on the rotor wheel, rather than mechanical contacts operated by a cam, peg or rotor wheel tooth. To match the actuator for relayless receiver operation it is possible to provide additional switching circuits giving the same switching function as the "back" contacts of a relay receiver. Only an actuator provided with such additional built-in switching can be used for secondary circuit signalling directly connected to a relayless receiver. Without such additional built-in switching it would need to be coupled to a relayless receiver via a slave relay for the secondary circuit switching to be usable.

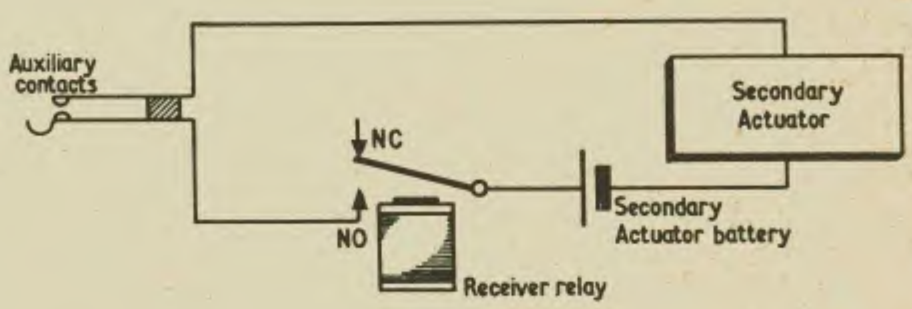
DRIVING THE ESCAPEMENT

Further compounding of actuator action is possible, using the switching services provided by the main actuator. Basically this involves interconnecting two or more specially designed compound actuators, so that the "third" position on each is available for switching, enabling four (or more) separate control output positions to be selected by sequence switching. Thus single-channel signalling can be extended to a multiplicity of selectable services, although any one service can only be selected through a definite sequence. This is normally known as "cascading", but has definite limitations in practice.

Where more mechanical output is required than that provided by rubber motor driven escapements, a motorised actuator can be employed. This, basically, is simply a sub-miniature electric motor controlled by a suitable switching circuit so as to have a similar output movement to the escapement movements previously described.

The main switching is conventionally arranged to drive the motor in bursts corresponding to a quarter-turn movement of the output spindle, thus giving an





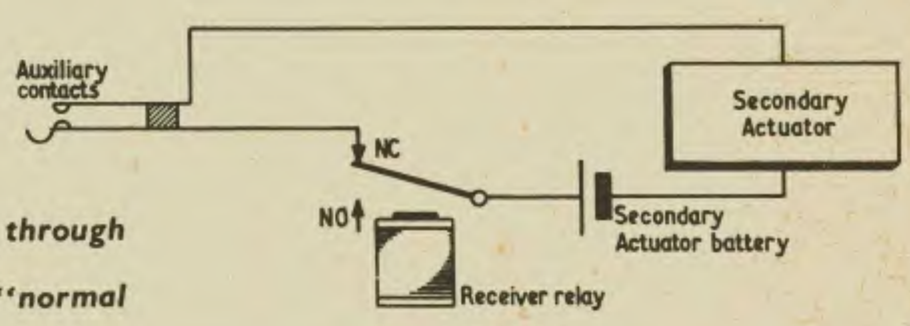


Fig. 4.5a (above left). Auxiliary contacts added with a third hold position for electrical secondary actuator

Fig. 4.5b (above centre). Auxiliary contacts are momentarily closed when traversed by the "N" tooth ("Quick-blip")

Fig. 4.6 (above right). Auxiliary contacts connected through "normal open" contact

Fig. 4.7 (right). Auxiliary contacts connected through "normal closed" contact

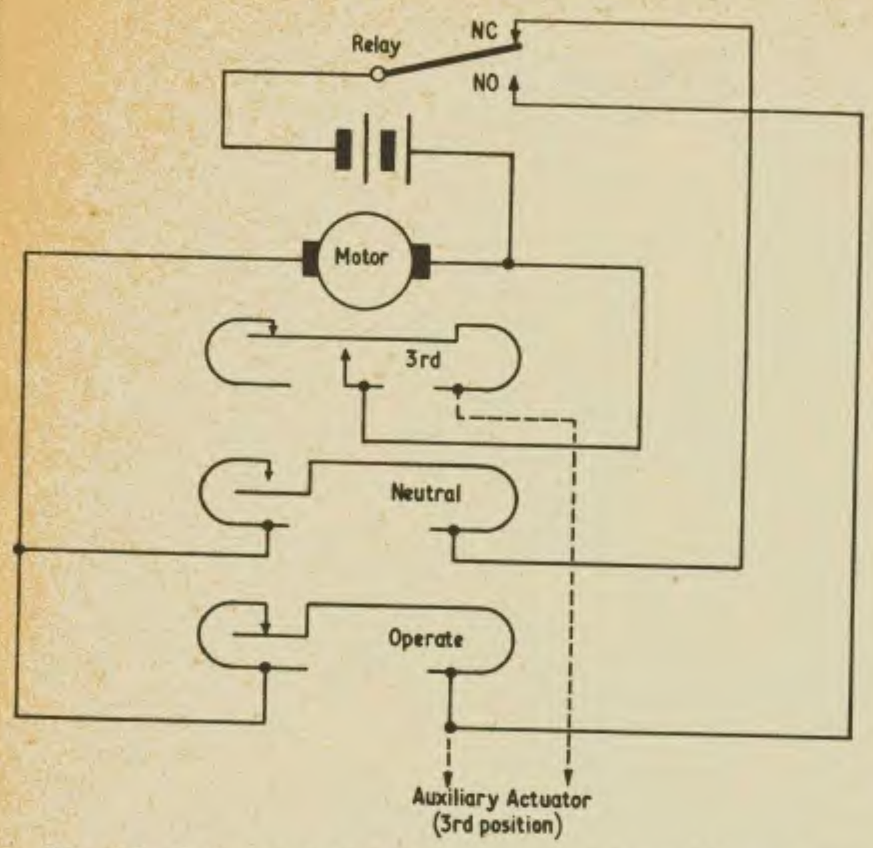


Fig. 4.8. Schematic diagram of 3-position self-neutralising contacts which would be actuated by copper strips on a drum attached to the motor shaft

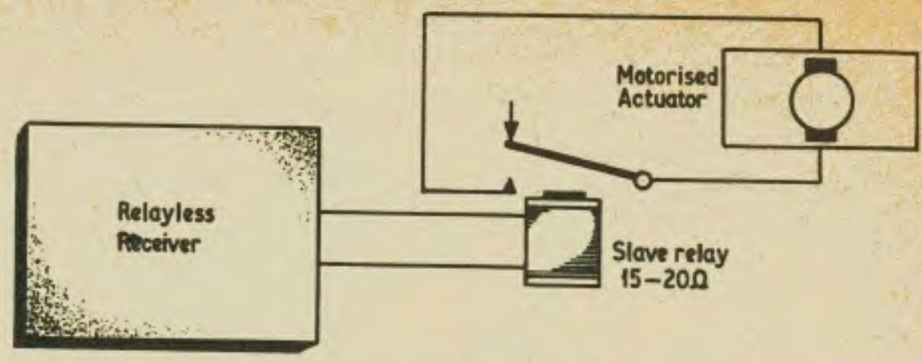


Fig. 4.9. A slave relay employed by a relayless receiver to operate a motor driven actuator

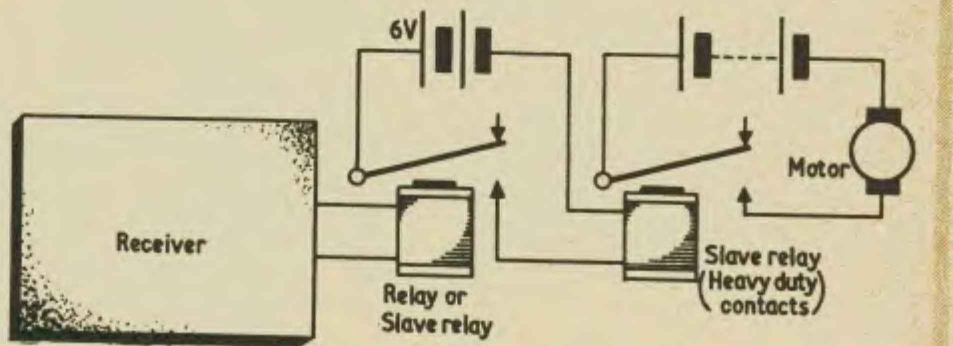


Fig. 4.10. A second slave relay employed here to switch a heavy current motor

identical sequential movement to an escapement output with self-centring action. This type of movement is characteristic of all conventional single-channel actuators, whether motorised types or escapements.

The design of suitable switching circuits—usually copper strips on a disc or drum on the output spindle and sweep brushes—provides an interesting exercise in ingenuity; especially when "compound" action and "third position" or "quick blip" auxiliary switching is also provided (see Fig. 4.8).

Motors employed are invariably of the sub-miniature permanent magnet type and need to be of high quality for consistent performance. In particular the commutation must be extremely good, as satisfactory working of a motorised actuator is dependent on consistently low brush resistance. Motors of this type have a nominal coil resistance of only a few ohms and are usually designed for 3-volt working. Current consumption varies with load, ranging from 100 to 200 milliamperes free running to 1 ampere or more when stalled. Free running (no load) speed may be as high as 8 to 10,000 revs/min; in order to utilise the motor at moderate levels of current consumption, reduction gearing is invariably employed between the motor spindle and output spindle. Even so the motor is only run in short bursts on actuator duties, so mean current demand can be as high as 500mA in some cases.

This has no significance when the motorised actuator is switched by a relay receiver since the separate actuator battery can be selected accordingly. Current demand is, however, higher than that normally available from the output of a relayless receiver; the variations in current demand with load-speed can interfere with the circuit operation of such a receiver. When using a motorised actuator with a relayless receiver, therefore, it is normally necessary to separate the two circuits.

This is done by employing a slave relay as the output load for the relayless receiver, utilising these relay contacts for switching the separate actuator circuit (Fig. 9). This is, in fact, the physical equivalent of a normal relay receiver hook-up, the only difference being that the relay coil resistance required is of the order of 15 to 20 ohms. The type of relay employed is otherwise identical to that used with a relay receiver, operating at a similar ampere-turns figure. The number of turns in the coil is substantially reduced and the current carried very much higher to compensate; it may be of the order of 200mA as opposed to the 3 to 4mA operating current for a receiver-type relay.

CURRENT RATINGS

All actuators designed for single-channel radio control do not demand operating currents higher than the safe carrying capacity of standard sensitive relay contacts, although arc suppression may be desirable, or even essential (see later). In certain cases, however, it may be required to switch much higher currents by the receiver, for example, a fractional horsepower motor.

In such cases it becomes essential to employ a heavy-duty slave relay isolating the receiver, the contacts of which are rated in accordance with the final circuit demand. In the case of a relay type receiver the heavy-duty slave relay is switched by the receiver relay and has its own separate battery supply; the final circuit switched by the slave relay contacts has its own separate power supply, which may be a heavy duty battery or even a mains power supply unit (Fig. 10). With a relayless receiver it is unlikely that the output will be sufficient to operate a heavy-duty relay direct so an intermediate slave relay matched to the receiver output must be employed, switching the heavy-duty slave relay coil circuit.

To complete a practical system further switching facilities will normally be required in the final circuit. With single-channel signalling the motor can only be driven in one direction for as long as a radio control signal is held on, and stop when that signal is released.

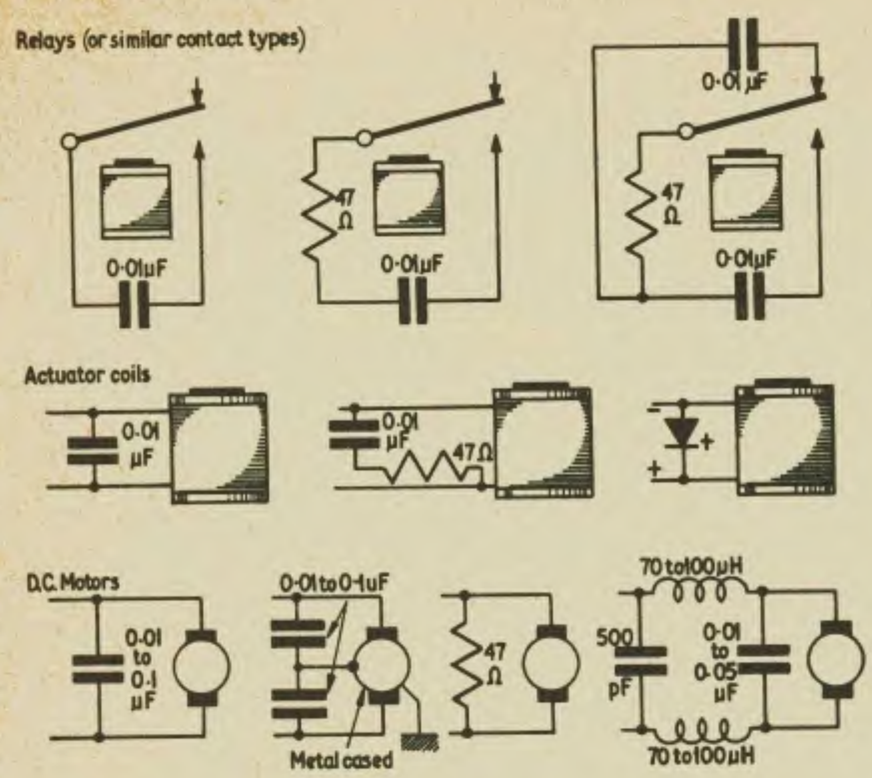


Fig. 4.11. A selection of interference suppression circuits for relay contacts, actuator coils, and d.c. motors using capacitors, and/or inductors

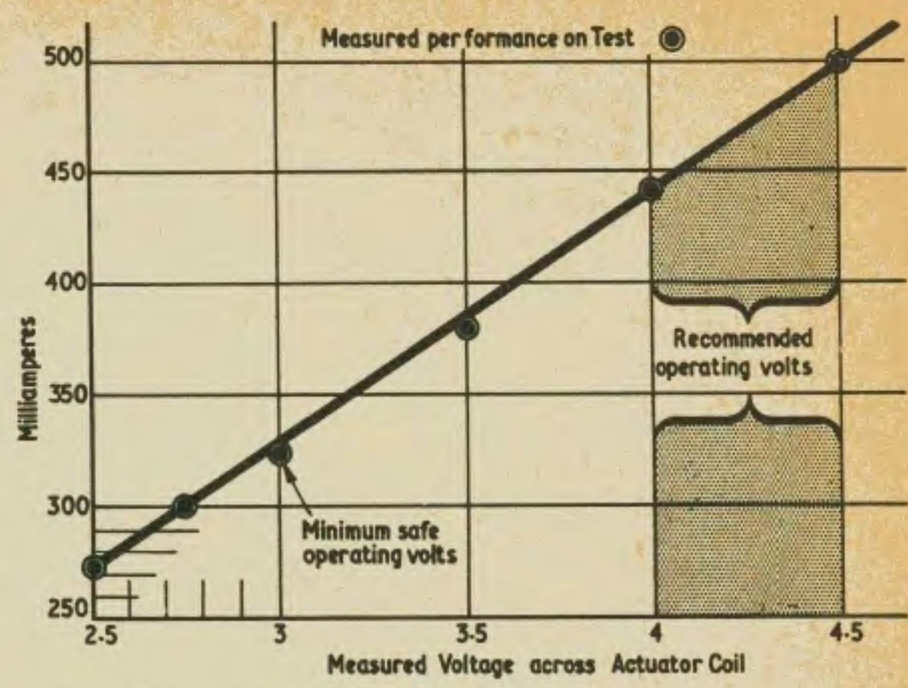


Fig. 4.12. Typical performance of a simple escapement using a 9 ohm coil. Where higher operating voltages are recommended with low coil resistance, a switch should be used to introduce extra series resistance to reduce the "hold" current. This method, at one time favoured, has now been largely abandoned in favour of improved actuator design and construction, resulting in lower operating currents and voltages

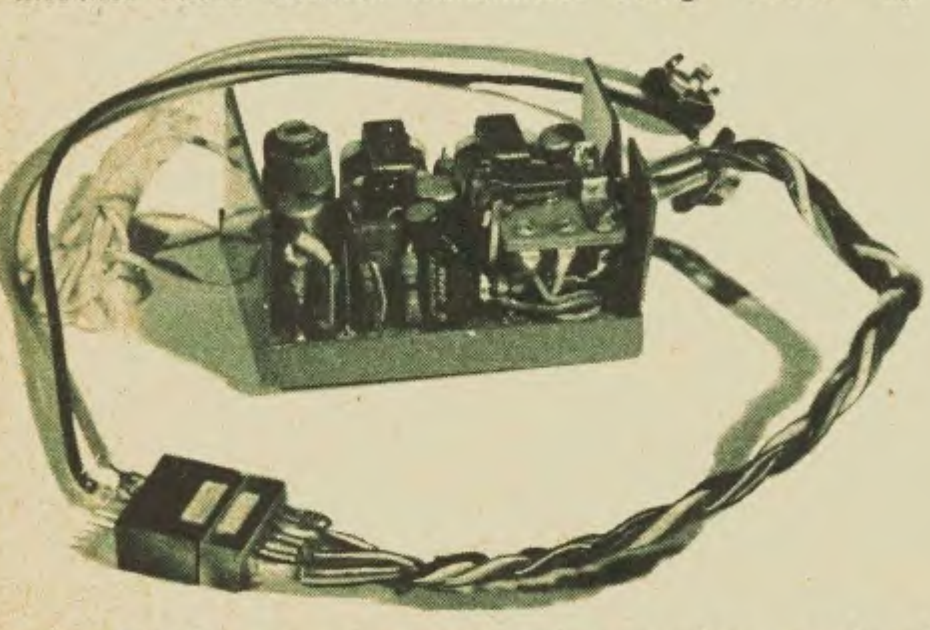
Table 4.2: SINGLE CHANNEL ACTUATOR DESIGNATIONS

Designation	Number of stopping positions	Self-neutralising
2P	2*	No
2PN	2*	Yes
3PN	3	Yes
4P	4	No
4PN	4*	Yes

* Normally equally spaced, i.e. diametrically opposite

INTERFERENCE SUPPRESSION

Some control systems utilising a simple single-channel radio link may be prone to interference by other radio signals. Thus one operation may be triggered by another radio control transmitter being "tested" by a modeller nearby. There is also the possibility of interference, and hence activation of the working system, by other stray signals in the 27Mc/s band. It is generally advisable to operate such systems with a superhet receiver which will respond only to the particular "spot" frequency of its own matched transmitter.



A 27·120Mc/s spot-frequency relay receiver produced by Futaba, Japan. The multi-way connector in the foreground connects the actuator circuit and battery to the receiver

Interference between individual system elements and the basic receiver is a far more common fault with any radio control set-up and suppression may be essential for satisfactory operation.

Sources of interference or "noise" are numerous. On the electrical side, relay contacts, switching contacts and electric motor brushes are all potential sources of noise. If a coil is connected to a pair of relay contacts, the inductive load will tend to promote a surge of higher voltage on "break", leading to the possibility of arcing at the contacts.

Common methods of suppression are shown in Fig. 4.11, a single capacitor across any set of contacts being the usual solution, although a resistor and capacitor in series across the contacts is better. A diode is also useful for suppressing a coil; or a single resistor for suppressing a low resistance motor. In particularly bad cases, however, a combination of capacitors and chokes may be necessary to produce satisfactory suppression of a "noisy" motor. All the values shown in Fig. 4.11 are consistent with the component elements forming standard radio control circuit components.

Even simple escapements are not free from self-generated interference, one source of "noise" which is commonly overlooked being the rubbing of one metal component on the other, such as the crankpin on the linkage it drives. This can be eliminated quite simply by soldering a length of light copper braid to the output spindle and the body of the escapement, thus ensuring that no potential difference can develop between the separate metallic parts in moving contact.

ELECTRONORAMA

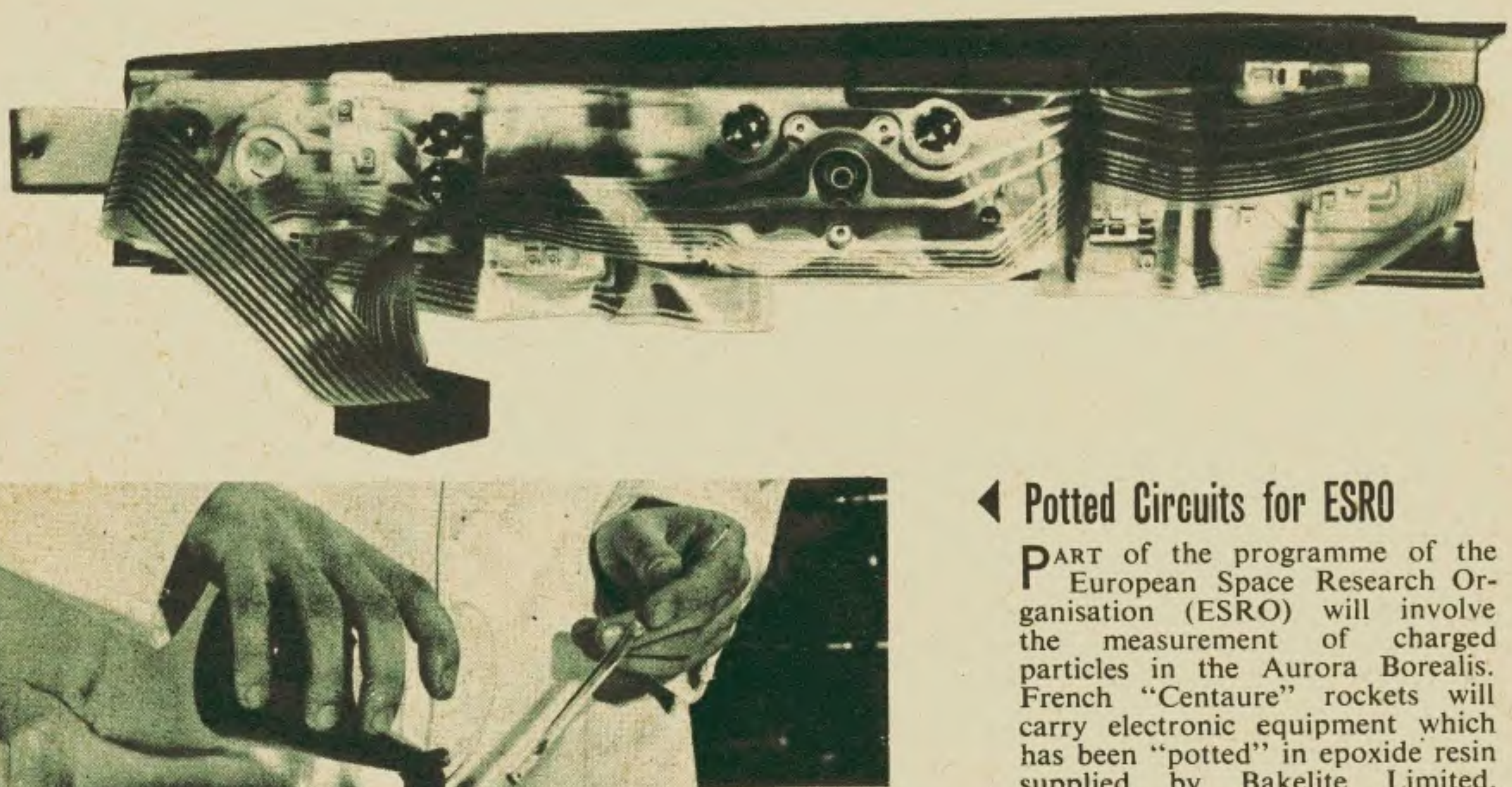
HIGHLIGHTS FROM THE CONTEMPORARY SCENE

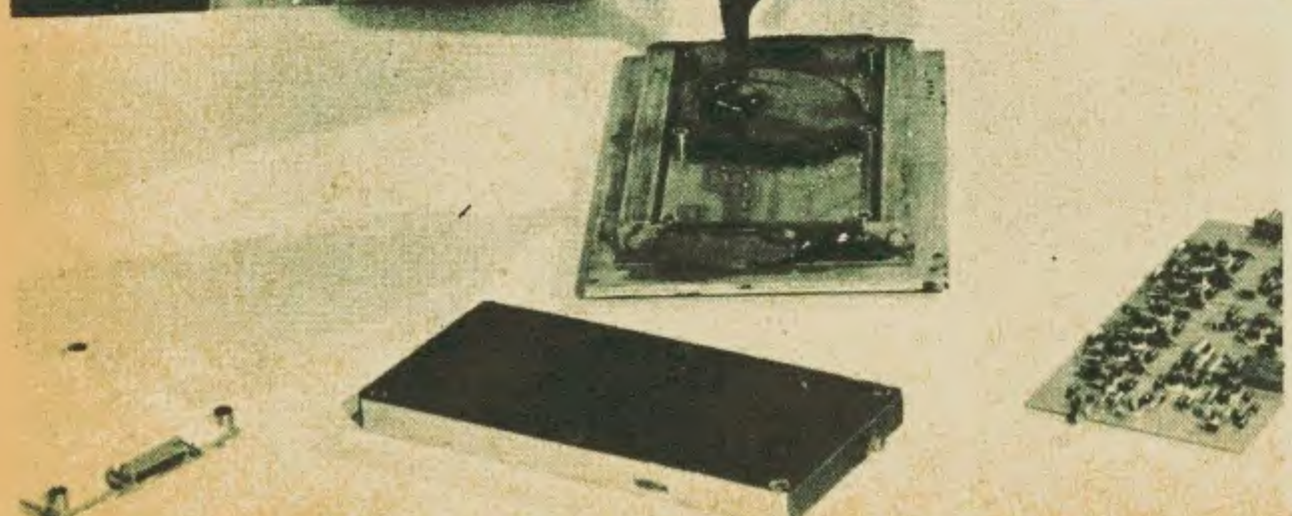
Quality Control

QUALITY control is all important in industry, particularly where precision and quantity production is involved. The diffusion room of Ferranti's Oldham factory (shown left) is used for the oxidisation and diffusion of silicon slices for microcircuits. Etching facilities are shown on the right (behind the pillar); quality control inspection in the centre island and filtration of the photo resist on the left.

Electronics in the Car

THE Motor Accessory Division of Smiths Industries Limited is currently engaged on many new gadgets, both mechanical and electronic, for motor cars. The photograph below shows how car electrical systems and wiring can be produced in flexible printed circuit form for the dashboard controls.

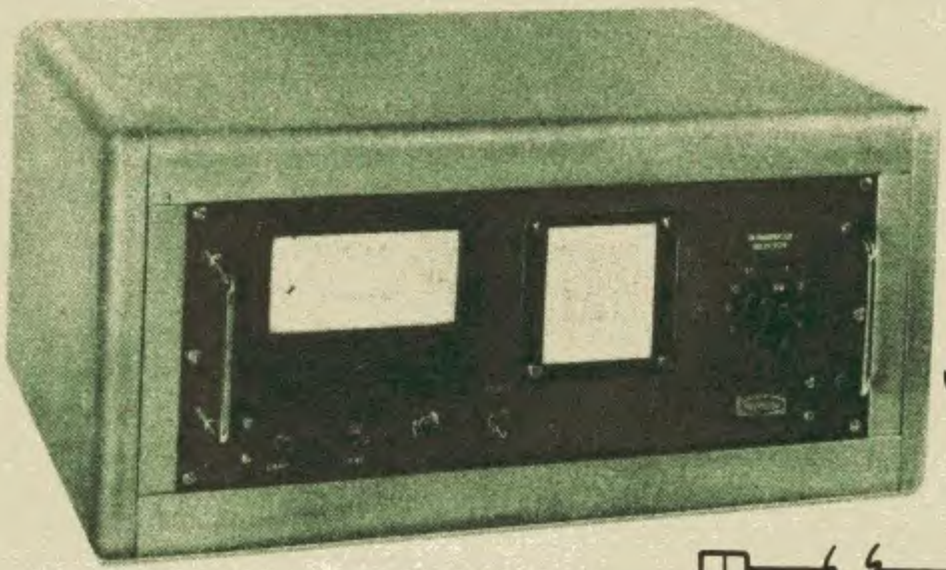


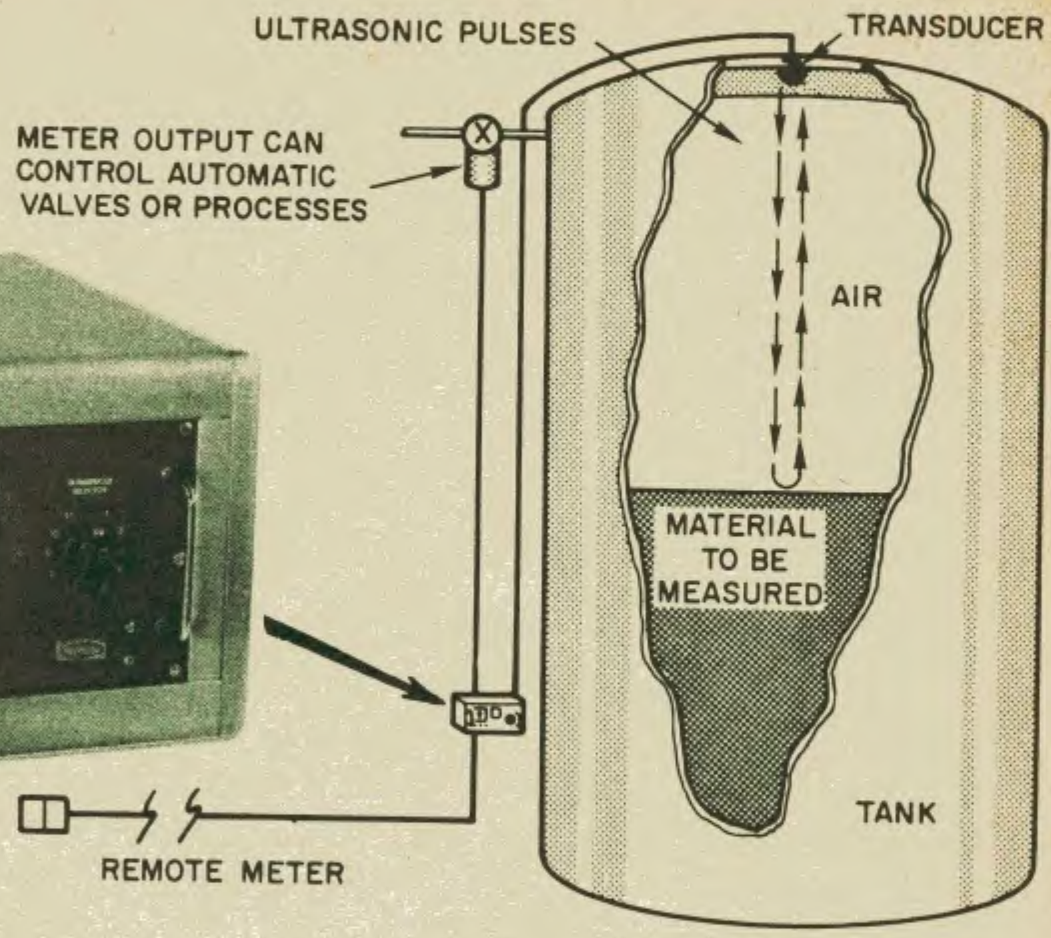


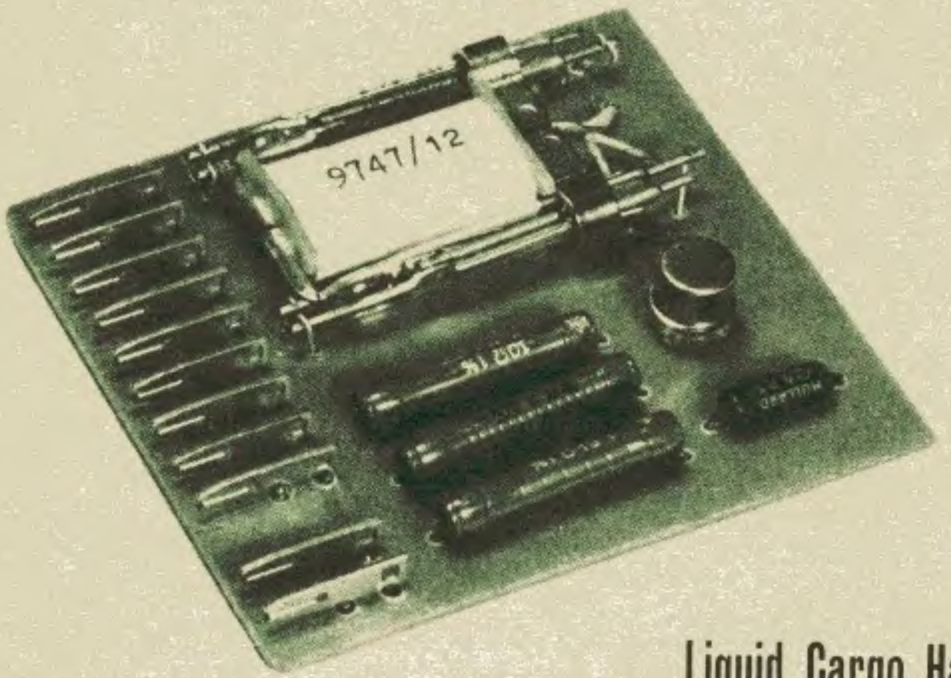
Potted Circuits for ESRO

PART of the programme of the European Space Research Organisation (ESRO) will involve the measurement of charged particles in the Aurora Borealis. French "Centaure" rockets will carry electronic equipment which has been "potted" in epoxide resin supplied by Bakelite Limited. This has been done to reduce the effect of vibration from the rocket and prevent damage from environmental sources. The resin provides a base for spraying a metallic covering, which acts as an electrostatic screen. The circuitry includes 26 transistors mounted on a printed circuit board 7in × 3½in × ½in and will process the signals received for storage prior to transmission to the ground.

ELECTRONIC CONTROL OF FLUIDS







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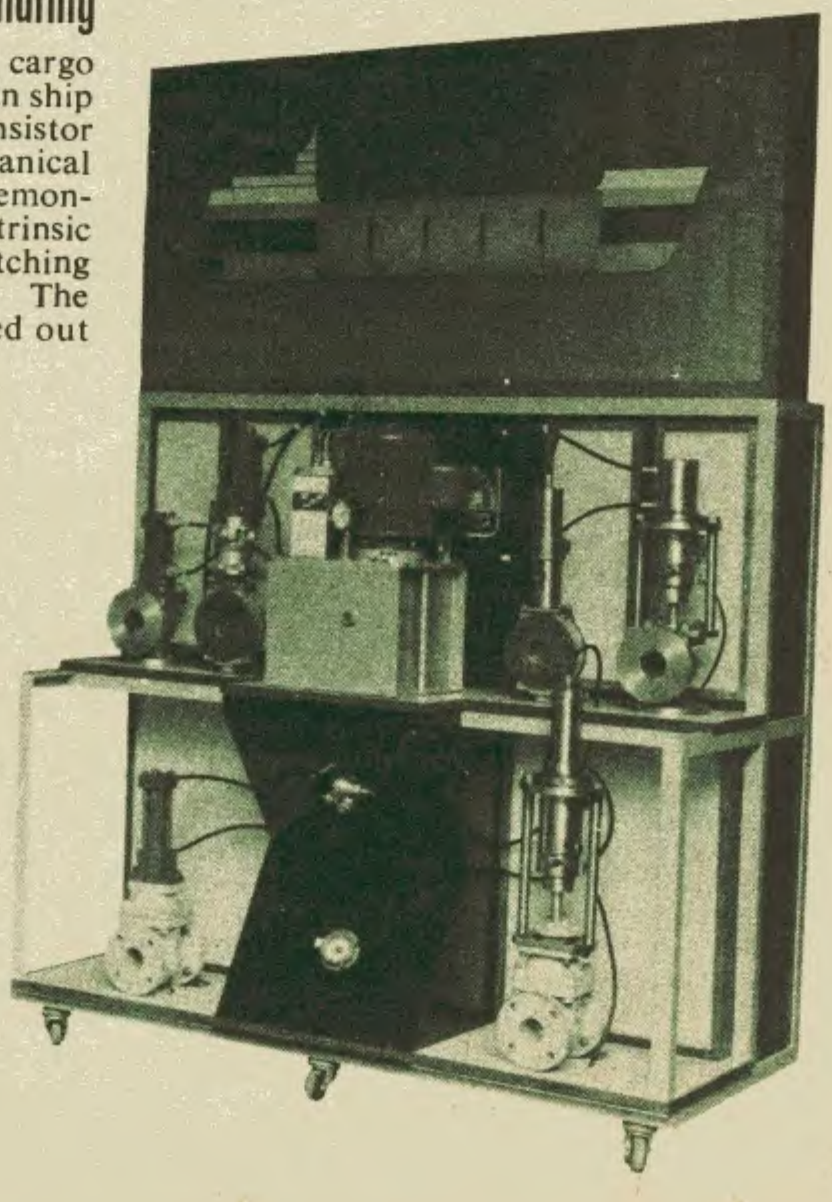
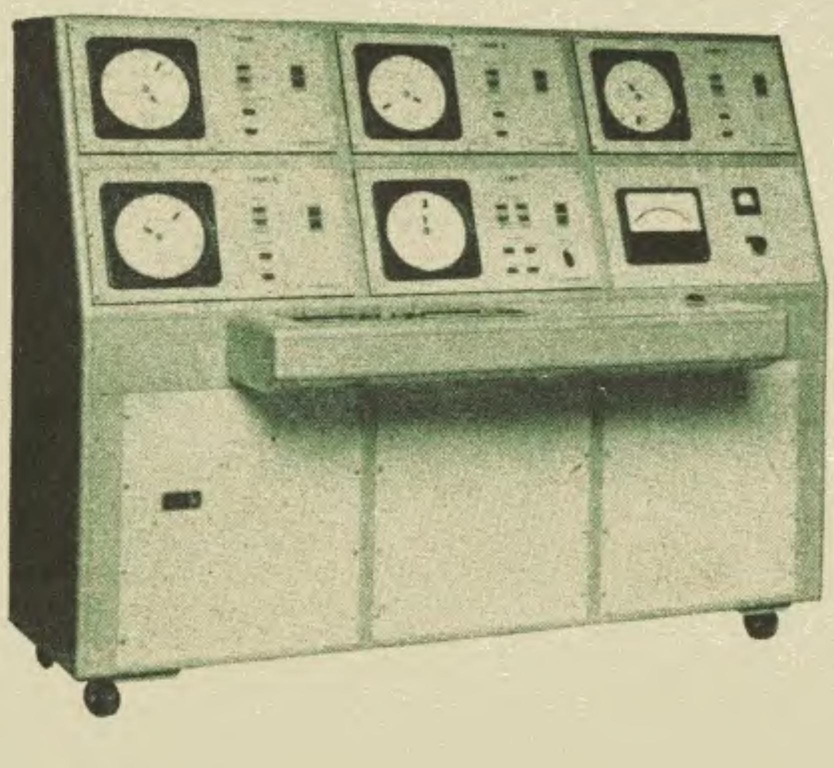
Ultrasonic Level Measurement

AN ultrasonic system for measuring the height of materials in storage tanks, processing vats or conveyors has been developed by Raytheon. Continuous readings are provided by an ultrasonic signal beamed downward from a transducer in the top of the container to the surface of the material. Soundings taken 20 times per second are displayed on a meter (top left) and can be used to control the flow of materials into the container.

Liquid Cargo Handling

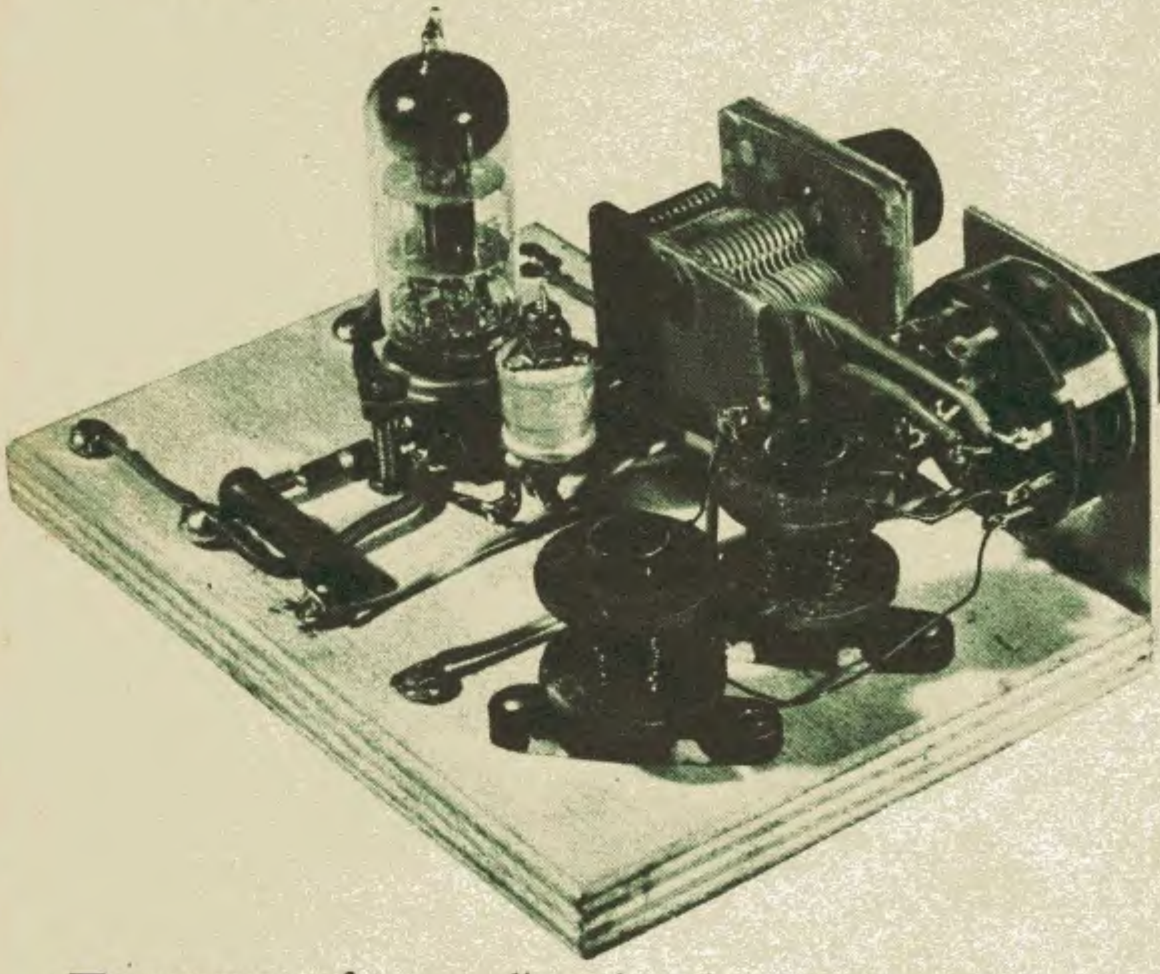
A SYSTEM of automatic loading and unloading bulk liquid cargo in tanker ships has been successfully employed by American ship owners. Tanks in the hold of the ship are controlled by transistor logic circuits using AND and OR gates to trigger electro-mechanical valves via reed relays. The system (illustrated by the demonstration model below) saves manual effort while increasing intrinsic safety, compared with conventional systems. One of the switching circuits is shown above employing a two-pole reed relay. The development and manufacture of the equipment is being carried out by Whessoe Limited of Darlington.





BEGINNERS start here... 19

An Instructional Series for the Newcomer to Electronics



COMPONENTS . . .

Resistors
R1 22kΩ 10% ½W carbon
R2 1·5kΩ 10% ½W carbon

Capacitors
C1 1,000pF paper 350V
VC1 500pF miniature variable, "tuning" type
TC1 3–30pF "Concentric" trimmer

Valve
V1 6J6 or ECC91 double triode

Inductors
L1 20 turns } of 24 s.w.g. enamelled, "pile" wound on *Aladdin* former
L2 100 turns

Switch
S1 Rotary switch, one pole, three way

Miscellaneous
Wooden baseboard. Brass wood screws. B7G valveholder. Two knobs. Two Aladdin coil formers. Two 6 B.A. screws, nuts, spacer collars.

FOLLOWING on from our discussion of the triode valve last month, we now move on to a constructional project employing a "double triode."

A VALVE OSCILLATOR

We describe now a practical use for a thermionic valve, namely, the production of continuous electrical oscillations. This is an example of a device such as a valve converting d.c. into a.c. The oscillator we shall talk about now will enable you to generate your own high frequency signal, and in fact the unit is a form of a useful test device known as *a signal generator*, albeit here much simplified.

Before you start the construction, you might be keen to go over the operation of the circuit, which is only one example of many oscillators possible with thermionic valves. The type we have chosen uses an easily obtainable double triode to provide the amplification needed. All oscillators require *gain* or amplification to keep up the steady output. Thus valves or transistors are always used. (We include in valves such quaint sounding types of oscillators as "Klystrons" and "Magnetrons", and in "transistors" such as tunnel diodes, in case you have heard of them.)

ELECTRICAL PENDULUM

One of the most important parts of most *single frequency* oscillators such as the one described here, is the *tuned circuit*. This has the remarkable property of acting as an electrical pendulum, as it were, and like the mechanical pendulum it has a well defined vibration rate, and also if left to itself the vibrations die away in exactly the same way.

In the case of a pendulum in a clock, the energy in the wound spring "kicks" the pendulum slightly each swing, thus keeping up the swings. How is it that the vibrations (or *oscillations*, as we say) of the tuned circuit arise? To get an idea of this, we must look back to how inductors and capacitors work.

In article 4 we saw how energy is stored in a charged capacitor, and in article 10 we noticed that energy is stored in the magnetic field around a coil carrying current. If we combine these two components, the energy stored in one (let us assume someone has already charged the capacitor), passes over to the other, then back again, ad-infinitum. That is, if no resistance were present.

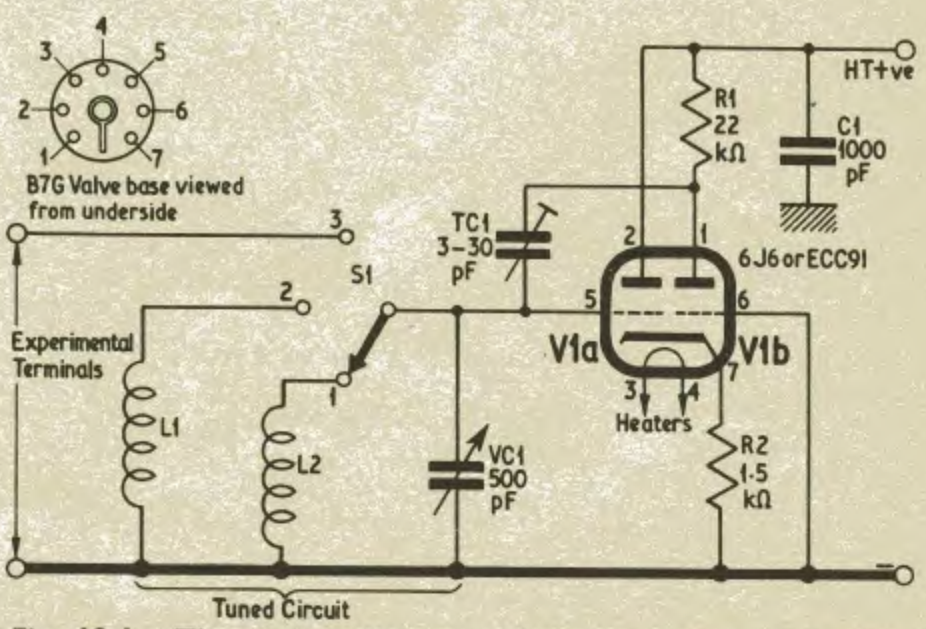


Fig. 19.1. The circuit diagram of the oscillator. The third inductor L3 can be connected across the experimental terminals (see text)

In fact, the amplitude of the oscillations die away because of resistance. This is where the valve, with its amplification, comes in. We arrange the valve such that the oscillations in the tuned circuit act as a signal which is first amplified, and then fed back *in step* with the original in the tuned circuit, thus keeping up the amplitude continuously.

THE CIRCUIT

Of course, the rate at which the oscillations are produced (the frequency) would be expected to depend on the sizes of the inductor and capacitor. This is found to be so, and in our oscillator (Fig. 19·1), the size of the coil or inductor L1, L2 or L3 can be changed using the switches, and the variable capacitor VC1 can be continuously changed by turning the knob. One coil has been chosen to cover the medium wave radio band, that is, from about 525 to 1,600 kilocycles (kc/s).

The oscillations applied to the grid of the first triode section V1a (pin 5) from the tuned circuit are passed to the second half of this valve V1b via the cathode (pin 7), which has a common load resistor R2.

V1a is known technically as a *cathode follower* stage. V1b receives the signal at the cathode, and because the grid (pin 6) is earthed, the signal is amplified and appears, larger, at the anode (pin 1). The name given to the second triode section V1b is a *grounded grid amplifier* stage. The signals at V1b anode are fed back through the trimmer capacitor TC1 so boosting the oscillations in the tuned circuit.

CONSTRUCTION AND USE

Following our simplified construction method, the unit is made on a wooden baseboard. It is best to solder the parts and leads onto the valveholder before mounting it. This is performed using two 6 B.A. screws about 1in long. Spacer collars are fitted on these screws and so the valveholder is held above the wooden baseboard. When this is done, and the inductors and variable capacitor are mounted, the final assembly can be completed by carefully soldering up the circuit leads to the appropriate screw head terminal points.

The inductors or coils are wound on formers known as "Aladdin" types, and these can be obtained at most electronic component shops. Number of turns required is given in the components list.

Anchor the ends firmly so that the coil does not unwind. A thin coat of varnish is also useful to keep the turns in place.

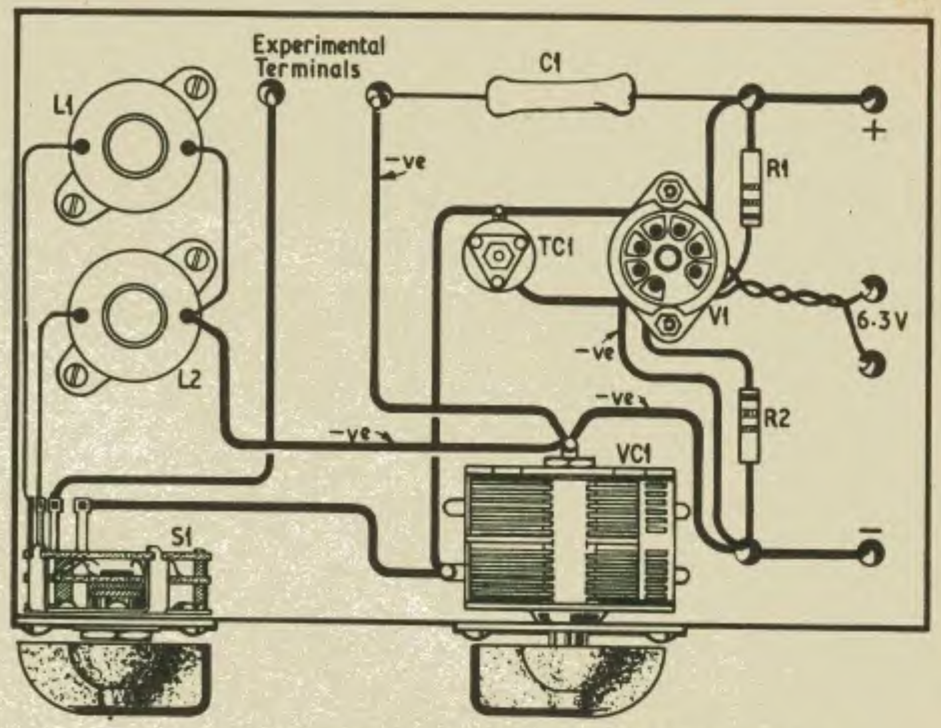


Fig. 19. 2. Arrangement of components and wiring

The switch S1 has three positions: two are used for the inductors L1 and L2, and the third brings into circuit the experimental terminals, across which you can connect any coil you have. An old loudspeaker transformer winding was connected across in the unit we built, and a loud whistle was produced in earphones connected to the other winding, showing that oscillations were being produced within the audio range.

The oscillator is used in conjunction with the filter unit and the power supply unit previously described in this series.

Connect up the valve heater terminals to the 6 volt a.c. supply on the power unit. Connect the positive h.t. lead to the appropriate filter terminal, and also the negative sides of course. Switch on the power unit, and notice that the valve lights up. Select the 100 turn inductor, and with a medium wave radio receiver operating nearby, slowly tune the oscillator capacitor VC1. The signal being produced by the oscillator unit should now be heard from the receiver as a loud "swish". Check the coverage possible and you could mark the frequencies at various knob positions, as checked against the broadcasting stations.

Do not try to connect an aerial to the oscillator to radiate a stronger signal. This may cause great interference nearby, and besides is ILLEGAL. The unit is meant as a piece of test equipment, NOT a transmitter, and is in fact very unsuitable for this purpose. It would be very antisocial for an experimenter to deliberately try to set up interference. Also, be careful of the h.t. points. As you know, the value of potential, although not high, is sufficient to give a shock.

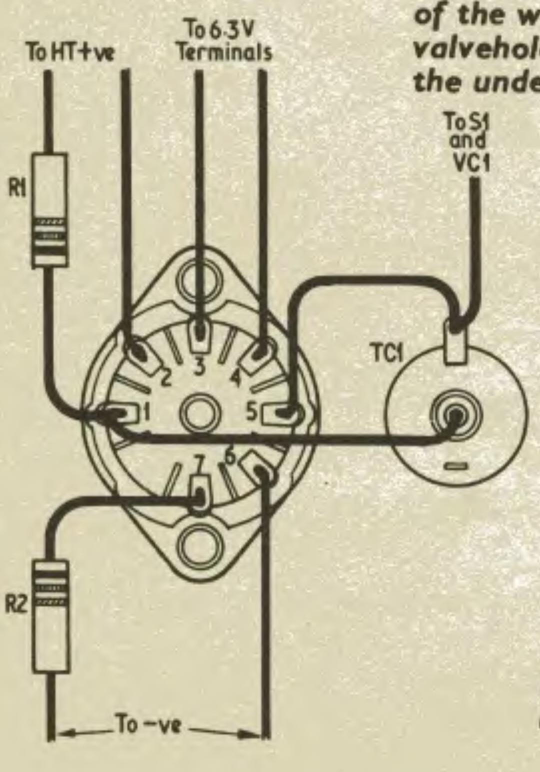


Fig. 19.3 (left). Detailed diagram of the wiring associated with the valveholder, which is viewed from the underside

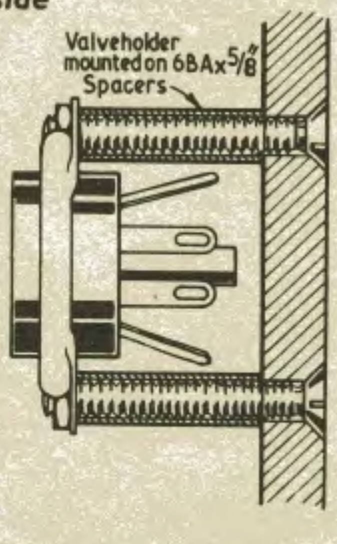


Fig. 19.4. Method of mounting the valveholder on the baseboard

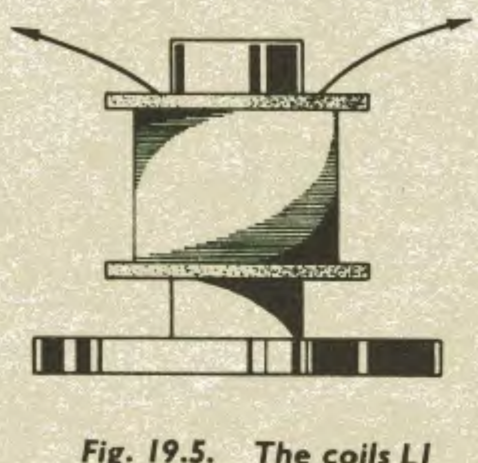


Fig. 19.5. The coils L1 and L2 are wound on Aladdin formers as shown here

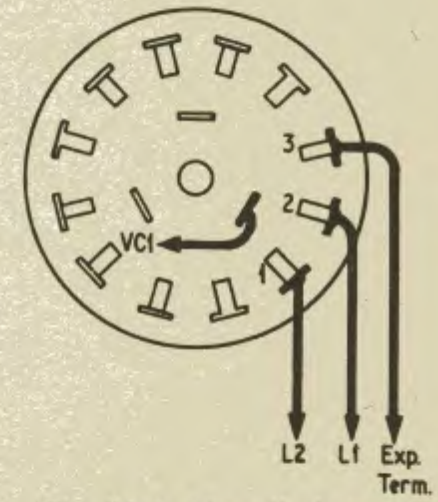


Fig. 19.6. Detailed view of the switch wiring

the 73 page by Jack Hum G5UM

"Very" and "Ultra"

We concluded last time, in reviewing the various high frequency areas allocated to the Amateur Service, with the observation that all six of these lumped together would fit comfortably into just *one* of the amateur u.h.f. bands.

What are these allocations above the h.f. band spectrum that seem to provide so much room to move, and how do they behave?

The *very* high frequencies are accepted as beginning at 30Mc/s, or 10 metres, and extending to 300Mc/s. Beyond that occur the *ultra* high frequencies. The "very's" and the "ultra's" have a common characteristic: their propagation obeys a general line-of-sight law.

Even at 10 metres, the 28Mc/s amateur band, which is not v.h.f. at all, this law prevails for a considerable part of any 11-year sunspot cycle, to be dramatically disrupted when "openings" occur. Then is torn aside the veil of silence that normally prevents penetration of a signal beyond the horizon as the ionised upper layers of the atmosphere, arranging themselves to allow reflection, carry transmission to enormous distances.

"The Bands Open"

These phenomena, very familiar on 28Mc/s, persist to a decreasing degree on each of the successively higher frequency bands.

But it is not only the effect of the sunspot cycle that produces these openings: temporary ionisation of patches of upper atmosphere regularly opens up the v.h.f. bands far beyond the customary horizontal limit for anything from a few hours duration to several days. What is more, the imminence of such openings can almost be sensed by experienced v.h.f. operators, to whom the sight of a clear sky accompanied by a high pressure weather system is a sure encouragement to make for the operating desk and see if "the band's open".

"Four, Two and Seventy"

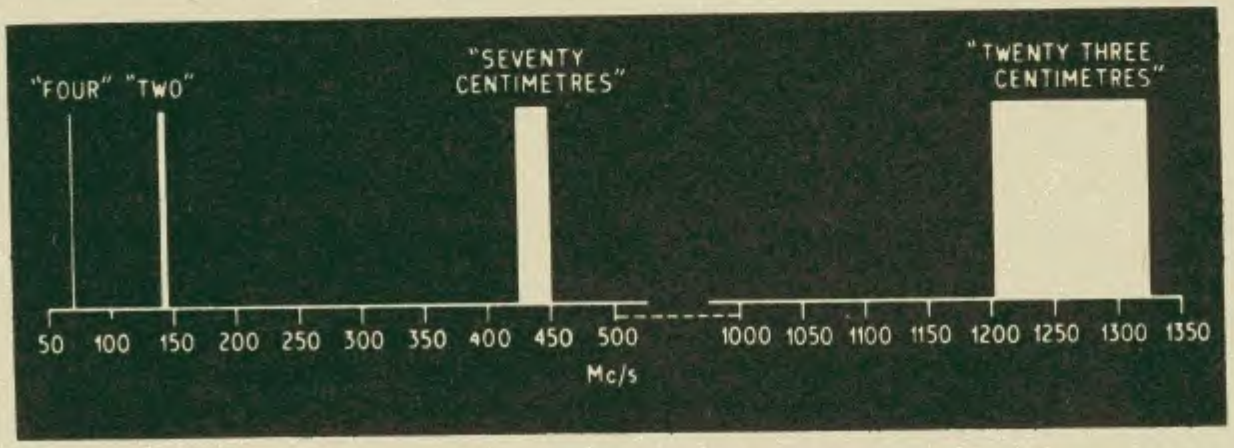
Reminding ourselves, now, that v.h.f. starts at 30Mc/s means that for the purpose of the present review we can omit the 10 metre band as being the "highest of the highs" and accept the four metre band as being the "lowest of the very highs".

The so-called four metre band although open to the British amateur service for many years was sparsely occupied for two very good reasons: first, that continental amateurs did not share it, and secondly that only a narrow band was assigned.

North Country users at the top of the band and all West Country users at the bottom, then a listener need only tune that portion of the 144–146Mc/s assignment which interested him. Londoners, Northerners and Westerners would not be scattered at random over 2,000kc/s, but would be neatly segregated into smaller and more convenient frequency "parcels" much easier to search on a tuning scale.

Quite voluntarily, and in the interests of their own operating efficiency, British amateurs adopted this planning of their two metre band many years ago and have adhered to it ever since.

Besides reducing the tedium of tuning over a large frequency area,



The diagram shows the relative positions of the four most popular amateur allocations in the v.h.f. and u.h.f. spectrum. There are five further allocations in the centimetric region. Frequencies allotted to the Amateur Service are:

"Four Metres"	*70·1 to 70·7Mc/s*	*"Seventy"*	*427 to 450Mc/s*
"Two Metres"	*144 to 146Mc/s*	*"Twenty Three"*	*1,215 to 1,325Mc/s*

Centimetric allocations:

2·3 to 2·45 Gc/s	*10 to 10·5 Gc/s*
3·4 to 3·475 Gc/s	*21 to 22 Gc/s*
5·65 to 5·85 Gc/s	

Within the last three years the band has been trebled in width and is now tremendously popular. Although contacts with Europe are still not possible (because continental licensing authorities have not opened "Four" to their amateurs), domestic operation is at a very high level, many amateurs having quitted noisy 1·8Mc/s in favour of 70·1Mc/s where a signal-to-noise ratio exists, not the other way round!

"Next up" from the 70·1 to 70·7Mc/s band is the two-megacycle spectrum of 144–146Mc/s, popularly termed "Two", available to British amateurs now for the better part of the last 20 years. This is an international allocation that discloses a high level of continental activity when the aforesaid "openings" extend the band's range far beyond the normal line of sight radius.

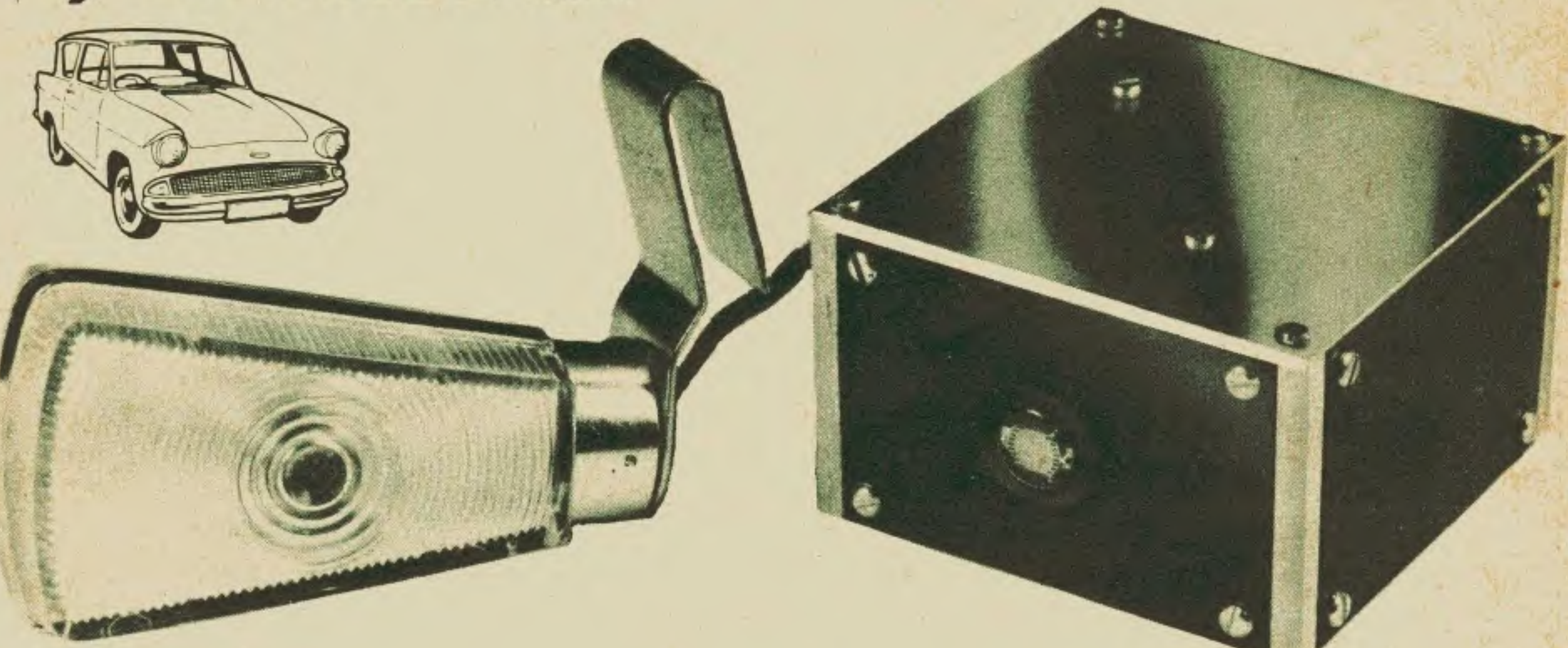
The two metre band is a demonstration ground for one of the most effective examples of self-discipline that exists within the amateur movement. Its great width means that tuning from one end to the other can be a long and tedious business. If, however, it were known that, say, all Home Counties users were to be found in the middle of the band, all

band planning at v.h.f. offers a further advantage: users of beam aerials know in which direction to steer them to receive North, South or West Country stations.

Just as on "Two" so on "Seventy Centimetres" band planning operates on a voluntary basis. But "Seventy" is such a huge band that commonsense dictates that only a portion of it be used for communication work. Custom now has it that the 432 to 434Mc/s segment be used for this purpose, reserving the upper part of the allocation for wideband activities such as television. More about this next time.

L.D.R. PARKING LIGHT

by B. DANCE M.Sc



An automatic parking light is one which switches itself on automatically at dusk and switches itself off again in the morning. The parking light described here is controlled by the amount of light falling onto a photoconductive cell. Many automatic parking lights contain a relay which is operated from the photocell; such a relay can be used to switch on the side lamps, rear lamps and the number plate lamp of a vehicle. The circuit described in this article does not employ a relay and reliability should therefore be improved, but it cannot be used to control these lamps directly. The circuit can, however, be constructed into a self-contained, small automatic parking lamp which clips to the side window of a vehicle. Attention must, of course, be paid to the law regarding such single parking lights, inside and outside the Metropolitan Police area.

The circuit described is suitable only for use in vehicles with 12 volt electrical systems.

DESIRABLE FEATURES

It is desirable that negligible current should be taken from a car battery during daylight by the unit. The circuit described consumes a current of less than 50 microamperes when the photocell is illuminated; this is quite negligible.

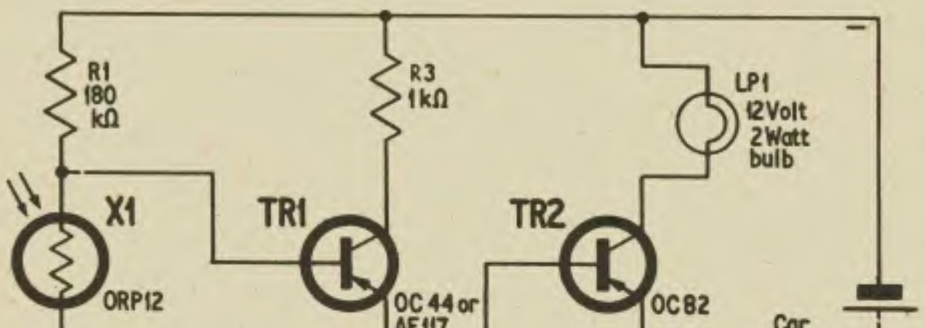


Fig. 1. Circuit diagram of the parking light unit

In addition it is desirable that almost the whole of the power consumed by the parking light at night should be used to heat the filament of the bulb. In the unit to be described the bulb is rated at 12 volts 2 watts, and is designed to consume 166mA. Of the 12 volts applied to the circuit, almost 11 volts appears across the bulb. This slight under-running of the parking light bulb should prolong the life of this bulb appreciably. This is an important point, since a burnt out bulb can lead to legal proceedings. Almost the whole of the current taken passes through the filament of the bulb.

CIRCUIT

The circuit of the automatic parking light is shown in Fig. 1. When light falls on the ORP12 photoconductive cell, the resistance of this cell falls from about 10 megohms to about 150 ohms. The 180 kilohm resistor R1 and the photoconductive cell act as a potential divider. When light falls on the cell, the potential at the junction of the cell and R1 becomes more positive. This change in potential is applied to the base of the transistor TR1 which is connected as an emitter follower. Thus the current in the collector-emitter circuit of this transistor falls and the voltage across the emitter resistor of the transistor is reduced almost to zero. This fall of potential across R2 is applied to the base of TR2. The current through this transistor also falls, thus causing the 12 volt bulb to be extinguished.

The transistor TR1 should have a high current gain. The types of transistor suggested are radio frequency types, but a high gain audio frequency transistor would be equally suitable. TR2 is an audio frequency type designed to be used in low power push-pull output stages. *It should be mounted on a heat sink* for thermal stability. This transistor will not pass a high current except after dark, therefore thermal runaway is not likely to occur in such a normally cool atmosphere. The unit should be kept away from a warm engine at all times.

The photoconductive cell must be placed in a shielded position, facing downwards, so that it is not affected by the street lighting. It may be necessary to carry out a few experiments to check that the circuit operates at the desired level of illumination. If, however, it is desired that the parking light shall not come on until the street lighting is extinguished, the photoconductive cell should be pointed towards the nearest street lamp. Again, check on the local laws governing this point first.

It is suggested that constructors obtain one of the non-automatic single parking lights which are designed to be clipped onto the side window of a car and which show a white light to the front and a red light to the rear.

COMPONENTS . . .

Resistors
R1 180kΩ
R2 680Ω
R3 1kΩ
R4 8·2Ω
} All 10% ½ watt carbon

Light Dependent Resistor
X1 ORP12 (Mullard)

Transistors
TR1 OC44 or AF117
TR2 OC82
} (Mullard)

Parking Lamp
LP1 12V 2W with appropriate mounting (e.g. Delite Accessories Ltd., 146a Queen Victoria Street, London, E.C.4.)

Miscellaneous
8-way component group board and backing plate
Cooling clip for TR2
Grommets for ½in and ⅜in holes
Box made up from "Masterbox" kit no. Mk/233 (Cockrobin Controls, 36 Villiers Avenue, Surbiton, Surrey)

FITTED IN THE CAR

This circuit has been found to give extremely reliable operation. If the unit is well constructed, a burnt out bulb is the only likely cause of failure. If there is some other reason which causes a fault, however, the voltage across the 680 ohm emitter resistor of TR1 should be measured in light and darkness. This potential should be about 2 volts when the ORP12 photoconductive cell is in darkness and should fall almost to zero in normal daylight. If these potentials are correct, any fault must be in the circuit of TR2 or in the connections to the bulb.

Various thoughts will come to mind on installing this unit. Normal daylight has to reach the ORP12, but one does not want to expose the unit to potential thieves. This is why the actual lamp and electronic circuitry are two separate units; otherwise the thief could pilfer both together. The box should be inconspicuously situated away from the engine. Some readers may like to fit it on the inside of the boot, for example, with the ORP12 fitted to the body of the car. Don't forget to shade the ORP12 from street lamps.

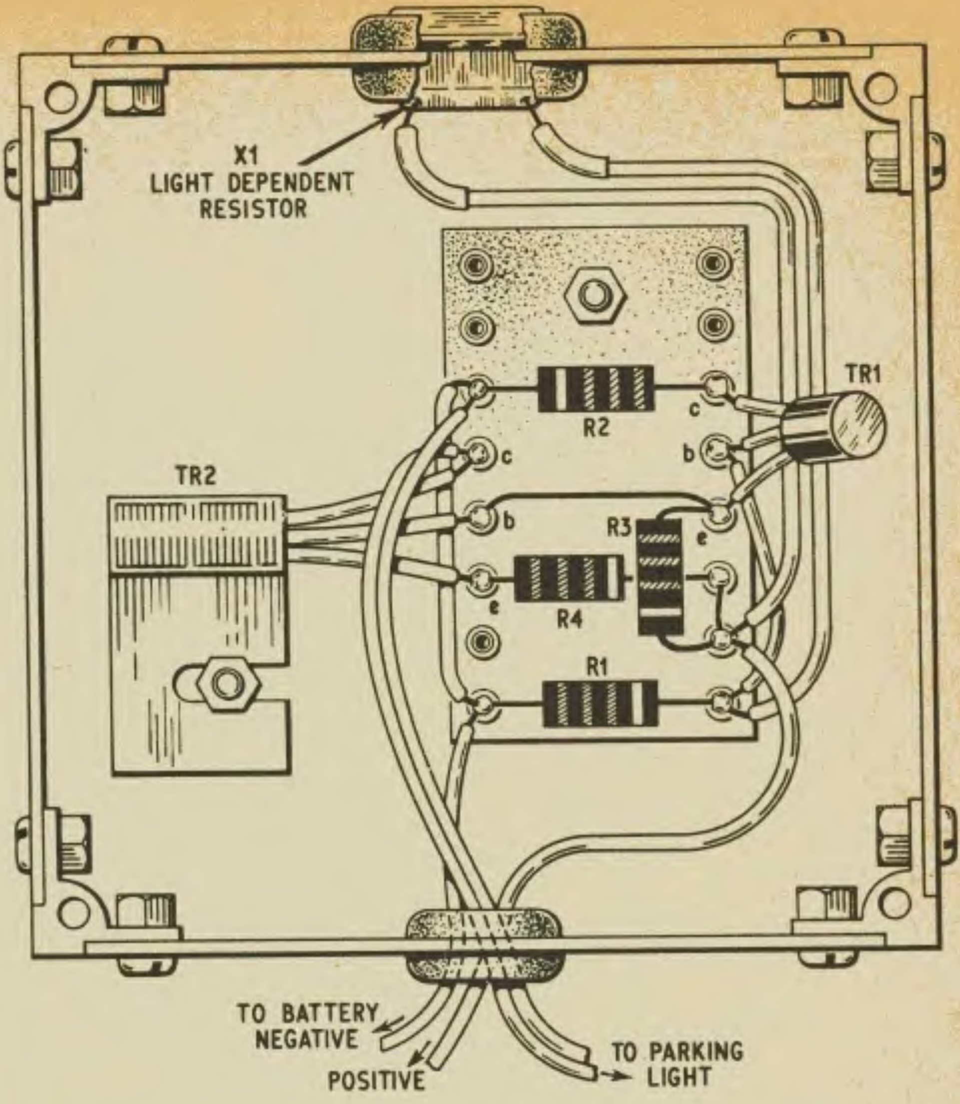


Fig. 2. Layout of components and wiring in the box. Notice the cooling clip on TR2. The collector wires of both transistors are those nearest the spot on the encapsulations

ASSEMBLING

The entire circuit, apart from the bulb and battery, is housed in a metal box 3in × 3in × 2in although it is possible to reduce this size a little so long as a heat sink about 9 sq in for the OC82 is maintained. The prototype used a "Masterkit" box no. 233 and provided a neat professional finish, although a suitable substitute can be made up from aluminium sheet.

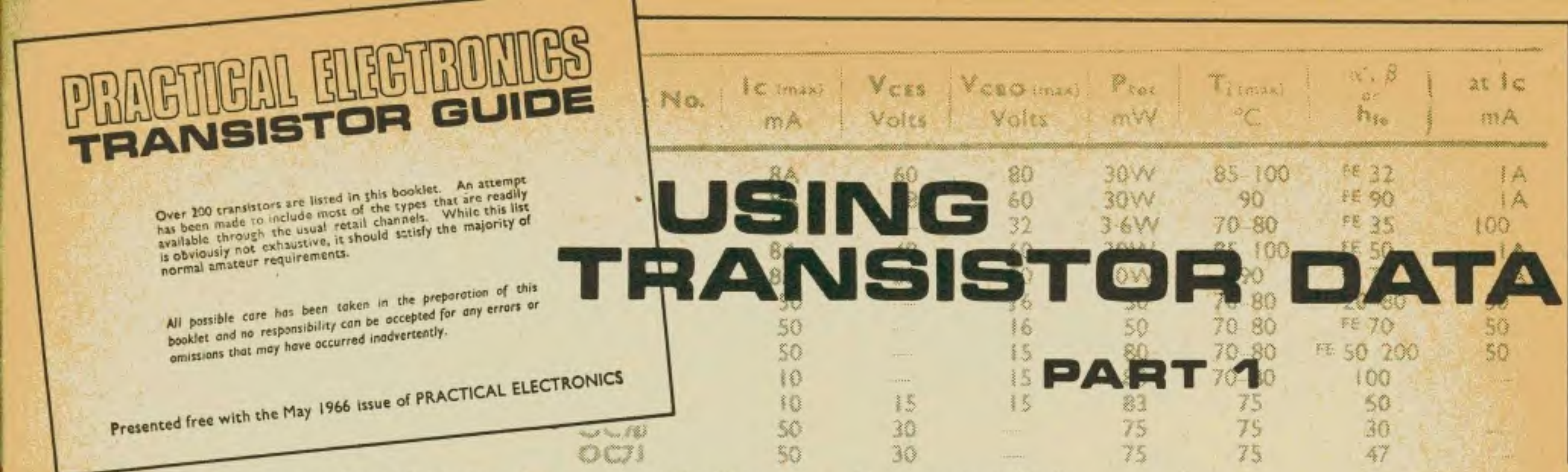
It is best to drill the necessary holes before the box is assembled. One hole (½in diameter) is first drilled centrally in one side. The ORP12 is then pressed into a grommet fitted in this hole, providing a secure mounting. It may be necessary to enlarge the ½in hole a little for a good fit.

Another hole (⅜in diameter) is drilled in the opposite side of the box to take another smaller grommet, providing a lead through for the lamp and battery wires.

The components are mounted on a miniature group board with eight pairs of tags (see Fig. 2). No difficulty in wiring should be experienced if the wiring diagram is followed, since the circuit is extremely simple. All incoming wires are connected directly to the component board as shown. Before soldering the connections to the ORP12, short lengths of sleeving are pushed on to the insulated part of the twisted leads. After soldering, slide these sleeves over the pins of the ORP12 so that they are fully insulated. Use a heat shunt when soldering.

The assembly is fixed in the box with 6 B.A. nuts and bolts through the component board and an insulating backing plate of s.r.b.p. A copper cooling clip is fitted to TR2 and bolted to the box as shown in Fig. 2.

The sides of the box are fitted using 6 B.A. nuts and bolts. ★



USING TRANSISTOR DATA

PART 1

TRANSISTOR operating data can be very misleading to the uninitiated. Incorrect interpretation may lead to disaster. For example, we heard recently of someone who used some expensive "15 volt transistors" in an amplifier worked from a 12 volt battery, only to find that they were destroyed in a few minutes. The transistors were all right: it was the operating conditions which were to blame, and a false interpretation of the operating data. The aim of this article is to help to avoid such catastrophies.

As an example of what can go wrong, take the data on the AC107 transistor, found at the beginning of the Transistor Guide booklet given away with this issue of PRACTICAL ELECTRONICS.

$V_{CES(max)} = 15V$

$V_{CBO(max)} = 15V$

$P_{tot(max)} = 80mW$

$I_{C(max)} = 10mA$

$h_{fe} = 70$ at $I_C = 1mA$

$f_1 = 2Mc/s$

The novice might be forgiven for thinking this to to be a transistor capable of operating at 15 volts, with a collector current of 10mA and having a current amplification of 70 at 2Mc/s. The expert, looking at the same data, will know immediately that this is an audio frequency transistor suitable for operation at low collector currents (1mA or less) and at collector voltages of not more than about 6 volts. He will know that any attempt to operate it at 15 volts, 10mA will end in immediate disaster.

The data are not really misleading, *if you know how to interpret them.* Let's look at the information given in the booklet, and other data supplied by transistor manufacturers, and see how these can be interpreted simply and correctly.

TYPE NUMBERS

The transistor type numbers sometimes contain information in code. Type numbers allocated under the *Pro-Electron* system, which operates in Europe, consist of two or three letters and a number. The first two letters convey information about the transistor, as follows:

First letter
A = germanium

B = silicon

Second letter
A = diodes

C = audio frequency transistor

D = audio power transistor

E = tunnel diode

F = high frequency transistor

L = h.f. power transistor

S = switching transistor

U = power switching transistor

Applying this to the AC107 tells us that it is a germanium transistor for audio frequency applications. Of course, not *all* type numbers belong to this scheme. Individual manufacturers invent their own numbers, and most American transistors just have type numbers like 2N2926, which tells you nothing about the transistor. All the same, many of the transistors made here and on the Continent do bear *Pro-Electron* codes and so their type numbers are meaningful.

COLLECTOR VOLTAGE RATINGS

If the base current of a transistor is kept constant, but the collector voltage is gradually increased, it is found that after an initial sharp rise the collector current increases only very slightly with increasing collector voltage, until at some high voltage there is a sudden increase. This sudden increase is a danger signal. If the transistor is operated above this voltage, it will automatically pass large currents, even if the base current is zero. The resulting large internal dissipation will destroy the transistor by overheating.

The voltage known as $V_{CBO(max)}$ is the maximum safe voltage which can be applied to the transistor *when the emitter current is completely cut off.* It does not, therefore, represent a practical working collector voltage, but merely a limiting voltage which must not be exceeded even under transient conditions.

Similarly, $V_{CES(max)}$ is the upper limit of collector voltage when the transistor is passing no current to speak of, and the base and emitter are shorted. Again, this is not a practical working condition.

A good rule of thumb is that, if a transistor is used with a collector load resistor, the collector *supply* voltage should not exceed V_{CBO} or V_{CES}. In tuned amplifiers or transformer coupled stages the collector voltage should not be more than half these limiting voltages.

Another maximum collector voltage found in makers' data is V_{CER}. This is the limiting collector voltage, with the transistor cut off, but with a specified amount of resistance between base and emitter. The higher this resistance, the lower the collector voltage which can safely be used. Makers publish graphs showing how V_{CER} varies with base resistance.

COLLECTOR DISSIPATION

In a class A amplifier, with no input signal, the power used up in the transistor is

P_c = collector volts × collector milliamps (mW)

This is the collector power dissipation and must not exceed a given amount under given conditions of temperature.

Low power transistors usually have a $P_{C(max)}$ rating at a given ambient temperature, often 25°C. In the case of power transistors, there are several collector power ratings.

One of these ratings, known as P_{tot}, or total power, is a delightfully unreal quantity. It is the amount of power that you could put into the transistor if it were fitted with an exceedingly efficient refrigeration system which removed all the heat as fast as it was generated, leaving the transistor at room temperature. No heat sink, however large, can achieve this, because there is always a resistance to the flow of heat (a thermal resistance) between the transistor and the heat sink. Thus a transistor with $P_{tot} = 30$W might, on a large heat sink, be able to handle 6W, and without any heat sink a mere 500mW.

In the case of our AC107, $P_{tot(max)} = 80$mW applies when the transistor is operated in free air at an ambient temperature of not more than 25°C. (At 45°C it comes down to 50mW.) We see now that operating conditions of 15V, 10mA would produce a dissipation of 150mW, and on this ground alone do not represent a practical situation.

MAXIMUM COLLECTOR CURRENT

There are two limits on collector currents. One is the average or d.c. value, the other the peak or instantaneous value. So one really wants to know which one applies. As it happens, 10mA is the peak rating for the AC107. The average rating is 5mA (max). Evidently this is a low-current device.

In the case of power transistors, it is important to have a high peak current rating, especially if the transistor is to be used in class B. It is also important, from the point of view of minimising distortion, that the current amplification of the transistor should be the same at the peak current as at lower currents. The maximum collector current of most transistors is limited only by collector dissipation, and provided the collector voltage is reduced, the collector current may be increased. The ultimate limit is then fixed by the "collector bottoming voltage", which is the voltage below which the collector refuses to fall in a practical circuit. Thus, if the bottoming voltage is 1V, and the $P_{C(max)}$ rating is 100mW, then if there is no limit on collector current in the makers' data, this transistor can probably be worked at 100mA.

The symbol I_{CM} is often used for the peak current, and $I_{C\,(AV)}$ for the average or d.c. value.

CURRENT AMPLIFICATION FACTOR

The current amplification factor is the most variable of the transistor characteristics. And, as if to emphasise this fact, it is referred to in the literature by a great number of different symbols, most of which mean virtually the same thing.

In the old days, when the basic circuit connection of a transistor was held to be the common-base (or earthed base, or grounded base) connection, the current amplification factor, in the common-base circuit was known by the Greek letter alpha (α).

When the common-emitter circuit became popular, the corresponding amplification factor was called α' (pronounced "alpha dash"), but simultaneously somebody christened it "beta" (β).

Later, it became known as h_{21e} and nowadays the most popular symbol is h_{fe}.

Of the others, alpha (α) is more or less obsolete. All the others mean the same thing, namely, the ratio of a.c. output current to a.c. input current produced when a *small* signal is applied to a transistor operated in class A, in common emitter mode.

Referring to the data on the AC107, we find that the current amplification factor (let's call it h_{fe} from now on) is quoted as 70 at $I_C = 1$mA. The reader will immediately suspect that it is different at some other current, and he will be right. The AC107 is a low-noise transistor for audio input stages, and in order to keep the noise as low as possible it is often operated at less than 1mA. The full data give $h_{fe} = 40-250$ at $V_{CB} = 5$V, $I_E = 0{\cdot}3$mA.

In the case of power transistors and switching transistors h_{fe} is not a very useful quantity, since the circuit designer wants to know the current gain when the transistor is working at full output, with *large* input signals. So for this kind of application the manufacturers quote the "large-signal current amplification factor" h_{FE}, with the subscript in capital letters. This is defined as the total collector current divided by the total base current.

It is often useful to know h_{FE} for small-signal amplifier transistors as well, since this enables one to work out the appropriate base bias current required to set up the transistor with a given collector current. Thus if $h_{FE} = 100$ at $I_C = 1$mA, then to operate the transistor at 1mA we must apply 10μA base current. If h_{FE} is not known, a useful approximation is $h_{FE} = 0{\cdot}8\,h_{FE}$. This has no theoretical justification, but it is often about right in practice.

The current amplification factor varies from transistor to transistor, with collector current, and with frequency. A casual glance at the AC107 data suggests that $h_{FE} = 70$ at 2Mc/s. In fact, at this frequency $h_{FE} = 1$, or thereabouts.

The h_{FE} is generally specified at a low frequency, usually 1kc/s, even for an r.f. transistor, but remember that it gets progressively smaller as the frequency is increased.

CUT-OFF FREQUENCY

The cut-off frequency has a lot of different names, too. They are: f_α, f_{hfb}, f_1, and f_T. Although these are defined in various ways, the actual frequency is about the same in each case, and it represents something near the upper limit of usefulness of the transistor.

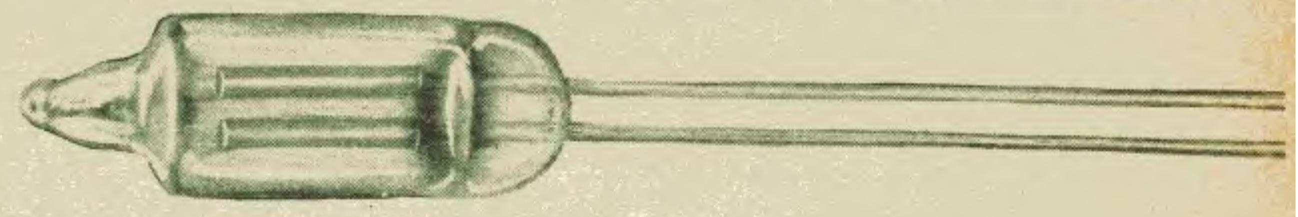
Whenever possible, transistors should be used well below the cut-off frequency. The gain is then high. But in u.h.f. applications it is often necessary to work *above* the cut-off frequency, because transistors with cut-off frequencies above about 1,200Mc/s are not generally available. Under these conditions, more power gain is obtained in common-base than in common-emitter, but the gain is in any case low—usually 10–20dB.

A rather different cut-off frequency is sometimes given in the data for audio frequency transistors. This is the frequency at which the current gain is reduced by 3dB when the transistor is operated in common emitter mode. It is known as $f\beta$ and it can easily be worked out from f_α, etc. and the current amplification:

$$f_\beta = f_\alpha / h_{fe}$$

Thus a transistor with $f_\alpha = 300$kc/s and $h_{fe} = 100$ has an f_β of 3kc/s, which means that it has built-in top cut. This value for f_β may seem uncomfortably low, but it is quite typical for a germanium power transistor.

NEON NOVELTIES



THIS is the ninth of a series of short articles illustrating some of the many uses of neon lamps. The neons employed are all miniature wire-ended types as shown above.

Two examples which are ideally suited to these applications are those supplied by Radiospares (striking voltage 65 volts), and the Hivac type 3L general purpose neons. The latter type requires a striking voltage of 80 volts and maintaining voltage of 60 volts.

Some neon indicators have a resistor wired in series with one of the neon wires to make them suitable for mains voltages. These would normally be unsuitable for the circuits described unless the resistor is removed or short-circuited.

NINE EXTENDED RANGE VOLTMETER

by R. Bebbington, GRAD., I.E.R.E.

VOLTMETERS are sometimes required to measure both high and low voltages on the same range. The high reading may be a fault condition, for example, in the batch testing of components. If no overload trip is incorporated then damage to such a meter will ensue if it is set to a low voltage range.

The simple neon shunt circuit of Fig. 1 provides protection against accidental overloads; furthermore, it is possible to calibrate the scale so that the degree of overload can be read.

Ideally, the neon should be located behind the meter scale as shown. If it peeps through a hole where the extended range starts, its glow will serve to indicate that this extension is operative.

The settings of VR1 and VR2 (Fig. 1) will depend on the meter and neon characteristics as well as the voltages to be measured. If, for example, we require to read voltages in the range 0–120V with possible overloads of up to 300V, the variable resistors can be adjusted so that the neon will strike with an applied potential of about 125 volts. Although the controls are somewhat interdependent, VR1 largely affects the applied voltage at which the neon strikes, whilst VR2 determines the degree of overlap between the scales. The neon will strike lower down the scale (at a lower applied potential) as VR1 is adjusted with the wiper approaching the input terminal of the circuit (i.e. at the "top" in the diagram). If VR2 is decreased, the overlap point where the meter automatically changes range will be increased due to the higher shunting effect. However, too low a resistance will excessively cramp the extended range.

Both variable resistors should be set to approximately mid-point during setting-up to avoid overloading the neon. Optimum settings can best be found by experiment and will depend on the constructor's actual requirement. The author initially made a three-scale version that employed a 0–100 microammeter and two neons. The scales were 0–150V, 140–310V and 300V–1000V. Fig. 2 illustrates the basic principles involved. When the resistance values have been determined the variable resistors can be measured and replaced by fixed resistors of equivalent value.

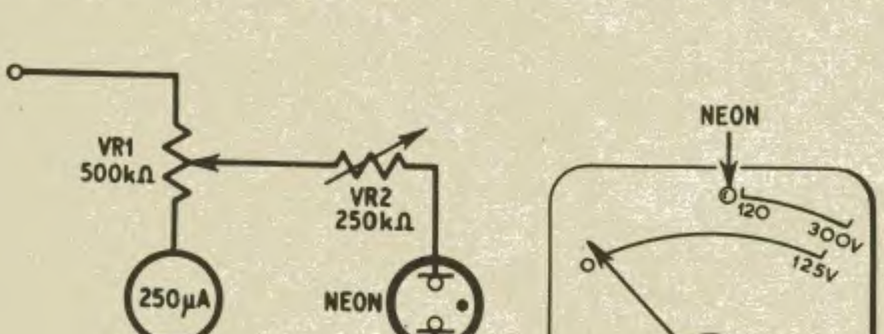


Fig. 9.1. Circuit diagram of the simple two-range extended voltmeter with a sketch showing how the extra range and neon are positioned on the meter dial

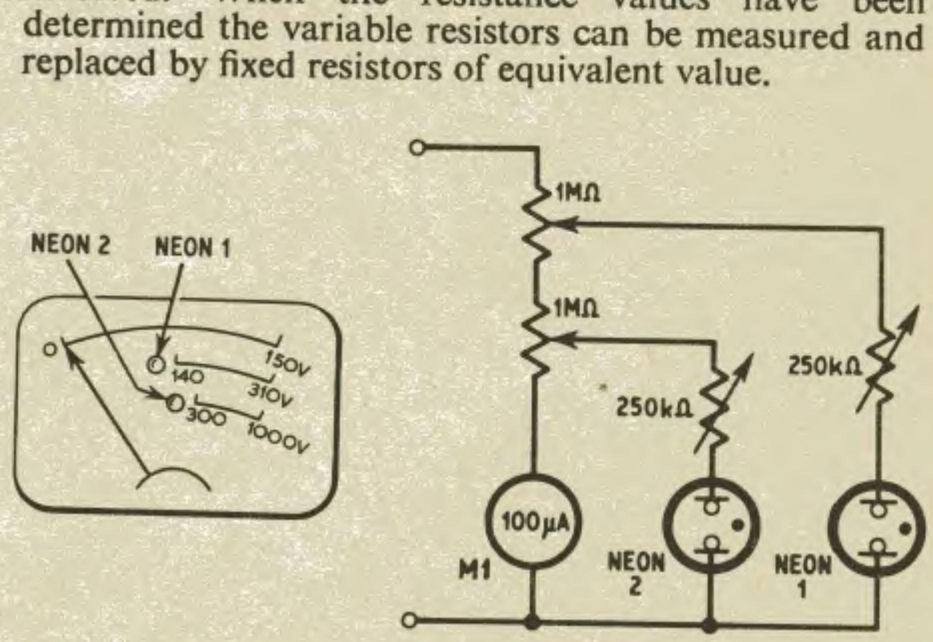
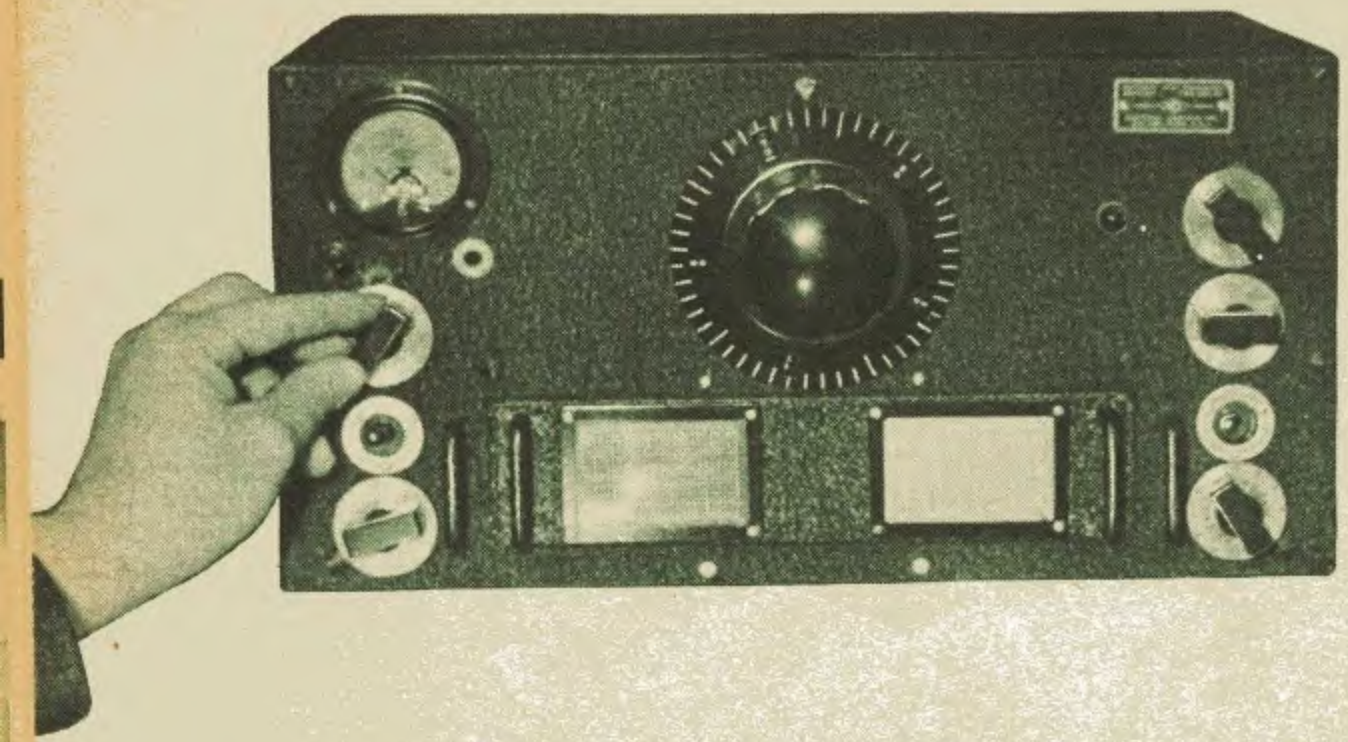


Fig. 9.2. Circuit diagram of the three scale version with the new scales and neons on the meter dial



THE H R O *Classic*

THIRTY years young and still going strong—this is the sort of description that comes instinctively to the mind in respect of the National H.R.O. receiver. Designed in the mid-Thirties to what was then a most advanced specification, the H.R.O. has dated very little during the intervening years. Indeed, of all the classic communication receivers that are still worth using it may well lay claim to being the most classical.

At a time when amateur communication was being performed almost entirely with the aid of TRF (tuned radio frequency) receivers that were proving increasingly inadequate to cope with growing congestion in narrow bands, the H.R.O.'s advent opened up to its users a new spectrum—almost literally. By offering a then unheard of standard of selectivity it automatically enabled many more stations to be accommodated within the confined frequency allocations available for amateur transmission. It also paved the way for consistent use of inter-continental amateur radio-telephony in a way which the TRF could never have done: for even if a TRF could have "pulled them in" it could not have "sorted them out".

Versions modified for special purposes are encountered from time to time, and the intending purchaser should therefore make sure by examination that the model offered him conforms with the instruction sheet that goes with it—and which he should insist on having when buying.

It is the H.R.O. in its standard form that is the subject of the following appraisal.

Origin

Designed originally by the National Company of Malden, Mass., U.S.A., the H.R.O. was directed at the very large American amateur communication market, but it quickly became recognised as the standard to be used for point-to-point commercial circuits. In the earlier models of the H.R.O. valves with 2·5V heaters were fitted, these being in widest currency in the U.S. in the Thirties. Later a change was made to 6·3V valves. In the interests of valve replacement the private buyer should seek a 6·3V version in preference to the 2·5V one. A separate power unit operates the receiver.

Separate power unit

One Type 5Z4G
One pilot light 6·3V at 0·3A

Basic Circuit (6 volt version)

Two r.f. amplifiers, both ..	6D6
Mixer	6C6
Local oscillator	6C6
Two i.f. amplifiers, both	6D6
Second detector	6B7
Beat frequency oscillator	6C6
Output stage	42
Pilot light	6·3V at 0·3A

COMMENT: Several stages employ common valves, which slightly eases the replacement problem—though this is likely to become aggravated as the years pass, since all the valves are pre-octal types—increasingly difficult to get. This is the best of reasons for going for a 6·3 volt version of the H.R.O. rather than the earlier 2·5 volt version, replacement valves for which may be virtually unobtainable in the future.

Both the mixer local oscillator and the beat frequency oscillator generate a considerable amount of power, and have been known to cause interference to television reception. It is therefore desirable to position an H.R.O. receiving aerial well away from adjacent television aerials.

Tuning and Band Selection

A distinctive feature of the H.R.O. is the large tuning knob which as it is rotated registers numerals 0–500 in a rectangular slot (see heading illustration). These numerals are related to a tuning graph from which frequency may be read off. Each numeral represents one scale division on the tuning knob, *e.g.* the receiver in our illustration is set to 67.

Below the tuner is the plug-in coil pack containing four screened inductance compartments, one for each of the r.f. stages, the third for the mixer and the fourth for the local oscillator. Several coil packs are available that cover an exceptionally wide spectrum from v.l.f. to—almost—v.h.f.; those required by the listener on the amateur bands are:

1·7 to 4Mc/s (covers the 160 and 80 metre bands).
3·5 to 7·3Mc/s (covers the 80 and 40 metre bands).
7 to 14·4Mc/s (covers the 40 and 20 metre bands).
14 to 30Mc/s (covers the 20, 15 and 10 metre bands).

The above are called General Coverage coils. Each

We present this month the second article in our series "Classic Communication Receivers". Intended as a guide to the prospective purchaser of a high performance receiver for use on the h.f. bands, this series gives the basic technical information he will need without delving too deeply into the circuitry. Readers should always make sure that a handbook or circuit diagram, at least, is supplied with any receiver purchased.

the receiver. For loudspeaker use there is a socket at the rear. No built-in step-down transformer is normally included, and one should be *in-situ* with any external loudspeaker used. Some suppliers can offer a matching external speaker unit.

Aerial Input

Twin aerial input terminals accept either direct connection to an external aerial or a balanced aerial such as a dipole.

Controls

Grouped round the prominent feature that is the main tuning control are:

Top Left: Audio gain, operating on headphones or loudspeaker.

COMMUNICATION RECEIVERS

can be adjusted by means of a removable screw in the base to give bandspread coverage of the *higher* marked amateur band, e.g. the coil-pack marked 1·7 to 4Mc/s can be adjusted to spread the 3·5 to 4Mc/s area over the whole 500 degrees of the dial.

COMMENT: The ingenious mechanical construction of the H.R.O. scale with its pop-up numerals allows extreme resetting accuracy and facilitates a return to an exact frequency. Particularly is this evident when the bandspread facility is in use: on the 80 metre band the accuracy is of the order of 1kc/s per division. Incidentally, the 80 metre bandspread covers the full American allocation of 3·5 to 4Mc/s. The British 80 metre band ends at 3·8Mc/s.

Frequency-against-dial-setting is read off from a chart provided on the front of each coil pack—at first sight a disadvantage to users accustomed to scales that provide the actual frequency; yet a few hours' operation of the H.R.O. rapidly accustom the owner to thinking of scale degrees in terms of kilocycles. The magnificent bandspread capability of the receiver in any event offsets any misgivings one may have in other directions.

Intermediate Frequency

456kc/s.

Optional Output

A front panel socket is for use with high impedance headphones and is fed from the penultimate valve in

Centre Left: Switch for a.v.c. on or off.
Bottom Left: Beat frequency oscillator switch combined with c.w. pitch control.
Top Right: Variable selectivity control; immediately below it is the Phasing Control and crystal filter switch. Using these controls in combination affords a high degree of selectivity such that a c.w. signal can be peaked up on the b.f.o. control (bottom left) to fantastic strength to the exclusion of almost any other interference within a few dozen cycles of the required signal.
The H.T. Switch, third down on the right, should always be cut before changing coil packs.
Bottom Right: The r.f. gain control, operating on the second r.f. stage and both i.f. stages.
Also on the front panel are: The red pilot light, top right; signal strength meter, top left; S-meter switch (below the meter); and the headphone socket.

The S-Meter

When the receiver is first installed a small setting-up operation is required on the S-meter if the readings it will give on incoming signals are to be meaningful.

The S-meter reading is a function of the signal reaching the second detector. It is influenced by the r.f. gain control but not by the audio gain control. The meter should be zero-ed by adjusting the r.f. gain control until the meter pointer is at "0", with a.v.c. off and b.f.o. off, and the selectivity control at maximum sensitivity. To obtain a reading turn a.v.c. to "on" and adjust the tuning control for maximum meter deflection.

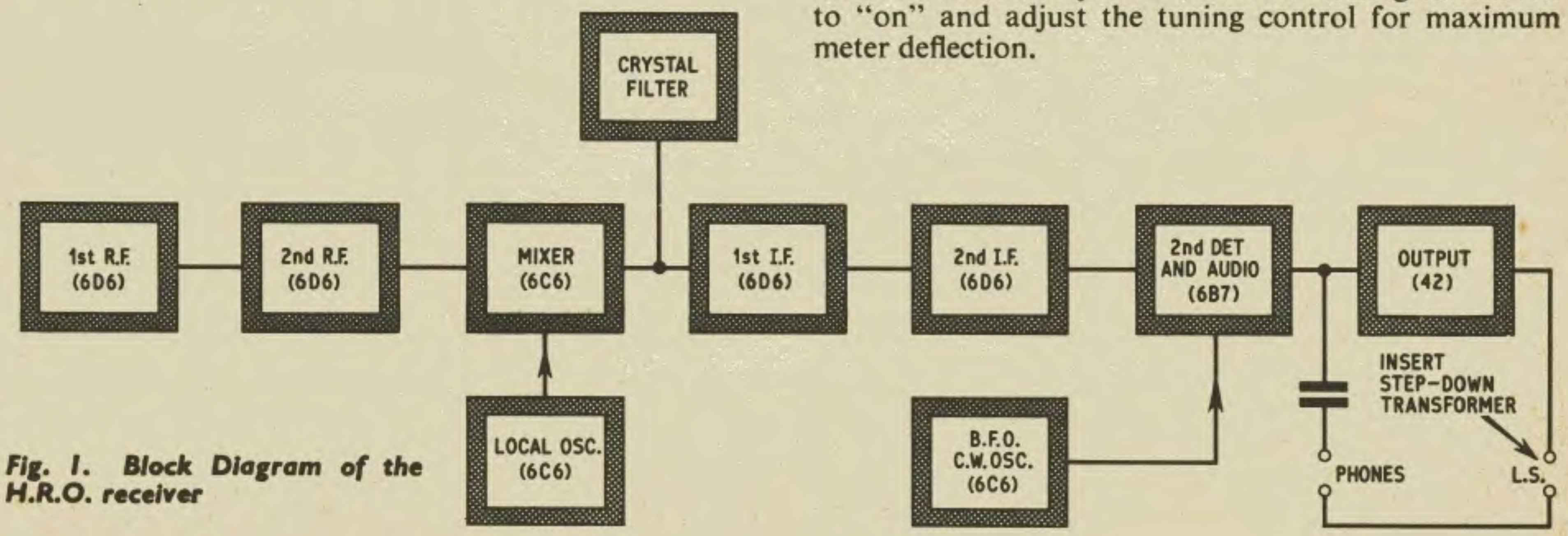


Fig. 1. Block Diagram of the H.R.O. receiver

STATUS FOR THE TECHNICIAN

By E. A. W. SPREADBURY

Chairman of the Society of Electronic and Radio Technicians

SERVICE engineers, to call them by a name by which they are very widely identified, are a very mixed category of individuals with a rather unsatisfactory public "image". The man in the street, to use another widely accepted metaphor, generally regards the man who repairs his radio receiver, and even more so if it is his television receiver, with distrust and suspicion. The distrust relates not to the service man's honesty, but to his ability; and the suspicion to the fear that he will charge more than the job is worth because of the man's possible incompetence.

This view illustrates the worst aspect of the public image of the service technician, but there is no doubt that it is one that has acquired very wide acceptance. It applies directly to retail service technicians, not to technicians in other branches of electronics, but it illustrates a lack of confidence arising from confusion with the many loose applications of the term "technician" in the past, and a lack of understanding of its modern significance.

This attitude of mind is quite unjustified in relation to qualified technicians, who are actually men of considerable technical attainment in their respective branches of electronics. The term "technician" has been in use for many years, but until recently it had no recognised definition, no accepted standard on which it could be pegged, and it was not regarded as a professional qualification.

The establishment of the Society of Electronic and Radio Technicians has begun to rectify this situation. Membership is open only to qualified technicians, and the description "technician" is already recognised as meaning an accepted level of technical qualification. The society is a qualifying body which gives professional status to its members, who must have reached the stipulated level of achievement. This imparts a substantial meaning to the term "technician", replacing the previous confusion with a recognised technical standard.

There is a serious shortage of properly trained technicians, and it was to raise the standard of technical personnel and enable properly skilled men to be distinguished from rule-of-thumb repairers that the Radio Trades Examination Board began to organise servicing examinations 21 years ago. Originally its purpose was to raise the standard of service work in retail shops and establish a recognised standard by which employers, both in shops and industry, could distinguish and select the kind of technical staff they wanted.

Later on, with the development of industrial electronics, the demand was felt for qualified technicians in the electronics industry. Special examinations were therefore organised by the R.T.E.B. in this subject, and technical colleges co-operated by preparing syllabuses for suitable courses of instruction in electronics. The R.T.E.B. Final Servicing Certificate is now the recognised national qualification for radio, television, and electronic technicians, and altogether so far 25,000 candidates have submitted themselves for the R.T.E.B. examinations.

It has been felt for some time that some recognition of these men as a class should be established, something which would establish their professional status as technicians, very much in the same way as the status of engineers is established by association with their respective engineering institutions.

It was this need that led to the birth of the Society of Electronic and Radio Technicians. The society is formed on the same lines as the engineering institutions, but at the technician level. It was founded by the R.T.E.B., and its first qualification for membership was one of the Final Certificates of the R.T.E.B. (radio or electronics) but this has been broadened to embrace quite a number of other qualifications of equal academic achievement in electronic engineering.

S.E.R.T. was inaugurated in June, 1964. There are three membership grades: full member, associate, and student, and possession of the R.T.E.B. Final Certificate is one of the qualifications for associateship, provided that the applicant is 21 years old and has had three years experience in radio or electronic service work.

To become a full member he must be at least 30 years of age and have had not less than ten years experience, five of them in a position of responsibility. Other qualifications include H.N.C., City and Guilds Telecommunications, or Electrical Technicians (with electronics), certain P.M.G. certificates and a number of qualifications in the Armed Forces.

Admission to either grade is very strictly scrutinised by the Membership Committee, who are determined to maintain a high standard of technical skill and ability. Students are admitted on possession of certificates of lower or intermediate grades, or if they are attending full-time approved courses. Annual subscriptions for membership in the U.K. are: members, £5; associates, £4; students, £1 or £1 10s according to age. Sir Ian Orr-Ewing, Bt., O.B.E., M.A., M.I.E.E., M.P., agreed to become the first President of S.E.R.T.

There are great opportunities for technicians in electronics, and membership of S.E.R.T. gives them status. Advantages of membership include regular technical meetings at which they can discuss common problems and hear lectures by engineers. These take place at ten centres throughout the U.K. Members also receive the S.E.R.T. Journal.

By this means the technician today has achieved recognised professional status that is denied to the less skilled man. He now has professional standing by which he can be distinguished. In industry, where the shortage of skilled technicians is very serious, an employer can confidently employ a technician who is entitled to add M.S.E.R.T. or A.S.E.R.T. after his name. In radio servicing, customers can gain confidence from the display of the technician's certificate in his dealer's shop. In the same way an employer can ensure the engagement of a serious, keen and consciencious apprentice or bench worker if he can claim to be a Student S.E.R.T.

S.E.R.T. was founded by the R.T.E.B., and the two bodies share the same offices, which are managed by their joint secretary, A. J. Kenward, B.Sc., A.M.I.E.R.E. Originally they were provided with office accommodation at the I.E.R.E. headquarters at 9 Bedford Square, W.C.1., but since January, 1965, they have had their own office, at 33 Bedford Street, Strand, London, W.C.2. ★

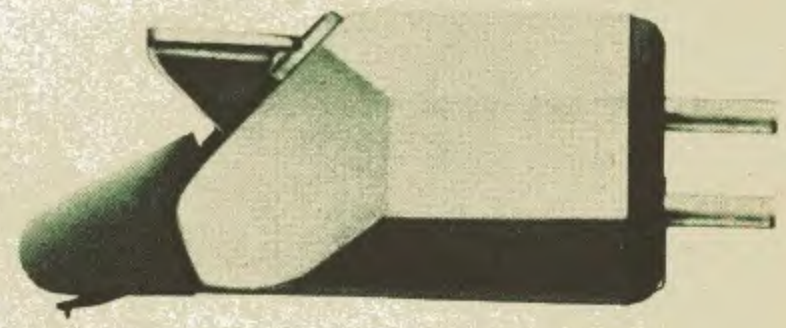
Audio TRENDS...

A Commentary on Sound Reproducing Equipment by Clement Brown

THE enthusiast who requires a ready-made stereo outfit at low cost is the least well catered for today. There are remarkably few equipments which, though costing no more than a radiogram, display the specialised approach that is likely to appeal to the discerning record collector. One manufacturer new to this field helps to fill the gap with a compact stereo disc reproducer which incorporates the Garrard SP25 player (with ceramic cartridge) and separate slimline enclosures containing 8in Wharfedale loudspeakers. The price is £75.

A transistorised amplifier rated at 10 watts per channel is built into the shelf-mounting unit which also contains the SP25. The most novel feature is the elimination of all controls except the volume control. On/off control of the amplifier is taken over by the switch on the turntable motor. The manufacturer, Hamilton-Mathers, sells the Model HM64 directly to customers for £75; a specification is obtainable from their address: 13 College Road, Bromley, Kent.

Constructors may like to know that Daystrom Ltd., Gloucester, are now publishing free brochures which describe Heathkit amateur radio equipment and electronic instruments. The general catalogue of Heathkit equipment, covering both kits and ready-made products, continues as usual and is published quarterly. Daystrom have opened a new shop at 233 Tottenham Court Road, London, where a large range of Heathkit equipment is on show.



Empire Series 888 stereo cartridge

MAGNETIC CARTRIDGES

Moving-magnet cartridges are very frequently used for high fidelity systems of the finest quality. Empire cartridges of this type have been available in the U.K. for some time, but recently the new Series 888 stereo models were introduced by the importers, Howland-West Ltd. These feature smaller stylus mass and smoother response. Very low playing weights are possible, and superior high frequency response is claimed. The least expensive model is the 888, which has a 0·0007in radius stylus and is priced at £12 15s 9d.

Then there is the 888P (£13 19s) which has a higher compliance and a 0·0006in stylus. The top cartridge in this range is the 888PE, with a still higher compliance of 20×10^{-6}cm/dyne. An elliptical stylus with 0·0002 and 0·0009in tip radii is fitted. The Empire cartridges employ an extremely small and light cone shaped magnetic element; the total cartridge weight of 7 grammes promises suitability for use in modern low-mass arms.

Garrard now supply wooden base boards for their various record playing units. The mounting boards are cut to suit particular models. Base type WB1 (£3 12s 8d) is intended for the SP25 player or for record changers, including the AT60. Type WB2, costing £5 0s 3d, is specifically designed for the Lab 80 transcription changer. The wood finish is in teak, and each base has a plastics cover.

NEW SPEAKERS

From the considerable number of speaker systems and drive units introduced recently, the Kelly ribbon h.f. unit, incorporated in a Decca system, was demonstrated to enthusiasts some time ago. The complete system, employing an acoustic lens and a 12in bass unit with 2·5kc/s crossover, is now available at 47 guineas. An acoustic "lens" may imply focusing, but in fact the "Kardioid" system, as it is called, is noted for its dispersion of high frequency output. The enclosure, an upright floor standing design, is finished in teak.

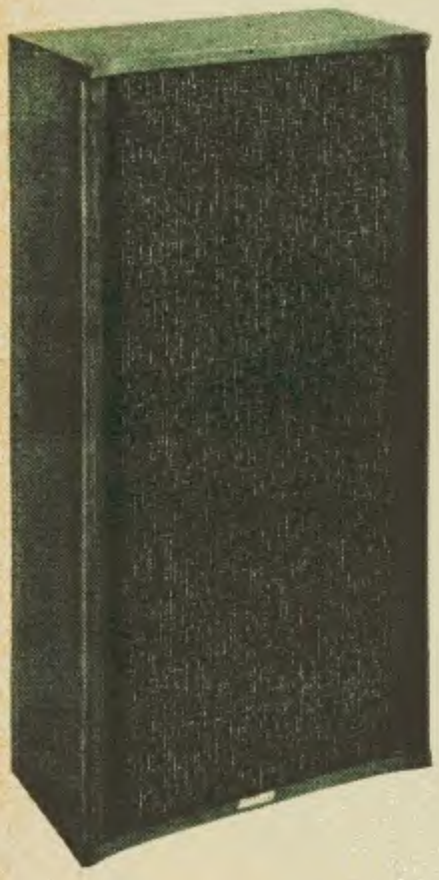
Other complete systems include those by Jordan-Watts. Six new presentations, prepared in time for the Audio Fair, employ the firm's metal-cone drive unit. One example is the "Jumbo", the smallest in the range and priced at £17 12s 6d. It is claimed to handle up to 12 watts with a bass response extending down to 70c/s. A larger system (0·6 cu. ft), known as the "Juno" (£24 10s) responds down to 40c/s. Another example is the "Jason", the enclosure of which employs resistive reflex loading. The price has yet to be announced.

Among the imported systems are those by Empire of the U.S.A. Although costly, these speakers are most original in styling and technical design. The example illustrated, Model 8000P, has a heavy cylindrical enclosure with a marble top; others are of rectangular design, suitable for shelf mounting. Here again, an acoustic lens is a principal technical feature, and the vents in the reflex-type enclosure can be adjusted by the user to suit prevailing conditions. A brochure dealing with these models and describing the Empire cartridges is available from the importers, Howland-West Ltd., 2 Park End, South Hill Park, London, N.W.3.

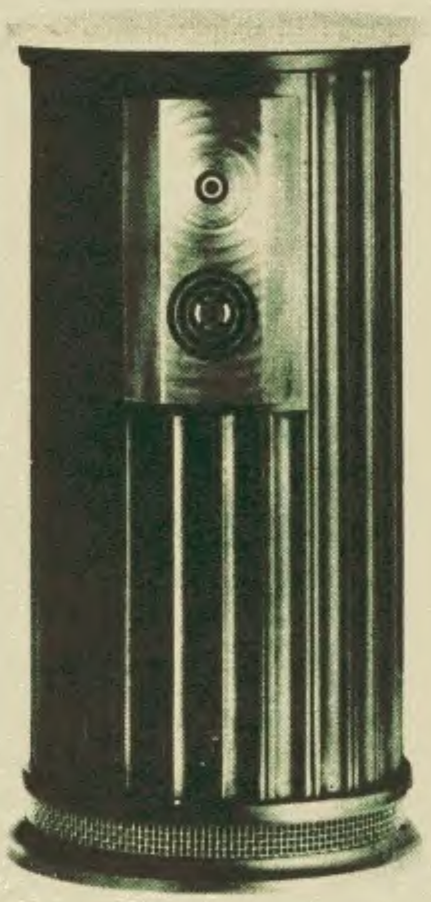
Baker speaker units, the products of a firm long established in the audio industry, include the DWI Laboratory Standard model. A special cone design contributes to improved performance on transients, less coloration and generally smoother response. Suitably enclosed, the 12in version (£22 10s) has a response of 50–15,000c/s $\pm$5dB. A 15in version is also available,

For example, the 633 has separate record and playback heads and amplifiers, so that the input and recorded signals can be compared. Echo effects are also possible. There are mixing facilities and the level meter can be read on either record or playback. The output is three watts. The input is suitable for magnetic pick-ups and a "spot erase" arrangement aids the erasure of short unwanted passages of recording. Priced at 120 guineas, the machine is likely to appeal not only to professional users but also to serious amateurs who demand a high standard of performance and versatility, particularly when dubbing.

Also of interest to amateurs are a new microphone and a range of special purpose tape amplifier units. Grampian's type GC1 is a cardioid microphone with 20dB front-to-back discrimination ratio. This reduction of sensitivity to sounds generated behind the microphone is useful in minimising the effects of high noise levels and in overcoming acoustic feedback.



Jordan-Watts "Juno" loudspeaker cabinet



Empire loudspeaker system Model 8000P

Grampian GC1 microphone

and there are several 12in models to suit the experimenter and constructor. One of these, the De Luxe Mk2, has a 14,000 gauss magnet and is priced at £9.

Britimpex Limited include speaker drive units among the many audio components they import. A twin-cone unit, type AF12 DFC, is an 8ohm, 12in model rated at 12 watts. The price is £7 17s 6d. There is also a mid-range horn (£3 19s 6d) suitable for use in multi-unit systems. Britimpex are at 16 Great Russell Street, London, W.C.1.

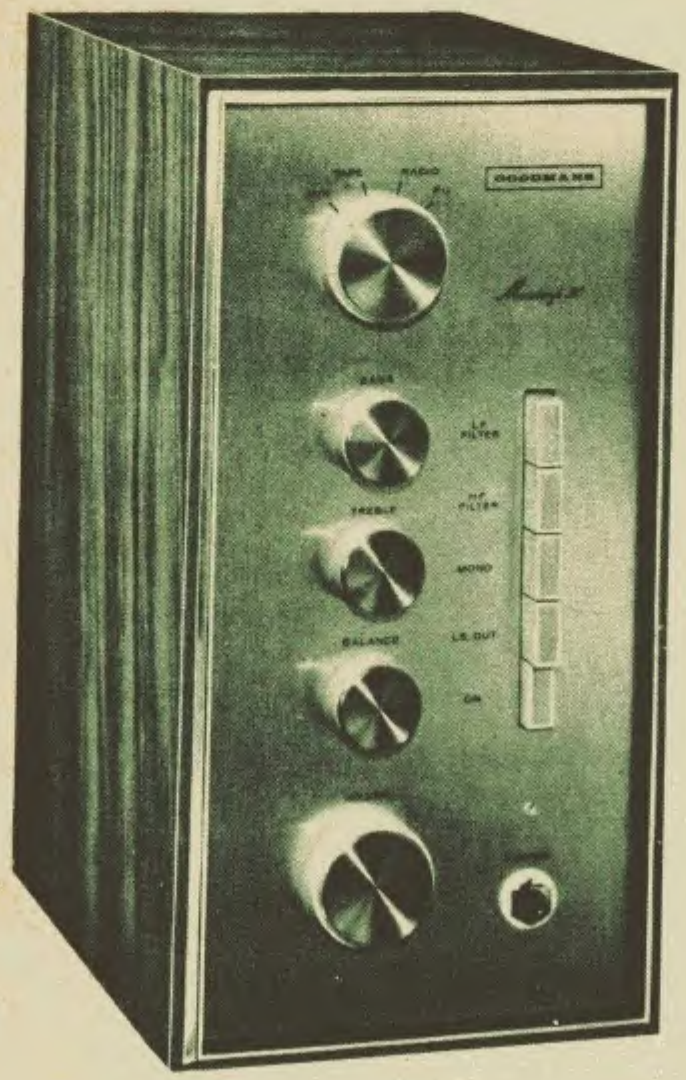
DE LUXE RECORDER

One of the most interesting events in the tape recording field has been the appearance of a new model in the Ferrograph Series 6 range. This de luxe recorder, known as the Connoisseur 633, is a mono machine designed to approach a professional standard as closely as possible. All the Series 6 technical features are included, but there are also some important new facilities.

The GC1 covers the range 40–12,000c/s and costs £14 for the low impedance (25 ohms) model. High impedance versions cost a little more. Accessories include table and floor stands, extension leads and matching transformers.

Deimos Ltd. make tape amplifiers which can be used by the amateur to link a tape deck to an audio installation. Flexibility is the aim, and the use of a basic framework with plug-in circuit modules ensures that a unit can be assembled at moderate cost to meet individual requirements. A mono recording unit, incorporating record and playback amplifiers, an oscillator and a meter, totals £37. An important facility is the matching of amplifier response characteristics to particular decks. Details can be obtained from the firm at 8 Corwell Lane, Hillingdon, Middlesex.

A final note. In the last Audio Trends (March) the price of the Thorens TD150A turntable and arm assembly was, due to a misprint, given as £82 0s 9d. The correct price is £28 0s 9d.



Maxamp 30 Integrated Stereo Amplifier

Goodmans Industries Ltd., Axiom Works, Lancelot Road, Wembley, Middlesex.

The Maxamp 30, now being demonstrated to the public for the first time at the Audio Fair, Hotel Russell, London, W.1, is the first Goodmans product to break away from their conventional products and venture into the hi fi audio amplifier field. Finished in an attractive polished wood cabinet measuring only 10½in × 5½in × 7¼in, with a "scratch grain" front panel, it is ideal for use in rooms where accommodation is limited or where one doesn't wish to disturb present furnishing layouts.

The frequency response is claimed to be 20c/s to 20kc/s ±½dB, and distortion is quoted as less than 0·4 per cent at 1000c/s. The output delivers 15 watts r.m.s. per channel into 8 ohms, or 10 watts r.m.s. with either 4 or 15 ohm loudspeakers. The hum and noise level is approximately 55dB below full output for all input channels and at least 80dB below full output with the volume control at minimum setting. With the input selector in any position and the unused channel open-circuit, the crosstalk is approximately –40dB with 10 watts output from a 8 ohm loudspeaker on the active channel. The input sensitivities are as follows: dynamic pickup (47 kilohm impedance) 3·5mV; ceramic pick-up (100 kilohm impedance) 50mV; radio (100 kilohm impedance) 100mV; tape (100 kilohm impedance) 150mV; auxiliary (50 kilohm impedance) 3mV.

The price of the Maxamp 30 is £49 10s 0d. An 8 page colour brochure giving full details of the amplifier is available, free of charge, from Goodmans.

Cardioid Dynamic Microphone

Reslosound Ltd., Reslo Works, Spring Gardens, London Road, Romford, Essex.

The new type CPD range of Reslo dynamic (moving coil) microphones, incorporates a miniature but rugged insert having a ribbed plastic diaphragm to which is attached a lightweight voice coil. The insert is specially designed to have unidirectional sound pick-up pattern. There are three alternative impedance models available: type CPDL single impedance 30–50 ohms, CPDM dual impedance 250 and 600 ohms, CPDH dual impedance 30–50 ohms and Hi-Z (40,000 ohms).

The frequency response is −2dB at 70c/s and 16kc/s relative to the level at 1,000c/s. The sensitivity is 88dB below 1volt/dyne/cm² (30–50 ohms impedance). The signal output generated from the microphone, held six inches from the mouth, at normal conversational level is 50–150 microvolts from type CPDL, 250–450 microvolts from type CPDM (600 ohms), 2–4 millivolts from type CPDH (Hi-Z). When the distance is reduced to one inch the output increases approximately ten times (20dB).

The CPD microphone is very suitable for high quality music recording and relay purposes, and the price of the CPD ranges from £14 to £16 according to impedance required.

Multirange Test Meter

Croydon Precision Instrument Co., Hampton Road, Croydon, Surrey.

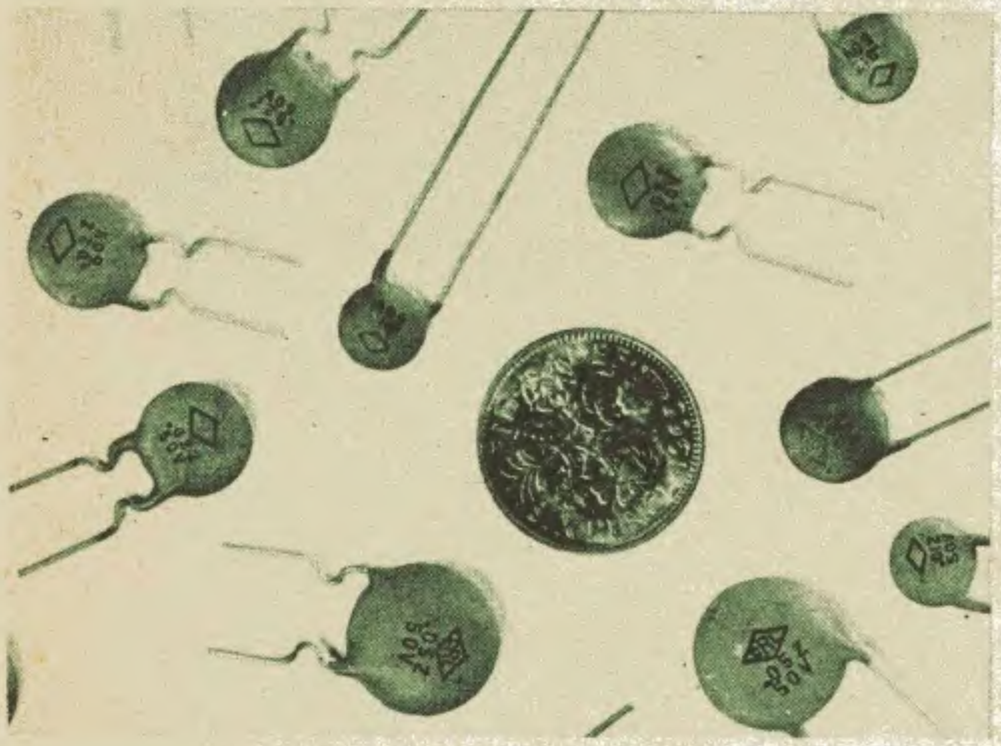
The Norma model 785 is an extremely compact and versatile multimeter having dimensions of $6\frac{1}{2}$in $\times$ $3\frac{7}{8}$in $\times$ $1\frac{3}{4}$in and a total of forty switched ranges: d.c. current $30\mu A$ to 6A in nine ranges; d.c. voltage 12mV to 600V in nine ranges; a.c. current $150\mu A$ to 6A in eight ranges; a.c. voltage 1·5V to 600V in six ranges; resistance 0 to 5 megohms in two ranges.

The meter also has a temperature scale of 20 to 240°C (68 to 464°F). For this latter measurement, a separate iron–constantan thermocouple feeler must be purchased as an extra.

The maximum d.c. error is $\pm 2{\cdot}5$ per cent and the additional a.c. error is: 15–500c/s ± 1 per cent; 500c/s–5kc/s $\pm 2{\cdot}5$ per cent; 5kc/s–30kc/s ± 5 per cent.

The clarity of scaling, both for the meter and the rotary function selector is extremely good and interpolation on the large a.c. and d.c. scales is made easier by the fine glass pointer, which is capable of withstanding large overload surges without mechanical distortion.

The model 785 retails at £11 10s 0d plus 17s for test leads. A twenty-three page illustrated booklet, containing table, data and application notes, is supplied with the instrument.



Low Voltage Ceramic Capacitors

Centralab Ltd., Northway House, Great North Road, N.20.

Our photograph shows a range of low voltage ceramic capacitors which should be in fairly large demand by our readers. These capacitors are available in three values of $0{\cdot}01\mu F$, $0{\cdot}02\mu F$ and $0{\cdot}05\mu F$ and their working voltage is 50 volts d.c., which are values fairly commonly used in our sphere of constructional articles.

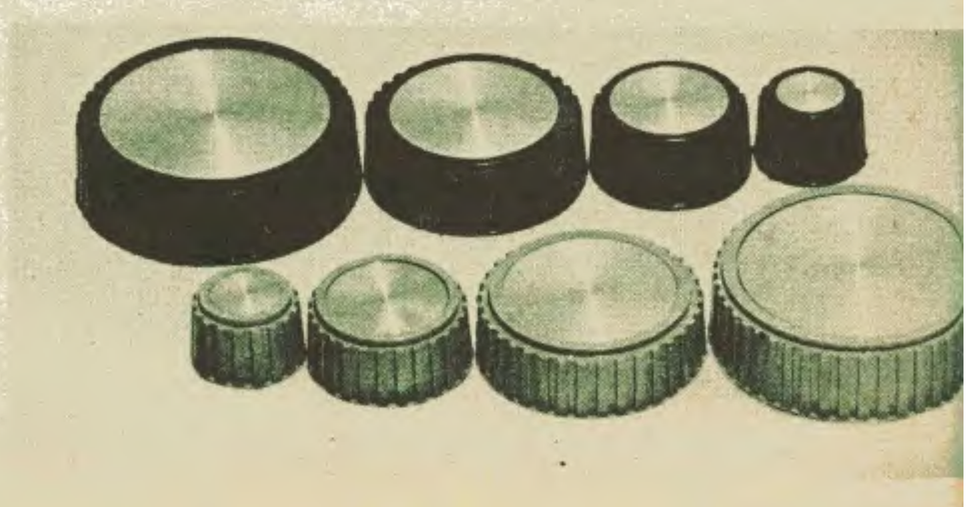
The capacitors have a maximum diameter of just over half an inch and the leads are either straight or terminated with a kink for use on printed circuit boards. The tolerance ranges from either $+80$ per cent -20 per cent, or ± 20 per cent.

New Instrument Control Knobs

A. F. Bulgin & Co. Ltd., Bye Pass Road, Barking, Essex.

These knobs are the first 1966 addition to the Bulgin range of components. There are four different sizes available in two colours, black or Admiralty grey. The standard range has a plain moulded face but types with satin or spin finished silvered discs can be supplied. The controls can be fitted with different size brass bushes to accept various shaft sizes.

It is possible to pair knobs for use on dual concentric shafts, which adds to the versatility of the knobs.



ANTI-THEFT ALARM

by N.W. BRIDGE

CAR thefts are rising rapidly in spite of appeals to car owners to make vehicles theft-proof. There is very little point in leaving the car unattended unless all doors, windows, bonnet and boot are securely locked. However, there are still some persistent thieves who have a large selection of keys to choose from to gain access to your car.

There is no point in allowing the thief to get away with it even if he has a set of keys. This article shows how he can be severely perturbed, baffled and disturbed, even if he goes as far as switching on the ignition.

There are several possibilities for switching the alarm on. One is to fit a switch in some unobtrusive place, and hope that a prospective thief will not find it. The main disadvantage of this, however, seems to be that the driver must remember to switch it on and off; this can be easily forgotten if the switch is sufficiently unobtrusive. A second method is to put the switch in a more obvious position, but disguised as something else, such as the head of a bolt. This may have the same disadvantages as the first method. A certain amount of human error comes into the success or otherwise of the alarm.

The third method, which was used in this case, is to use a switch on the instrument panel in the usual way, either wrongly labelled, or unlabelled, so that it is not in the least obvious what it is for. It then becomes quite easy to remember to operate the switch at the appropriate times, just as part of the normal sequence of operations for starting the engine or parking the car.

HOW IT WORKS

The switch is of the type which makes one circuit and breaks another, in each position, and is arranged so that it both switches the alarm circuit into an operable state, and also switches the petrol pump off, though this part cannot be used if one has a mechanical pump! Thus if the burglar does manage to stop the alarm working without having discovered the switch, he won't get very far without the pump working. The switch could also be arranged to make the fuel meter read empty!

The alarm itself uses a relay, driven by a transistor multivibrator, to flash the headlamps and sound the horn intermittently. The circuit is powered as soon as 12V is connected to the coil, whether this is done with the ignition key, or a jumper lead straight from the battery. It would of course stop if the ignition were switched off again, so a lock-on relay is also included so that the alarm continues to work until the entire supply is disconnected at the battery or the lock-on relay is manually disconnected.

It is possible to eliminate relays and use more power switching types of transistors, but probably at extra expense and complicating the normal car wiring. The relays used here have two sets of heavy duty changeover contacts each and have a coil resistance of 120 ohms.

Referring to the circuit diagram (Fig. 1) all switches and relay contacts are shown in the normal quiescent condition. When the driver leaves his car he should switch off the ignition first before operating the "alarm set" switch S1. The ignition coil is disconnected from the petrol pump by S1, and connected to relay RLB and the negative rail of the multivibrator via terminal (1). Relay RLB is operated as soon as the ignition switch is closed or when battery negative is connected to the ignition coil. RLB1 closes to maintain the battery supply to the relay coil and the multivibrator, even if the ignition is switched off again.

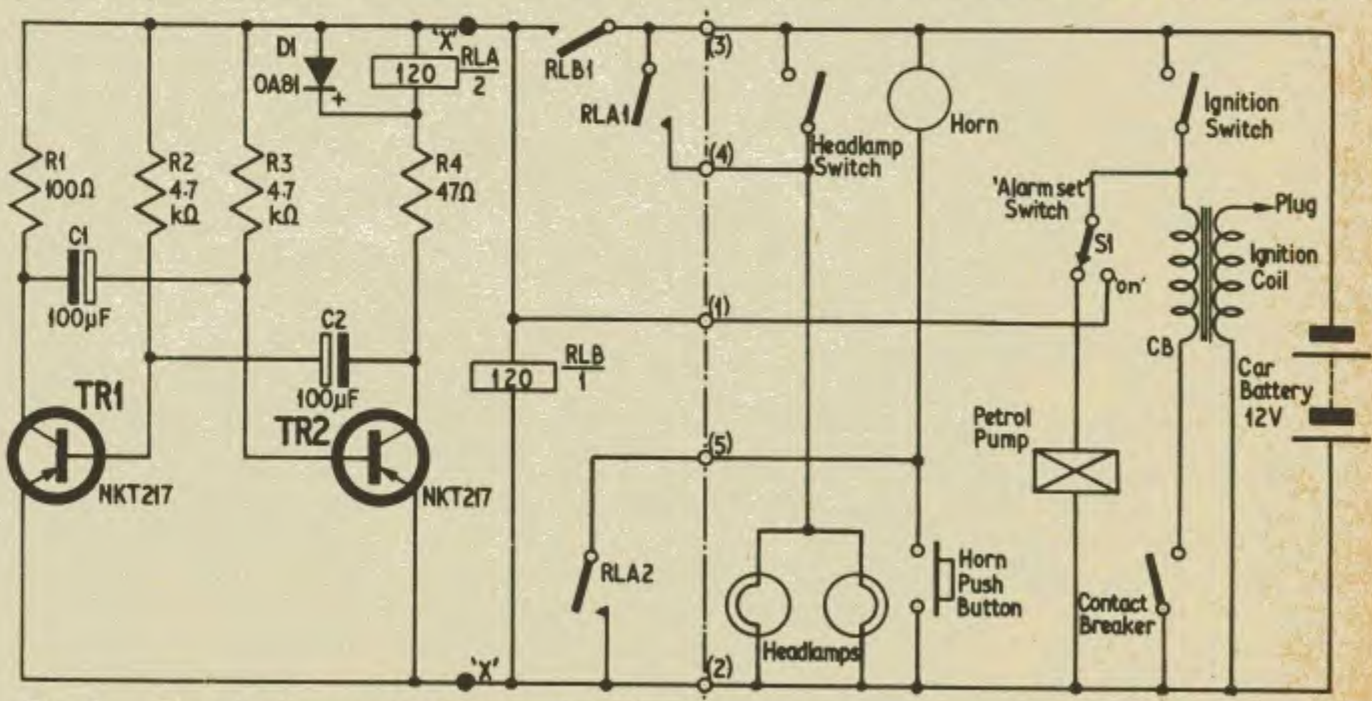


Fig. 1. Circuit diagram of the anti-theft alarm unit for use on 12 volt positive earth systems (see text). The terminal numbers in brackets refer to those shown in Fig. 2

The circuitry around the two transistors constitute a free running multivibrator which is timed to operate relay RLA about twice per second, but this can be adjusted to suit individual requirements by altering the values of C1 and C2. On no account should the values of the resistors be altered otherwise there is a danger of over-running the transistors and causing thermal runaway.

Diode D1 is connected across RLA to suppress transient peaks induced by the relay, which could damage TR2. The frequent on/off operation of RLA will close and open contacts RLA1 and RLA2, causing the headlamps to flash and the horn to sound with bursts of disturbing regularity.

Before connecting contacts RLA2, make sure that the horn on your car is wired to the negative side of the battery, with the horn push button connected to the positive terminal. If they are not, then connect RLA2 directly across the horn push button.

TWELVE VOLT SYSTEMS

This circuit has been devised for use on 12 volt car battery systems with the positive terminal connected to the car body. If the body is negative, RLA1 and RLA2 should be connected directly across the headlamp switch and the horn push button, and isolated from terminals (3) and (2).

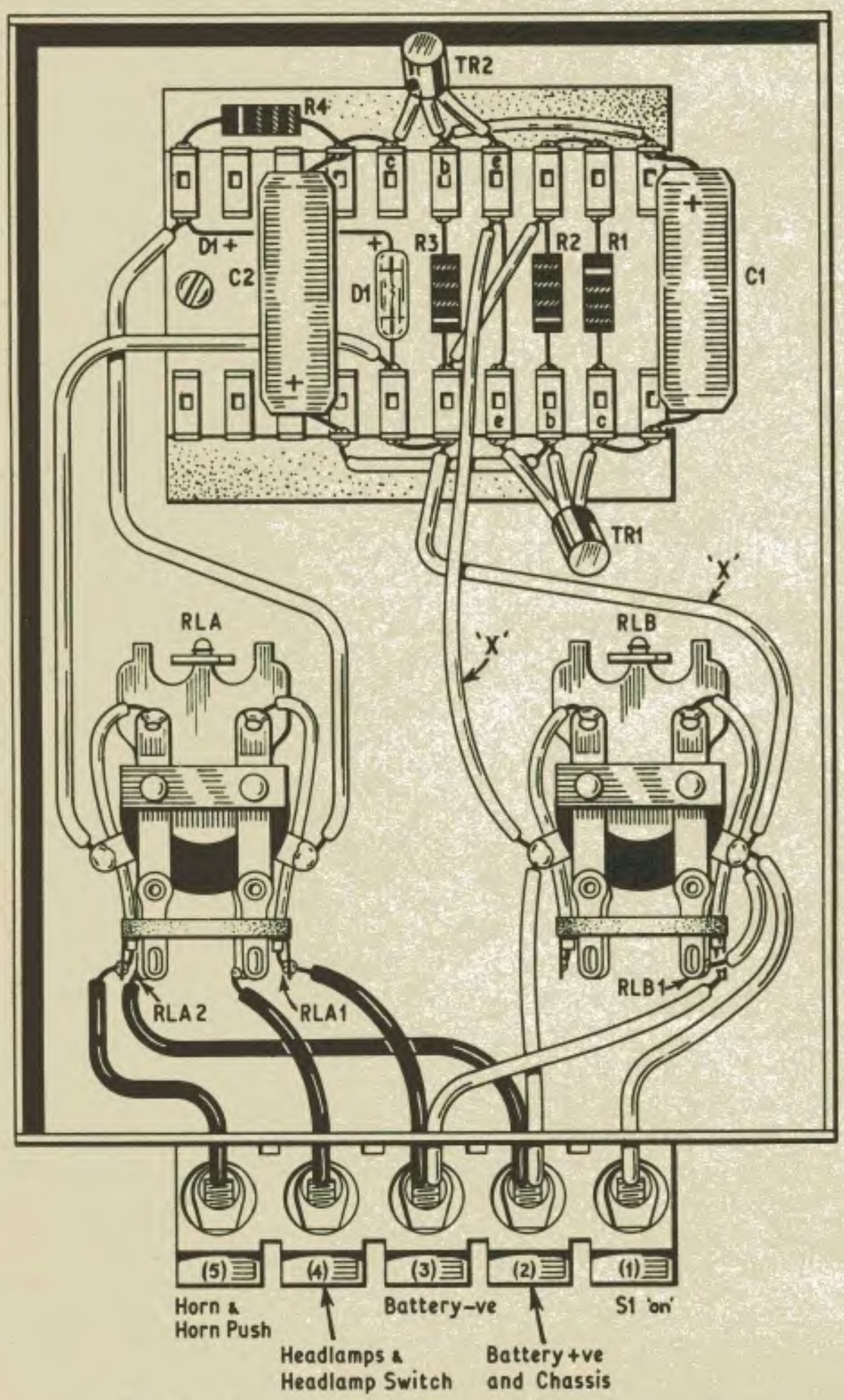


Fig. 2. Layout and wiring of the alarm unit

COMPONENTS . . .

Resistors
R1 100Ω
R2 4·7kΩ
R3 4·7kΩ
R4 47Ω
All 10% ½watt carbon

Capacitors
C1 100μF elect. 12V
C2 100μF elect. 12V

Transistors
TR1, TR2 NKT 217 (2 off) (Newmarket)

Diode
D1 OA81 (Mullard)

Relays
RLA, RLB 120Ω, 12V d.c. with two sets of change-over heavy duty contacts (2 off) (Radiospares type 11)

Switch
S1 Single-pole, changeover toggle switch

Miscellaneous
Aluminium chassis 6in × 4in
Screw terminal strip, 5 ways
Component tag panel 10-way and backing plate
P.V.C. covered connecting wire
Heavy duty wire 40/·0076 (see text)

Always check which "earthing" system is used on the car and make sure that the positive of the battery will be connected to the emitters of the transistors when the alarm becomes operative. If the battery is connected in reverse to that shown in Fig. 1, it is necessary to interchange the connections at X—X. Make sure the ignition circuitry is as shown in Fig. 1.

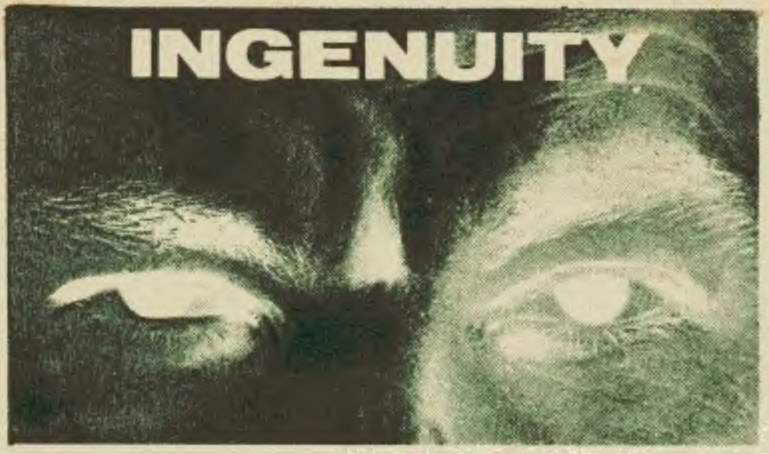
This circuit will not operate on 6 volt systems because insufficient voltage will be available to operate the relays. The circuit would need to be redesigned with different component values and relays.

WIRING

Being basically a simple circuit, the multivibrator and relays can be housed in a box, which would be hidden or disguised so that it is not easily recognisable. A suitable housing, shown in the photograph, is an aluminium chassis which can be fitted with a cover plate. The layout and wiring is shown in Fig. 2. The terminal connections are numbered to correspond with those in Fig. 1.

Some of the wiring will be called upon to carry a heavy current, mainly the leads to headlamp and horn switches. These should be 40/·0076 since the current is expected to be between 7 and 10 amperes. Similarly, the appropriate wires inside the box should be of the same rating. These are the connections between RLA1, RLA2 contacts and the terminal strip, and are shown in Fig. 2 as thick black wires. The terminal strip should be rated at 10 or 15 amperes.

When installing the unit in the car, it should be kept away from heat. The wiring is done in such a way that it is confusing to anyone trying to trace it, except yourself, of course. Some wires can be duplicated and routed round the car in different ways. The lead from the ignition coil to S1 is likely to be the most obvious one, but it need not be if it is well concealed. ★



UNLIMITED!

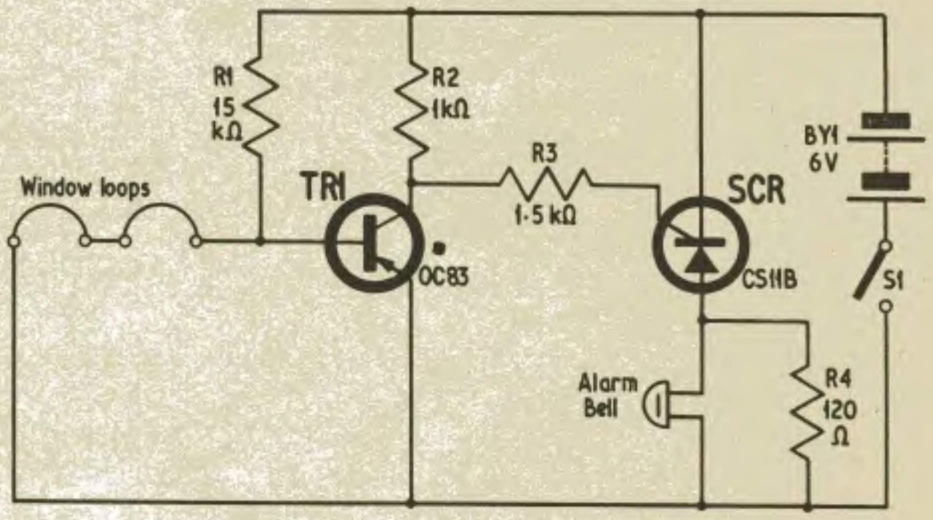
IN THIS feature we hope, from time to time, to be able to publish suggestions submitted by some of our readers on the possible improvement of projects previously described in PRACTICAL ELECTRONICS; short contributions on other subjects may be included. The aim is not to find fault or undermine the abilities or knowledge of our contributors. It may well be that the original article is *par exellence* but it could be improved or adapted to suit individule requirements. The views expressed by readers are not necessarily those of the Editor.

S.C.R. BURGLAR ALARM

HAVING got round to building the *Burglar Alarm*, featured in the February issue, I found that I did not have a suitable relay, but I did have an s.c.r. This led me to modify the circuit to suit the components I had to hand.

I enclose a copy of the circuit used hoping it will be of interest to other constructors.

J. F. Cook,
Swaythling,
Southampton.



QUICK ETCHING METHOD

I HAVE found that by just immersing the printed circuit in ferric chloride solution, it takes a lot of ferric chloride to etch away a small amount of copper, which can be an expensive method.

However, if an old carbon rod from a dry battery is introduced into the solution, a "cell" is produced with a voltage of ½V. If the carbon rod is connected to the copper of printed circuit board by a piece of well insulated wire, the copper is quickly etched away, whatever the condition of the solution.

Care must be taken to varnish all exposed connections of the wire so that this is not etched as well. By using ordinary household varnish to paint the design on the copper, and using this etching method, printed circuits can be produced quickly, conveniently and cheaply. The solution and the carbon can be used again and again.

G. Burke,
Manchester, 14.

FERRITE CORE PIPE LOCATOR

SOME TIME ago I built a locator for conduit tubing operating on the principle similar to that described by Gordon J. King (see January 1965 issue).

The search coil was wound on a "U"-type ferrite core removed from a line output transformer. This would be a useful modification to the instrument described in PRACTICAL ELECTRONICS. This coil would have fewer turns than the open search coil described. The "U" core gives sensitivity and precise location.

Loudspeaker operation is possible by arranging TR2 and TR3 in a reflex circuit, and substituting the OC71 in the output stage for a power type such as an OC72.

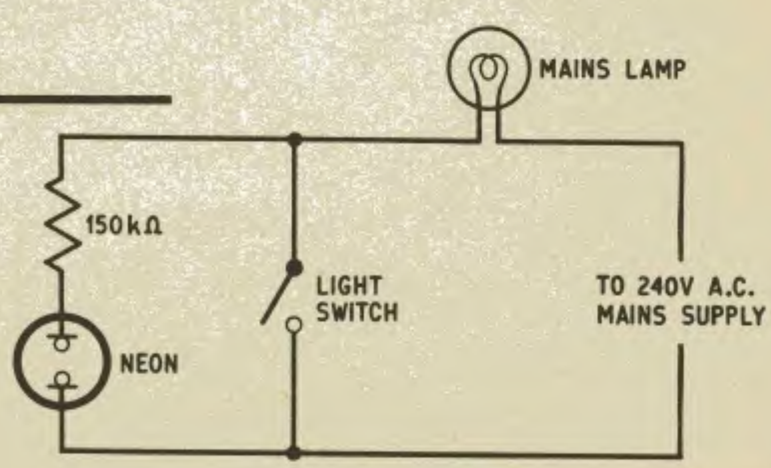
A. Bartholemew,
Kirkcaldy,
Fife.

The use of a ferrite core search coil is a very good idea and, of course, would tend to improve the sensitivity. The ferrite core would require a fewer number of turns.—G.J.K.

LIGHT SWITCH LOCATOR

LOCATING the house light switch in the dark can be very difficult. A small neon with a 150 kilohm ½ watt resistor in series can be wired across the switch. If the neon lamp is fitted behind the switch cover plate, which should be white for best results, it will show up sufficiently well to locate it easily.

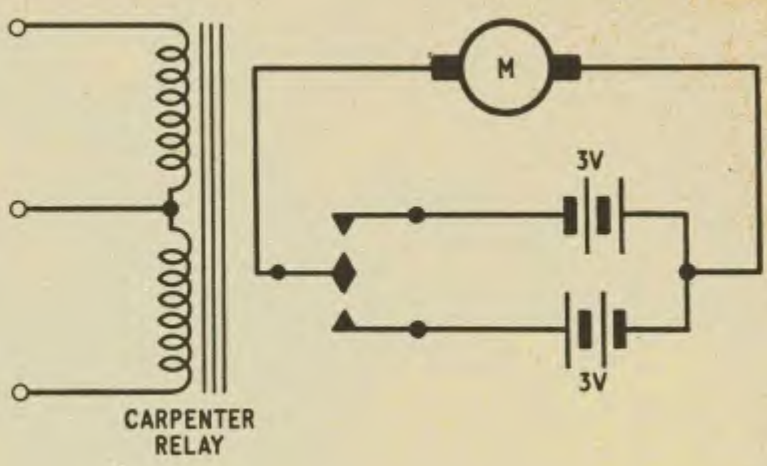
W. E. Norman,
Breston,
Cheshire.



CARPENTER RELAY IN THE SERVO

I HAVE studied the circuit of the *Simple Servo System* in the January PRACTICAL ELECTRONICS and I would like to suggest a simplification.

It appears that transistors TR7 and TR8 are superfluous. Switching motor polarity can be accomplished directly from the Carpenter relay, thus saving the cost of two transistors and two resistors. The enclosed drawing shows this part of the circuit less the required switching and plug and socket connections.

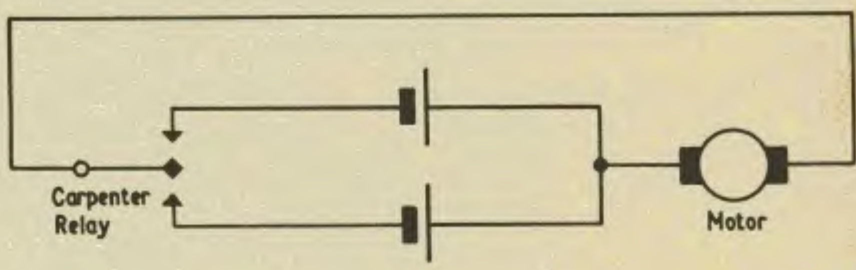


C. Wright,
Aylesbury,
Bucks.

Whilst experimenting with the servo, a large number of circuits were tried, including Mr. Wright's. To explain why the final circuit was used, I will discuss some of these apparently satisfactory circuits and my reasons for rejecting them.

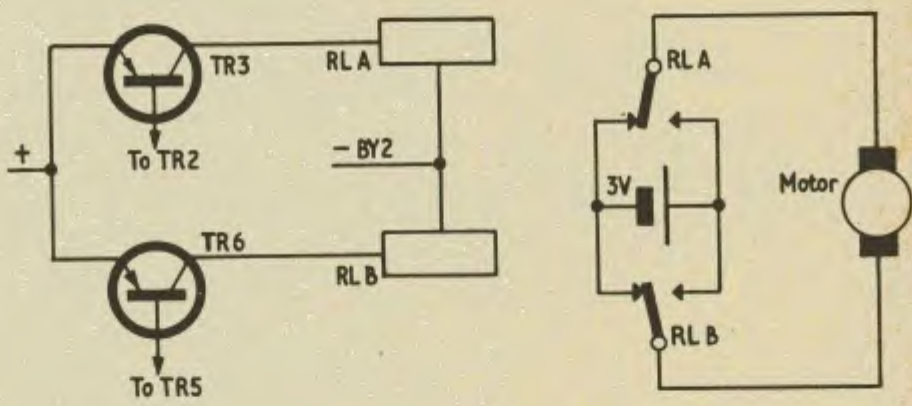
CIRCUIT A

As per Mr. Wright's suggestion, which on the face of it appears to be the simplest solution. But the Carpenter relay is a very delicate item, its contacts are light and are not intended to switch motor currents. This circuit would result in the destruction of the relay contacts.



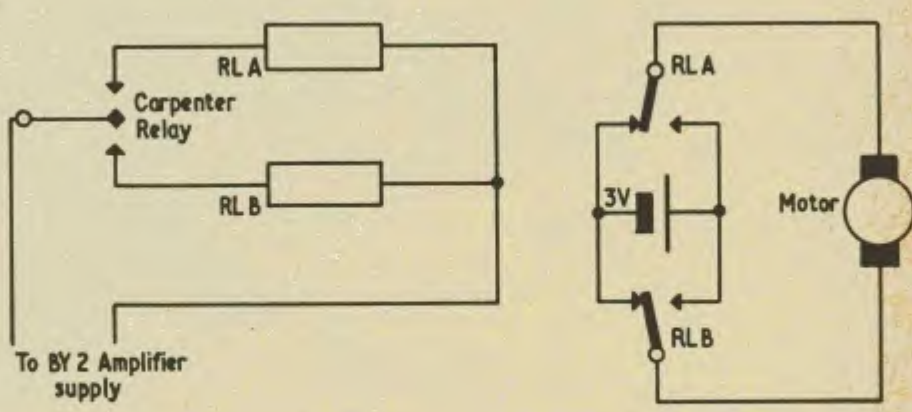
CIRCUIT B

This was used in one of the original servos. The main advantage being cost; no Carpenter relay, no transistors, only a battery is required. Another advantage is the fact that the motor is short-circuited when switched off. This means that when the balance point is reached, the motor is regeneratively braked by back e.m.f. flowing in the short circuit. This circuit was rejected due to lack of sensitivity in favour of circuit "C" which is a combination of A and B.



CIRCUIT C

This circuit performs very well incorporating the above mentioned advantages. This was rejected after the final circuit was developed. Due to the velocity feedback, the relays have to operate at very high speed when approaching balance point. This fact coupled with the heavy motor current would, in the opinion of the author, accelerate relay wear. This method is mechanically noisy, which may or may not be a disadvantage. It also generates a large amount of r.f. interference which could at extra expense be filtered.



METHOD D

Model aircraft enthusiasts may know of a method of motor control employing six transistors, at least four of which have to be capable of carrying motor current. This completely removes the necessity for relays and is the best solution, but was rejected on the grounds of expense.

The method used in the final design was in my opinion, the best compromise between expense, sensitivity, reliability, noise, and other factors mentioned.—B.C.

Book reviews

PICK-UPS: THE KEY TO HI-FI
By J. Walton
Published by Sir Isaac Pitman & Sons Ltd.
100 pages, 7¼in × 4¾in. Price 10s

THIS author, possessing much specialised knowledge of pick-up design and performance, tells us that in general the pick-up is the weakest link in the chain. Although there are some advanced pick-ups, the run-of-the-mill devices not only distort the reproduction but also physically distort the record. Mr. Walton explores these aspects in an interesting and informative way and with the help of some very good illustrations.

Possibly the most important chapter is that dealing with requirements for pick-up design. Certainly it contains numerous points for the enthusiast to ponder and relate to his own practical experience. The explanations of tracking error and tracing distortion are most valuable.

Such explanations lead in most cases to good advice. For instance, in choosing a pick-up you should give first consideration to low tip mass (the effective mass at the stylus tip). I must say that the advice would be worth more if tip mass were more generally quoted in specifications, but perhaps the way Mr. Walton spotlights this topic will help toward an improvement.

The chapter on trouble-shooting encourages an organised approach to the tracing and curing of faults. There are some surprises. For example, thin turntable base-plates and thin-walled arms can be responsible for emphasising record surface noise.

There is little to criticise. The use of "stylii" as the plural of stylus is a common error (one "i" is quite enough). A lower response limit of 40c/s is mentioned, but I think 30c/s is desirable and practicable.

Actually this work is a paperback of only about 100 pages, but it is packed with facts and free from padding. Warmly recommended to both beginners and more advanced enthusiasts.

C.B.

AERIAL HANDBOOK
By G. A. Briggs with R. S. Roberts, M.I.E.R.E., Sen. M.I.E.E
Published by Wharfedale Wireless Works Ltd.
144 pages, 8½in × 5½in. Price 8s 6d

WE normally find Mr. Briggs associated with books on audio subjects. It may come as a surprise, therefore, to some readers, that he has written this excellent handbook on aerials of all kinds, including those for microwave communications. This work is a by-product from the re-writing of his well-known book "Sound Reproduction".

As he says, the subject of aerials is vast, but he presents a mine of information in the most readable, and sometimes humorous manner, that few others can. This book will appeal to most readers, but more to those specifically engaged in aerial design and erection, or radio wave communication of almost any kind.

Aerials embrace other networks apart from the familiar indoor or outdoor array: diplexers and multiplexers, boosters and attenuators, waveguides, tuned circuits, signal strength meters, and filters. The subjects are not confined solely to domestic radio and television; satellite communications, relay services, microwave telephone and television links, Eurovision, short wave transmission—these are all described.

Let me hasten to add that for the technically-minded, technical specifications and characteristics are given. For the newcomer, enough material is provided to help his comprehension of aerials so that he can made his own (for television bands, of course).

This book is well written, well illustrated (the cartoons are good, too!), and presented in purposeful sequence. Although it is a paperback, it is 8s 6d well spent.

Don't blame me if you are caught reading it under the blankets!

M.A.C.

DESIGN AND CONSTRUCTION OF TRANSISTOR SUPERHETS
By R. H. Warring
Published by Museum Press Ltd.
104 pages, 8¾in × 5¾in. Price 17s 6d

WELL known in the field of model control, R. H. Warring has neatly combined simple radio theory with practice in the domestic field in this hard-back volume, which is rather on the expensive side.

No space wasting—straight in on the first page with radio transmission and reception, frequency and wave-length; page two, a.m. and f.m. The author doesn't waste words in coming straight to the point. This may seem a little off-putting to some, because it can lead to rather a "dry" style. However, the facts are there and well illustrated.

Chapter 2 inevitably had to be on the theory of transistor circuitry (*pnp* only). Then, from the third chapter onward, we can get our teeth into the practical side with the making of printed circuits, component assembly, practical circuit design and the choice of values. Professionally designed circuits are given with hints on testing and fault finding, followed by a chapter on testing and alignment.

A.M.

DIRECT CURRENT AND MAGNETISM
Edited by Edgar J. Black
Published by N.V. Philips Gloeilampenfabrieken
Distributed by Iliffe Books Ltd.
119 pages, 8½in × 5¾in. Price 10s 6d

THE words chosen for the title always suggest to me physics lessons at school. On opening the pages, there they were, and I nearly thought it was written for my ex-science-master.

Atoms, Ohm's law, temperature and resistance, questions and answers; resistors, thermistors, potentiometers, questions and answers; also batteries and accumulators, magnetism, electromagnets, and meters.

An excellent book for the beginner (aged about 12 years upward) or for dad who wants to jump on the electronics bandwagon.

M.A.C.

detached particles

JOHN VALENCE

BEGINNERS START HERE!

Australia now having "gone decimal", we in the U.K. are almost in total isolation with our non-decimal currency. But not indefinately it seems, for now comes the promise that we will surrender our individuality and get into step with the rest of the world in 1970.

Despite all the upheaval this will entail, a change in the monetary system will be but child's play compared with a change of our rule of the road. Driving simulators already widely used in America are now being installed in Europe, but our drive-on-the-left convention has prevented the introduction of this particular kind of simulator here as yet. Modifications, including the preparation of special colour films of traffic, are in hand and this modern aid to good driving is likely to be seen here in a few months' time.

It does seem rather strange that we should have to wait for an imported simulator. I recollect that there are one or two British firms who have done much work in this field. Flying a VC10, driving a diesel locomotive, or indeed fighting a war!—all these activities are realistically enacted with the aid of computer controlled trainers. The general use of simulators for initial training of motorists is of course long overdue. Putting raw beginners into the driving seat of a car on the roads of today is about as scientific as tossing an infant into the deep end of the pool in order to teach him to swim. Even more important, it is infinitely more dangerous to other parties!

WAIVING THE RULE

From the various reports in the press, one gathers that a number of "pressure groups" are busily at work furthering the interests of local commercial radio. The BBC has long been aware of this danger and is preparing to face this challenge with its own plans for a network of local stations.

Meanwhile, down at the dockside, feverish activity goes on as yet another fishing vessel undergoes transformation to a floating juke box. What with oil derricks and pirate radio masts, the North Sea must be beginning to resemble a cross between a Texas oil field and Rugby radio station.

Who supplies the transmitting equipment for the pirate stations? Not the better known, well established manufacturers of broadcasting equipment—or, so I am assured by one of the firms in this category. After all there is no point in jeopardising good business with the BBC and GPO for the sake of a few peanuts.

Personally speaking, I consider it deplorable that these pirate stations should be able to cock a snook at authority and carry on their money making business entirely free of obligations to international regulations and to commercial performing rights. Pirate is certainly the right word. But let us remember it is a term of stigma and should not be falsely glamourised even by accounts of storm buffeted disc jockeys manfully carrying out their duties.

There may well be a good case for introducing commercial radio into this country but to condone, much less applaud, these illegal activities is in my view completely wrong. Such attitudes can only open the door to anarchy.

"At anyrate, we now know what it's like to be on the flip side"

STAND BY FOR BLASTING

Lighter evenings and (we hope) brighter weather are just around the corner. Relaxation in the garden is a comforting thought after the vigours of a strenuous day's toil. But the image is already somewhat marred, I am afraid, by the recollection that the finer weather brings out not only the buds, but the ice-cream vans complete with the inevitable public address system.

Too often in the past has the relative calm of our neighbourhood been violated by the modern version of the hokey-pokey man. Amplified jingles punctuate the still air at a seemingly increasing repetitive rate as the curfew hour approaches: a last desperate attempt by the salesman to dispose of his wares before he too retires for the day.

Having learnt about a 1kW loudspeaker, claimed to be the most powerful acoustic transducer ever made, I will be almost afraid to indulge in a quiet nap in the deck chair this summer. Just imagine the horrible nightmare this could produce of a fleet of ice-cream vans parading around the roads with this latest audio monster squatting on their roofs!!

Fantasies apart, you may be interested in some of the technical details of this speaker to end all speakers produced by Stromberg-Carlson in the U.S.A. A woofer unit covers the frequencies up to 300c/s. The speech coil is kept cool by a small fan as the cone moves up to two inches in an air gap of nearly 700,000 maxwells produced by a 24lb ring magnet. A second unit covers the middle range from 300 to 2,400c/s. It does not finish there, however, for the makers are planning tweeter units to extend the range up to 15kc/s. A mere 13 of these h.f. units will be installed around the middle frequency unit.

Although news of this gargantuan loudspeaker came into my hands some weeks ago, I deliberately withheld any mention until the 31 March had safely passed. Didn't want to give *them* any ideas . . .

Pleasant snoozing.