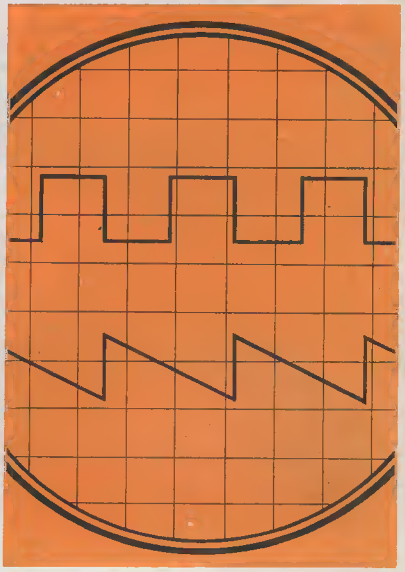
THE
RADIO CONSTRUCTOR
RADIO · TELEVISION · ELECTRONICS · AUDIO

Vol. 22 No. 4
NOVEMBER 1968
3/-
A DATA PUBLICATION

OSCILLOSCOPE TRACE DOUBLER



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Specifications

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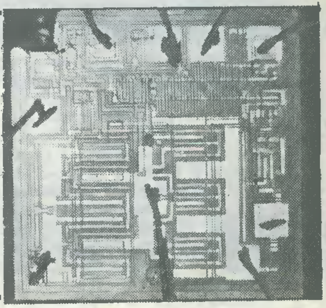
Frequency response	5 Hz to 100 KHz ±1dB
Total harmonic distortion	Less than 1% at full output
Load impedance	3 to 15 ohms
Power gain	110dB (100,000,000,000 times) total
Supply voltage	8 to 18 volts
Size	1 x 0·4 x 0·2 inches
Sensitivity	5 mV
Input impedance	Adjustable externally up to 2·5 M ohms for above sensitivity

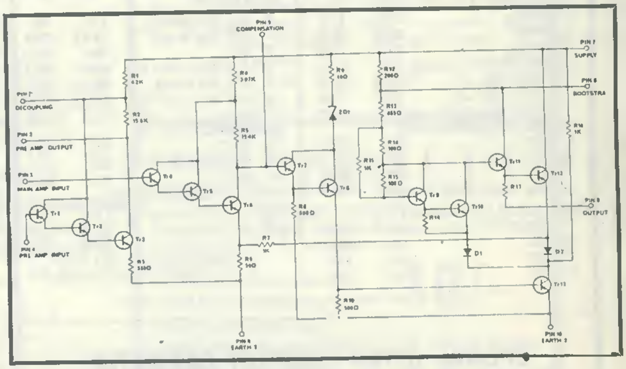
■

ABOVE SHOWS ACTUAL SIZE OF IC-10.
TO RIGHT, VIEW OF AMPLIFIER MAGNIFIED 625 TIMES.



Circuit Description

The circuit diagram of the IC–10 is shown on the right. The first three transistors are used in the pre-amp and the remaining 10 in the power amplifier. The output stage operates in class AB with closely controlled quiescent current which is independent of temperature. A high level of overall negative feedback is used round both sections and the amplifier is completely free from cross-over distortion at all supply voltages. Thus battery operation is eminently satisfactory.



Construction

The monolithic I.C. chip is bonded onto a gold plated area on the heat sink bar which runs through the package. Wires are then welded between the I.C. and the tops of the pins which are also gold plated in this region. Finally the complete assembly is encapsulated in solid plastic which completely protects the circuit. The final device is so rugged that it can be dropped thirty feet on to concrete without any effect on performance. The circuit will also work perfectly at all temperatures from well below zero to above the boiling point of water.

Applications

Each IC–10 is sold with a very comprehensive manual giving circuit and wiring diagrams for a large number of applications in addition to high fidelity uses. These include public address, loud-hailers, use in cars, inter-com, stabilised power supplies, electronic organs, oscillators, volt meters, tape recorders, solar cell amplifier, radio receivers.
The transistors in the IC–10 have cut off frequencies greater than 500 MHz so the pre-amp section can be used as an R.F. or I.F. amplifier making it possible to build complete radio receivers without any additional transistors.

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5" 1200'	43/2	35/–
*5¾" 1800'	56/11	46/–
*7" 2400'	79/–	63/6
10" 4600' Agfa only	140/9	112/9
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3" 600' Scotch only	24/10	19/9
4" 900'	40/–	32/3
*4¼" 1200' Agfa, BASF only	50/–	40/3
5" 1800' Not Scotch	66/2	54/–
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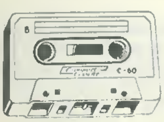

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150 WATT AMATEUR BANDS TRANSMITTER

by

F. G. RAYER, G3OGR

This article, the first in a series of three, is mainly intended for the amateur transmitter who has already obtained constructional and operating experience at powers below the full legal output. The driver of power amplifier stages are described in this issue, whilst next month's article covers v.f.o. design

INTRODUCTORY NOTES

The best way of finding out how to do a specific job consists of following the advice of a person who has carried out that job in practice, and the present series of articles describes the very successful 150 watt transmitter designed and built by the author. The text gives theoretical and constructional details of each section of the transmitter, with specific reference to the assembly methods adopted in the author's own installation. Alternative approaches are also dealt with.

The author's transmitter uses a 19in rack assembly with the sections fitted, from top to bottom, in the following order: driver/p.a. stages, meter panel, v.r.o., modulator, power supply. The v.f.o. and modulator are of versatile design and may be employed with driver/p.a. sections other than that covered this month. Power supplies are standard, and suitable circuits have already been described by the present author in "Power Supplies For Transmitters And Other Equipment" in the June 1967 issue.

Several obvious but nevertheless important points have to be made. Some of the components are of standard type and do not need to be specified by individual manufacturer's name and type number. The more experienced transmitter constructor may already have many of these to hand. In common with much home-constructed transmitter equipment, a few of the parts may not be available through component retailers handling normal receiver parts. *Finally, the supply voltages encountered in transmitters of the type to be described are high and have a large current reserve, whereupon it is of the utmost importance to ensure that full precautions against accidental shock to the constructor and other persons are provided. Even after switching off, always ensure that smoothing and reservoir capacitors are fully discharged before touching any h.t. points in the equipment.*—Editor.

CIRCUITS FOR THE FULL LEGAL INPUT OF 150 WATTS need be no more complicated or difficult to build than lower power equipment—they simply use valves and other components of larger size and rating. The driver and p.a. described here have operated without trouble for some years, both with input from a variable frequency oscillator, and as a 2-stage crystal controlled 150W transmitter.

Fig. 1 gives the circuit. VR_1 controls the 807 driver output, whilst VC_1, with the tapped coil L_1, tuning 80, 40 and 20 metre bands. R_3 provides protective bias in the absence of grid drive, which develops bias across R_2. The 807 is generally operated at about 20–25mA anode current (easily within its rating) so the 100mA anode meter is actually optional.

R.F. input to the 813, V_2, is across RFC_1 and this stage is operated with about 10mA grid current, developing 150V bias across R_4. This bias cuts off the 6L6, V_3. Should drive cease (from keying or wrong adjustment, etc.) the bias across R_4 disappears and the 6L6 conducts, dropping the 813 screen grid potential to a level which keeps anode dissipation easily within the valve limit. The 100mA screen grid meter, M_4, was fitted to check 813 and 6L6 clamp valve operation, and can be omitted since currents are actually well inside maximum limits.

The 813 was chosen as p.a. because it is not difficult to obtain on the surplus market and has a maximum anode dissipation of 125W. It will thus withstand periods of off-tune operation which would destroy smaller valves. A convenient input for 150W is 150mA at 1,000V, but other voltages have been used. This supply is modulated for a.m. A screen grid modulator has also been employed with the circuit, and has given excellent results.

For v.f.o. working, 1·75 Mc/s input was used to the 807 for 3·5 Mc/s, and 7 Mc/s input for 7 Mc/s and 14 Mc/s. In each case L_1 is tuned to the transmitter output frequency so that the 813 works "straight through".

CRYSTAL CONTROL

Crystal control has been used both with the 807 and at

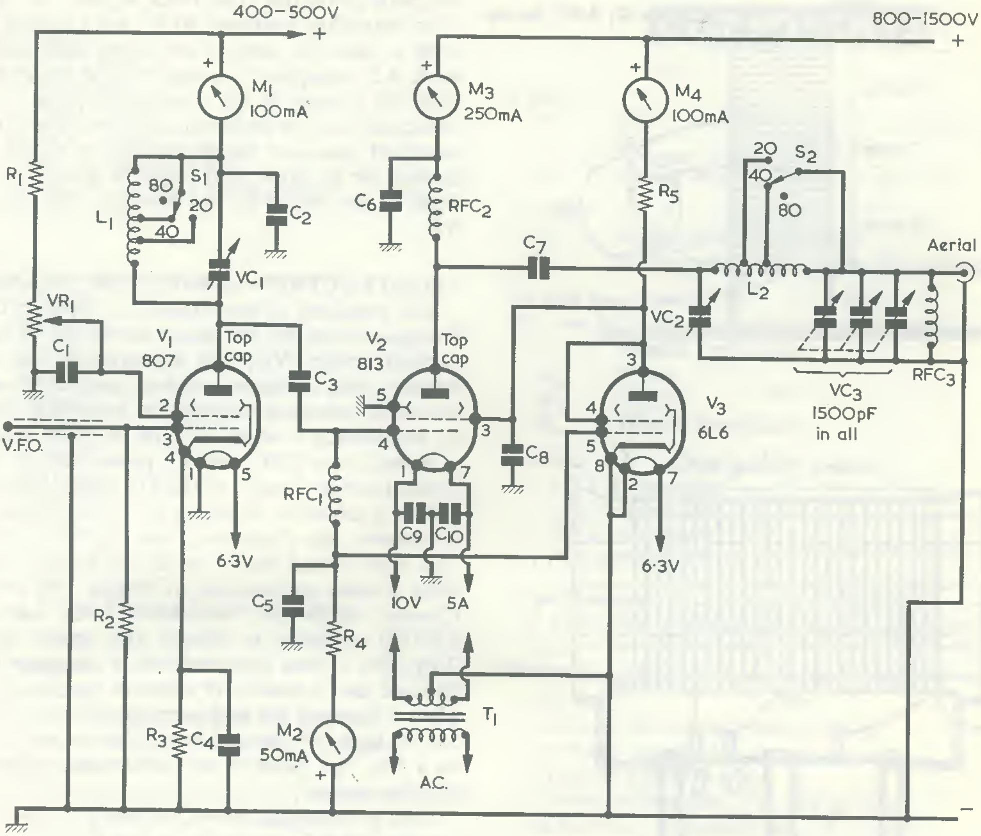


Fig. 1. The circuit of the driver and 150 watt power amplifier

an earlier stage. Fig. 2 shows the 807 modified for crystal control. This gave 20mA 813 grid current on 80m with 160m crystals; 20mA grid current on 80m and 40m, with 80m crystals, and 15mA on 40m and 20m with 40m band crystals. Therefore any of these combinations can be used, VR_1 being turned back for about 10mA p.a. grid current.

L_1 operates on the crystal fundamental or crystal harmonic, and VC_1 is adjusted in the usual way for maximum p.a. grid current. Many local and Dx contacts on various bands have been made with two or three crystals, though the main advantage of crystal control is its simplicity. Also it is possible to start working with a crystal until a v.f.o. has been constructed.

L_1 AND L_2

Coils L_1 and L_2 are as shown in Fig. 3. L_1 has a $1\frac{1}{2}$in diameter former about $3\frac{3}{4}$in long. The 20m section consists of 10 turns of 20 s.w.g. enamelled wire wound to a length of 1·2in. For 40m a further 7 turns are in use, also wound with 20 s.w.g. wire, the turns having a winding length of 0·6in. The final 15 turn section uses 22 s.w.g. enamelled wire and has a length of 1·4in.

With a 100pF capacitor in the VC_1 position, these windings cover the required bands, and do not allow tuning to unwanted harmonics. Any similar type of coil should do, and turns may be adjusted as needed. VC_1 should be nearly fully open for resonance on 20m.

L_2 is wound with 16 s.w.g. wire on a large Eddystone ribbed former. This takes 26 turns in all, occupying a winding space $3\frac{1}{2}$in long, and the winding is $2\frac{1}{2}$in in diameter. Brackets were cut from aluminium to mount the coil on the bandswitch, so that the assembly is supported from the panel.

The 40m tap is at 13 turns, so that 13 turns remain in circuit when 40m is selected. The 20m tap is 6 turns from the VC_2 end of the coil, giving resonance near minimum capacitance.

COMPONENTS

There is some latitude in capacitor values, but it is very important that voltage ratings be adequate for the various circuit positions. C_1 and C_2 can be 500V working or similar. C_4 can be 150V or lower. C_3 is preferably 1kV

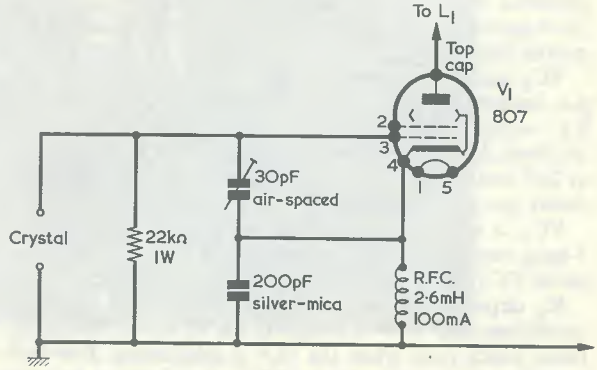
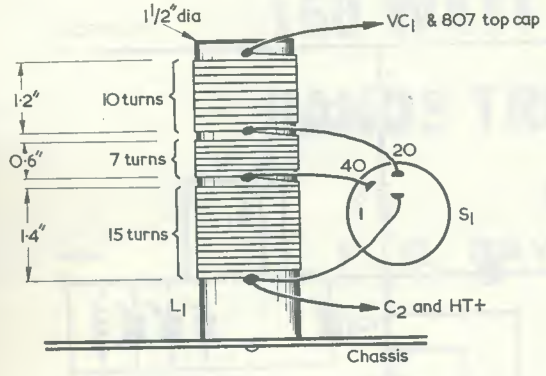


Fig. 2. Modifying the 807 stage for crystal control



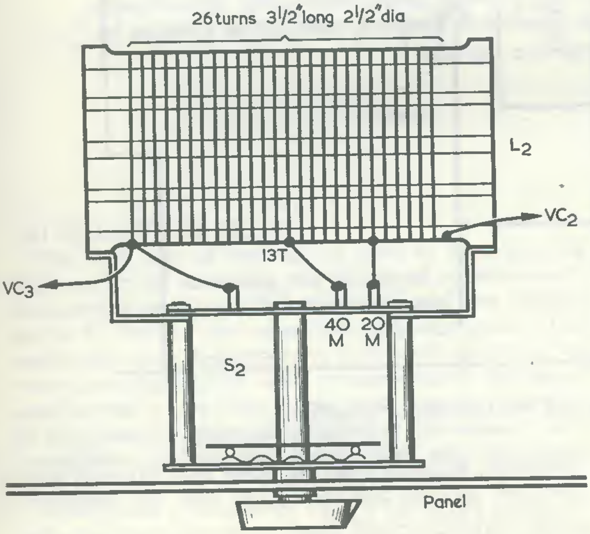


Fig. 3. Coil winding details for (a) L_1 and (b) the p.a. tank coil, L_2

mica. C_6, C_7 and C_8 were all 5kV mica in the writer's equipment, though 2kV would do for C_8. C_5, C_9 and C_{10} are small mica or ceramic, 500V.

VC_1 is returned to h.t. positive to avoid adding the h.t. potential to the r.f. voltage and a capacitor with 0·015in plate spacing is satisfactory. Spacing could, of course, be greater than this.

VC_2 had 0·08in plate spacing (3·5kV rating). With the p.a. loaded, the r.f. voltage across VC_2 about equals the h.t. voltage. With anode modulation, this voltage is doubled. A spacing of 0·03in is rated at 1·5kV, with 0·05in at 2kV and 0·07in at 3kV. Sparking on modulation peaks shows spacing is too small for the h.t. voltage.

VC_3 is a standard size (*not* miniature) receiver type 3-gang capacitor. RFC_3 is included to keep h.t. from the aerial if C_7 leaks, and does not influence working.

R_5 depends somewhat on h.t. voltage and working conditions and 50W is adequate for all needs, including those which exist when the 6L6 is conducting. For 1kV supplies, R_5 need only be 25W. If clamping is only employed briefly to protect the the p.a. under fault or temporary no-drive conditions, R_5 may be 10W.

In the author's version, RFC_2 was a 2·5mH choke fitted with a base for upright mounting and obtained from ex-R.A.F. equipment. A suitable alternative is the Denco RFC.9A quoted in the Components List. This is wire-ended and may be anchored at its lower end at the adjacent stand-off insulator which couples to C_6. If needed, an anchor for its upper end could be given by a solder tag fitted to the rear of L_2 coil former at the end adjacent to VC_2.

CONSTRUCTION—ABOVE THE CHASSIS

The positions of most items can be seen from Fig. 4. Components in the 807 anode circuit are to the right of a vertical screen. VC_1 has a clearance hole in a metal bracket with insulated washers each side, and also an insulated extension coupling, to avoid h.t. short-circuits. L_1 bandswitch is below VC_1, on the same bracket.

A lead from RFC_1 and C_3 passes directly through the vertical screen to tag 4 of the 813 holder (see Fig. 5). This holder is mounted on pillars above the chassis, and wired as shown. An aluminium box 3in high, 7in long and 3½in wide is then placed round the holder. The two long sides of these are provided by bolting 7 by 3in "Universal Chassis" single side members (Home Radio Cat. No. CU147) vertically to chassis and screen. A top plate, 7 by 3½in, is then prepared with a clearance hole for the 813 and also a number of adjacent ventilation holes. This plate is screwed on, and supports the stand-off insulator for the high voltage lead here. The box end is then closed by a 3 by 3½in piece of expanded metal secured with self-tapping screws.

This arrangement places the 807 grid circuit under the chassis, the 807 anode circuit and 813 grid circuit above chassis to the right of the vertical screen, with all other connections to the 813 (except anode) inside the box. The box top lies in about the same plane as the interior circular screen inside the 813. Note that in Fig. 5 the holder sockets are numbered anti-clockwise because the holder is viewed from *above*, while in Fig. 1 pin connections are numbered clockwise in the usual way.

All the connections shown in Fig. 4 should use stout wire, this being short and direct in r.f. circuits. Insulation should also be suitable for the h.t. potentials present. Vehicle sparking plug cable was used for the lead from the stand-off insulator alongside RFC_2 and for other high voltage circuits. This is readily obtainable at garages, but is really thicker than is necessary. Ordinary insulated wire, with two extra coverings of insulated sleeving, one inside the other, will alternatively be satisfactory for 1kV. Adequate rubber or p.v.c. grommets must be fitted at all points where wiring passes through holes in the chassis or screen.

CONSTRUCTION—UNDER THE CHASSIS

Fig. 6 shows the connections and layout here. In the writer's version, R_5 was mounted in clips fitted to insulators. A short length of co-axial cable passes from the 807 control grid to the v.f.o. section, which occupies a lower position in the rack. The v.f.o. could, however, be in a separate cabinet, positioned at the side of the driver p.a.

There is ample space below the chassis for a heater transformer for the three valves. Both the 807 and the 6L6 require 6·3V at 0·9A, whilst the 813 requires 10V at 5A. Heater transformers for the 813 are found on the surplus market, as this valve has had quite extensive

COMPONENTS

Resistors
(All fixed values 10%)

R_1	27kΩ 5 watt
R_2	27kΩ 1 watt
R_3	270kΩ 1 watt
R_4	15kΩ 2 watts
R_5	50kΩ 50 watt (see text)
VR_1	25kΩ 5 watt, potentiometer, linear, wirewound

Capacitors
(see text for working voltage and other details)

C_1	0·01μF
C_2	0·01μF
C_3	100pF
C_4	0·01μF
C_5	0·01μF
C_6	2,000pF
C_7	2,000pF
C_8	2,000pF
C_9	5,000pF
C_{10}	5,000pF
VC_1	100pF variable
VC_2	150pF variable
VC_3	1,500pF (3-gang 500pF) variable

Inductors

L_1	see text
L_2	see text
RFC_1	2·6mH 100mA, type RFC5 (Denco)
RFC_2	2·6mH 250mA, type RFC9A (Denco), see text
RFC_3	2·6mH 100mA, type RFC5 (Denco)
T_1	heater transformer (see text)

Valves

V_1	807
V_2	813
V_3	6L6 or 6L6G

Switches

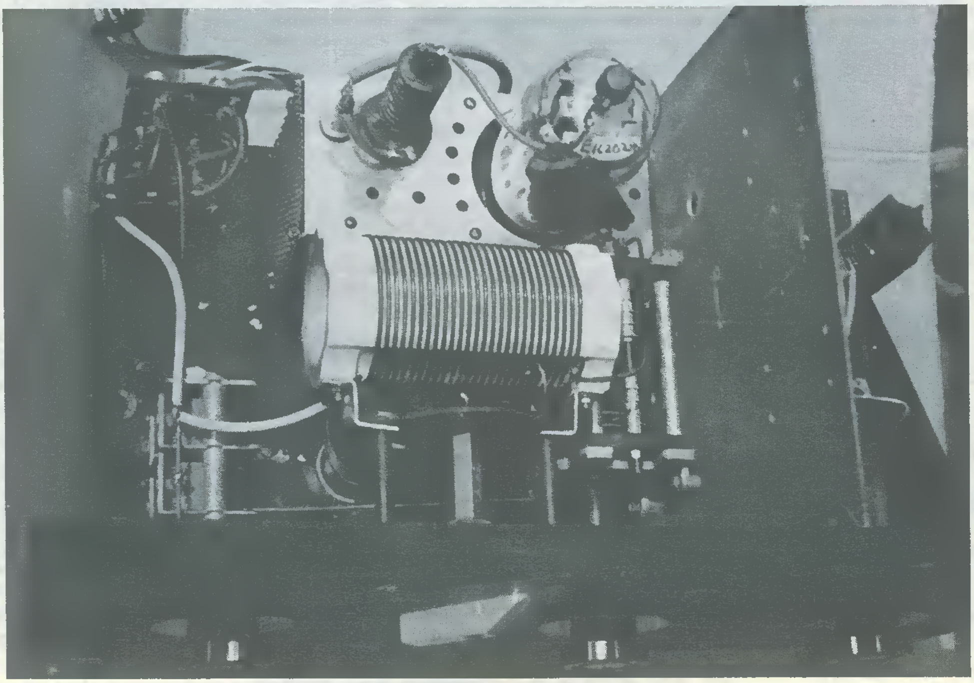
S_1	single-pole 3-way, wafer
S_2	single-pole 3-way, wafer, non-miniature

Meters
(M_3 and M_4 must be totally insulated types for 1·5kV)

M_1	100mA (optional)
M_2	50mA
M_3	250mA
M_4	100mA (optional)

Sockets
1 UX5 valveholder
1 UX7 valveholder
1 Octal valveholder
1 Coaxial socket

Miscellaneous
2 extension spindles, bushes and couplers (VC_2, S_1)
—1 extension spindle, bush and insulated coupler (VC_1)
Insulated mounting washers (VC_1)
2 top cap connectors
2 pointer knobs (S_1, S_2)
3 knobs with scales (VC_1, VC_2, VC_3)
Metalwork, grommets, etc., as required



Top view of the driver/p.a. illustrating, in particular, how the tank coil is mounted on switch S_2

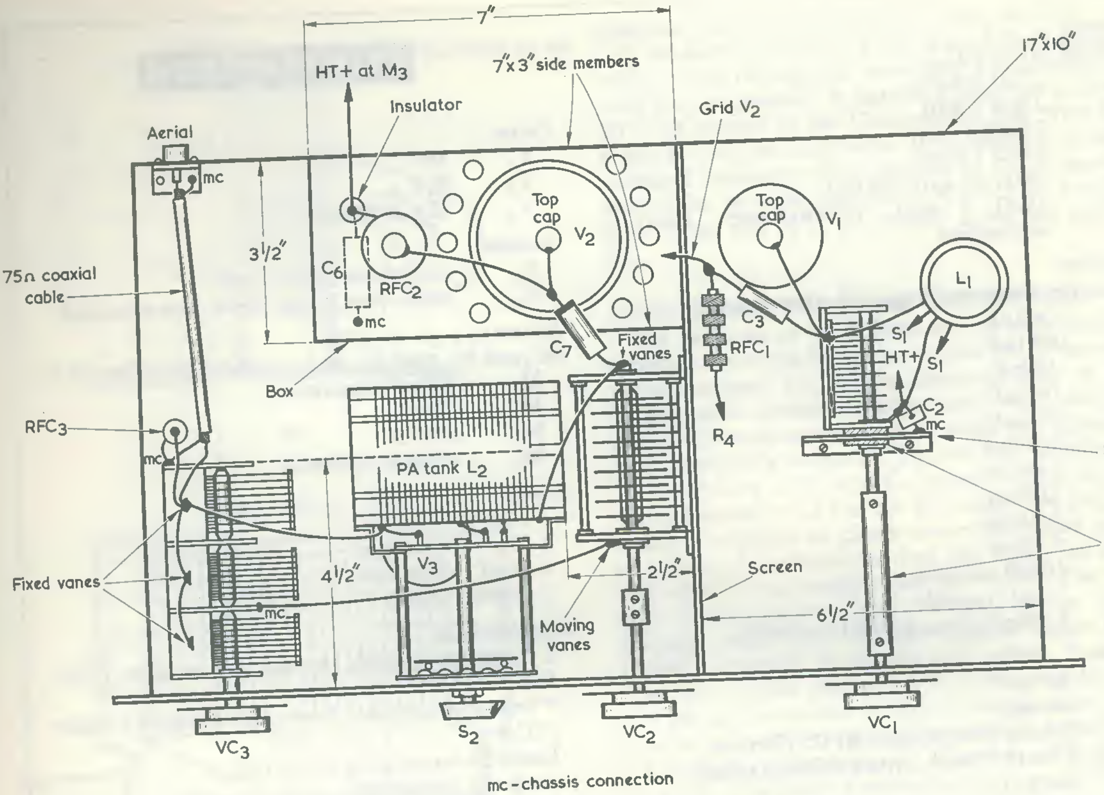


Fig. 4. Component positioning and wiring above the chassis

amateur use. (A commercially manufactured transformer offering 10V at 5A is the Woden type DTF22.—EDITOR). The centre-tap should be connected to chassis, as shown in Fig. 1. An alternative approach, which has been used successfully by the writer, is to employ a transformer with two 6·3V 6A windings connected in series with the junction between them earthed to chassis. One winding supplies the 807 heater, the other the 6L6 heater, and the two outside ends supply the 813 heater with an 0·5Ω

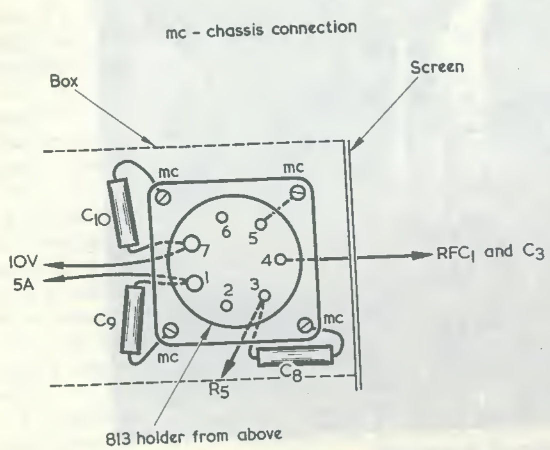


Fig. 5. Connections to V_2 valveholder inside the screened box

wirewound resistor in series in one lead to drop the excess voltage. Again, separate 10V and 6·3V transformers may be used, if necessary.

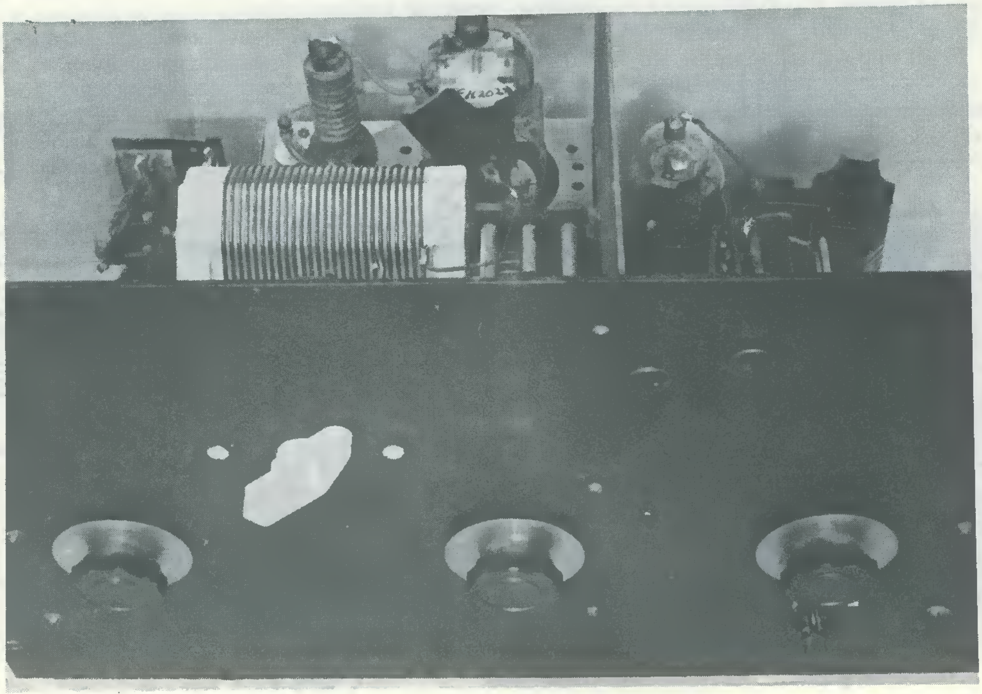
METERS

The meters occupy a second small panel in the author's assembly, but there is easily enough space on the driver p.a. panel for the 813 grid and anode current meters. As already mentioned, the 807 anode and 813 screen-grid meters are optional.

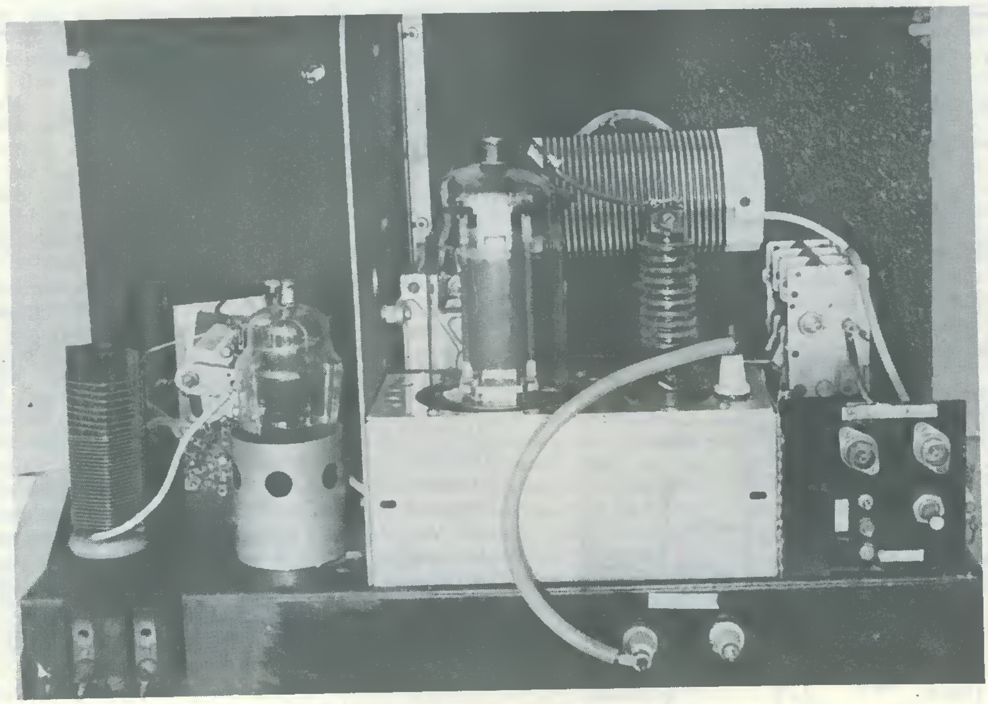
VR_1 can be mounted under the chassis or, as in the writer's equipment, on the v.f.o.panel.

Various methods of controlling the whole equipment can be used. The one adopted by the author is shown in Fig. 7. When S_1 in this diagram is closed, all heaters are on. A mains voltage relay controls current to the primaries of the h.t. supplies. S_2 can be left open to permit adjusting the v.f.o. and tuning for grid current, etc., without voltage on the p.a. The T/R switch closes the relay circuit, switches the aerial to the tank, earths the receiver aerial lead, and interrupts the receiver speaker circuit. When S_2 is closed, the T/R switch gives complete changeover from Transmit to Receive.

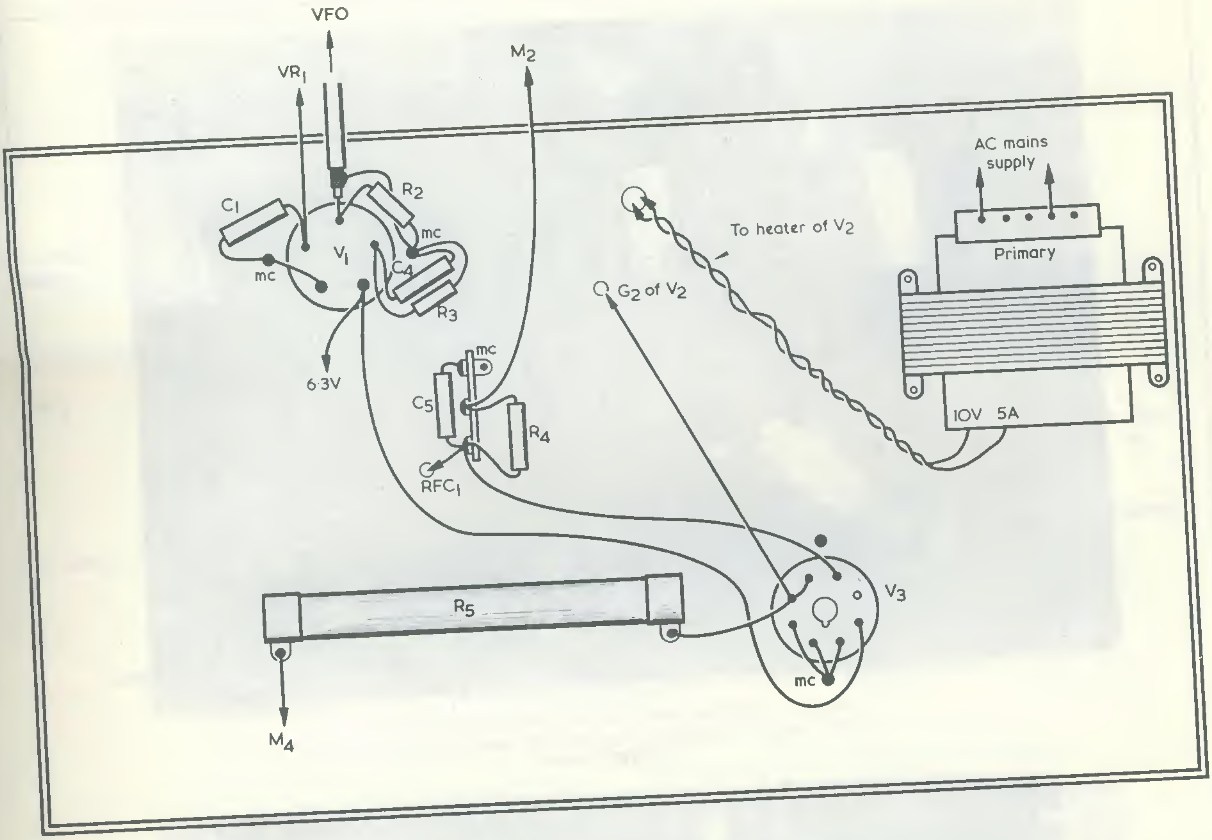
In the writer's transmitter, the T/R switch was mounted on a bracket in the position of the coaxial aerial connector (Fig. 4) and operated by an extension link and crank. The switch is not shown in Fig. 4 because some other method of controlling the equipment may be adopted. An ordinary receiver type 2-wafer rotary switch has, incidentally, proved quite satisfactory since it was installed in this circuit position.



Another top view, showing also the panel controls. The knob for switch S_1 can be seen below that for VC_1



Rear view of the driver/p.a. stage. At the right is the spindle of the Transmit/Receive switch of Fig. 7 together with an aerial socket for the receiver. This arrangement is optional and the switch and additional aerial socket are not shown in Fig. 4



mc - chassis connection

Fig. 6. Wiring below the chassis. See text for further details on the heater transformer and its wiring. Pin 1 of V_3 is earthed to chassis to accommodate a "metal" 6L6, should this be used

TESTING AND TUNING

A check should be made for grid current on each band, with no h.t. on the p.a. If L_1 is not made as described, a wavemeter can be used to make sure that resonance is around 3·5, 7 and 14 Mc/s. More grid current was possible on each band than was required, and VR_1 reduces this.

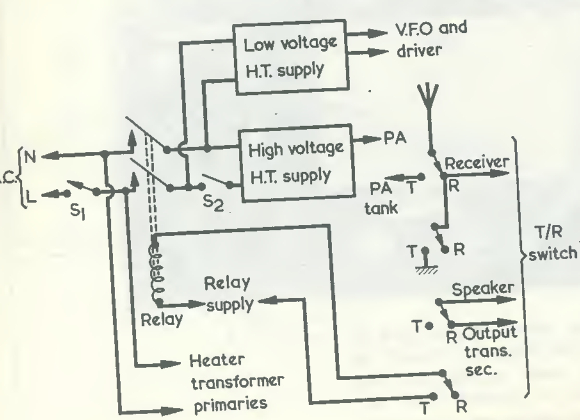


Fig. 7. The overall Transmit/Receive switching arrangements employed by the author

VC_1 need not be readjusted for relatively small adjustments to working frequency in a band.

A simple test for transmitter output can be made with a 150W 240V domestic lamp in a holder connected to twin-flex or co-axial lead. This can be plugged into the aerial outlet, or clipped across VC_3. Obtain 10mA grid current on the wanted frequency. Put the T/R switch to Receive. Close VC_2 and VC_3. Close S_2 of Fig. 7 (or otherwise apply high voltage). Turn the T/R switch to Transmit, noting p.a. anode current and rotating VC_2 for a current dip. This will be too low, and anode current is increased by opening VC_3, meanwhile slightly re-tuning with VC_2. In this way the wanted input is obtained, VC_2 always being adjusted for *minimum* anode current. With 150W input (say 150mA at 1,000V) the 150W lamp should light with considerable brilliance.

To check clamping, turn VR_1 to zero. Grid current should cease, r.f. output should cease, and p.a. anode current should drop to a low level. During normal phone operation the 6L6 plays no part, but it gives instantaneous protection to the 813 if grid drive ceases. Without this drive there is no grid bias, and the 813 anode current could rise so high as to cause rapid damage were the 6L6 clamp not in use. Since the 6L6 controls the 813 screen-grid voltage in this way the transmitter can be keyed in an earlier, low-powered stage, for c.w. Cathode keying of the

807 has been used for some time without snags.

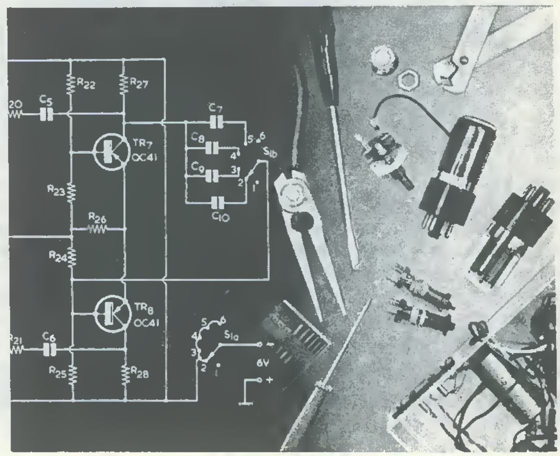
Parasitic suppressors were originally included, but were found unnecessary with the layout shown. With a good earth connection and an end-fed aerial operated through a tuner, it was found possible to operate on 3·5, 7 and 14 Mc/s bands without any T.V.I. on the home receiver in a nearby room. But this does not necessarily assure freedom from T.V.I. in other circumstances. Having power supplies on a separate chassis seemed helpful in keeping r.f. out of the mains. The transmitter has also had long periods of use with dipoles fed directly by 75Ω coaxial cable in the usual way.

(To be continued)

SUGGESTED CIRCUIT No. 216

LOW VALUE CAPACITANCE BRIDGE

by G. A. FRENCH



With present-day circuits and components it is often desirable to be able to measure very low values of capacitance, and a simple and reliable test instrument capable of carrying out this function can be a considerable asset to the constructor. The instrument which is described in this month's article is specifically intended for measuring low values of capacitance, and it offers a range from less than 1pF to greater than 12,000pF. The circuit has been designed with economy in mind, but this does not prevent it from giving indications at the low capacitance end of the range which are clear and sharp, and which involve no guesswork in their interpretation. An incidental feature of the instrument is that it incorporates two field effect transistors to provide null indications in a manner which has not, so far as the writer is aware, been previously reported.

DEVELOPMENT APPROACH

There are quite a few novel features in the overall design of the capacitance bridge, and a good method of introducing these consists of first discussing some of the decisions which were taken by the writer during initial development, always bearing in mind that the primary requirement of the instrument is the measurement of very low values of capacitance.

To start off with, a bridge circuit is the most attractive for the present *application* because of its simplicity and the fact that it does not have to rely on expensive meters or similar components for indications. The great advantage of a bridge is that indications can be provided by any uncalibrated device having the requisite sensitivity, the actual readings being taken from the component settings in the bridge itself after it has been balanced.

Considering the high level of sensitivity they can provide, a pair of headphones probably represent the cheapest null indicator for a bridge. It was, in consequence, decided to use headphones for the design under consideration. The bridge could then be energised by a.c. at an audio frequency.

The choice of audio frequency had next to be resolved. Since the reactance of a capacitor decreases as frequency increases, a high energising frequency would result in a low reactance in the capacitor to be measured, whereupon the risk of error due to leakage resistance between the connections to that capacitor would become reduced. Also, a low reactance in the capacitor to be measured would allow greater power to be fed to the balance indicator, with the result that off-balance indications would be stronger and the balance position itself more sharply evident. Conflicting against this, however, is the fact that the audible level offered by headphones above some 1kc/s decreases as frequency increases, as also does subjective perception by the human ear. It was initially intended to use a bridge energising frequency of 5 kc/s, but later experiment showed that a somewhat better compromise was given by reducing it, slightly, to 3 kc/s. At 3 kc/s a capacitance of 1pF offers a reactance of about 50MΩ. This is sufficiently low to reduce to negligible proportions the risk of errors caused by poor insulation resistance between the connections to that capacitor. Also, a frequency of 3 kc/s offers a reasonably satisfactory audible level when reproduced by standard diaphragm headphones.

A basic capacitance bridge may be made up with either one side of the energising supply earthed (i.e. connected to the chassis of the associated instrument) or with one side of the null indicator earthed. If one side of the null indicator is earthed, both terminals of the a.c. energising supply have to be "floating", whereupon the most convenient method of applying this supply is by way of a transformer. Unfortunately, the transformer secondary feeding the bridge will inevitably have stray capacitance to its primary and to earth, and these then appear across the bridge arms. With normal home-constructor a.f. transformers such

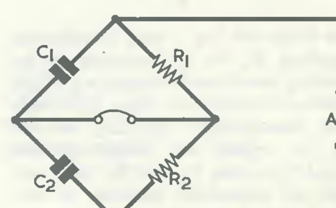


Fig. 1. A simple capacitance bridge

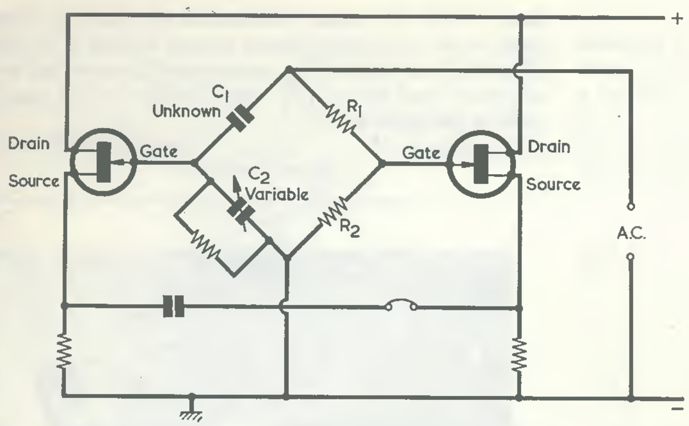


Fig. 2. The capacitance bridge with field effect transistors coupled to the arm junctions. These isolate the headphones from the bridge, and ensure that tray capacitances between the headphone leads and earth do not cause errors in readings

stray capacitances would almost certainly be well in excess of the 1pF minimum it is intended to measure, with the result that readings around this value could be more difficult to resolve accurately and sharply. It was decided, therefore, to have one side of the energising supply earthed instead, whereupon it is the null indicator terminals which become "floating". As is discussed shortly, a special coupling technique is used to prevent stray capacitances between the null indicator (the headphones) and earth from upsetting the operation of the bridge.

The bridge circuit, as so far described, is shown in Fig. 1. Two arms are given by R_1 and R_2 and two by C_1 and C_2, whilst one side of the a.c. energising supply is earthed to the chassis of the instrument. Balance is given when

$$\frac{C_1}{C_2}=\frac{R_2}{R_1}.$$

The relationship is "opposite" to that given with a bridge consisting of four resistors, because the reactance of a capacitor varies inversely as its capacitance. From the equation, we may also say that

$$C_1=\frac{R_2C_2}{R_1}$$

The bridge of Fig. 1 may be adjusted by making R_1 or R_2 variable or by combining these two resistors in a single potentiometer with the right hand side of the headphones coupling to the slider. Or, again, the bridge may be adjusted by having R_1 and R_2 fixed and one of the capacitors variable. It was decided to avoid having variable resistance in the present design since the only suitable component for long term reliability would have to be wirewound and, at the relatively high frequency to be used, this might introduce undesirable reactances into the resistance arms. The final decision consisted of making C_2 variable and C_1 the "unknown". A wide range of continuously variable capacitance for C_2 (starting from a quite high arbitrarily chosen minimum) can be provided by connecting the sections of a standard ganged capacitor in parallel. Such a component will not, as would a carbon variable resistor, exhibit any wear affecting its electrical performance even after a considerable amount of use. Having C_2 variable instead of C_1 means that the frame of the variable capacitor employed in the C_2 position can be at chassis potential, giving a significant easing of constructional problems. The only disadvantage is that neither terminal of the unknown capacitor, C_1, is at chassis potential (although its upper plate may be at a fairly low impedance to chassis).

The next problem during initial development was to overcome the possibility of errors being introduced due to the fact that both connections to the null indicator are "floating". In the circuit of Fig. 1 stray capacitances between either headphone lead and chassis will upset the conditions in the bridge and cause incorrect readings to be given.

The solution appears in Fig. 2, in which the two central junctions of the bridge are applied to the gates of two field effect transistors powered by the positive supply line shown. The two transistors function as source followers and their gates present an almost infinite resistance to the bridge as well as a very low capacitance. The headphones connect across the sources via a d.c. blocking capacitor and, in consequence, are at a low impedance to chassis. The signals at the sources have very nearly the same amplitude as those at the gates, so that the bridge may be balanced in the same manner as if the headphones were connected to it directly. Thus, by interposing the field effect transistors between the central junctions of the bridge and the headphones, the bridge junctions remain "floating" and are virtually unaffected by varying stray capacitances between the headphones and chassis. Another advantage conferred by using field effect transistors in this manner is that they allow an off-balance signal of good amplitude to be fed to the headphones even when the reactances appearing in the bridge are of the order of tens of megohms, and they thereby impart increased sharpness to the balance setting.

Fig. 2 shows C_2 in its variable form, with one terminal connected direct to chassis. As already stated, C_1 is the unknown capacitor. From the second equation given earlier, we know that C_1 varies directly as R_2. In the complete instrument different values for R_2 are selected by a 4-way switch to provide 4 capacitance ranges.

It will be noted that a fixed resistor is connected across C_2. The function of this resistor is to maintain a d.c. path between the gate of the left hand f.e.t. and chassis, thereby keeping this electrode at chassis potential. The resistor may have a value around 10MΩ, any unbalancing effect it may have on bridge performance being taken up during calibration. Actually, this effect is quite small in the complete instrument, because the calibration for each range starts with an arbitrarily chosen minimum capacitance in C_2 of about 100pF, which corresponds to a reactance at 3 kc/s of around 0·5MΩ.

COMPLETE CIRCUIT

The complete circuit of the capacitance measuring instrument appears in Fig. 3. The components to the right of the vertical dashed line constitute a 3 kc/s generator and we shall discuss this section of the instrument later. A 3 kc/s output from this generator is passed, via C_3, to the bridge section around TR_1 and TR_2. The bridge section is based on the circuit of Fig. 2, but component identifications (R_1, R_2, etc.) are different.

In Fig. 3 the capacitor whose value is unknown is connected to the Test Terminals, whereupon it takes up the same position as did C_1 of Fig. 2. C_2 of Fig. 2 appears in Fig. 3 as C_1. It has a value of 1,500pF and is given by a 3-gang capacitor having 500pF in each section, and with all the sections paralleled. The frame of C_1 bolts to chassis, thereby providing a connection for the moving vanes. The resistor across C_1 is R_1, and it has a value of 10MΩ.

R_1 of Fig. 2 is now R_4, with a resistance of 47kΩ. R_2 of Fig. 2 is replaced by whichever resistor is selected by the Range switch, S_2. On Range 3 the selected resistor, R_7, has the same value as R_4. In consequence this range corresponds to the actual range of capacitances offered by C_1 and is nominally 100 to 1,200pF. S_2 switches in the 4·7kΩ resistor, R_6, on Range 2. R_6 is one-tenth the value of R_4, whereupon the range of capacitance measurement becomes 10 to 120pF, or one-tenth of the actual capacitive range offered by C_1. Similarly R_5, at 470Ω, is one-hundredth of R_4, causing Range 1 to be one-hundredth of the actual capacitive range given by C_1. On Range 4 R_8 is selected and this, at 470kΩ, is ten times the value of R_4. Range 4 is correspondingly ten times the actual capacitive range offered by C_1.

The two field effect transistors of Fig. 2 are shown in Fig. 3 as TR_1 and TR_2. These are insulated-gate N-channel depletion transistors type 40468, and are available from Amatronix, Ltd. Both function as source followers, with R_2 and R_3 as source resistors. The output from the two sources is passed, via C_2, to the headphone terminals.

A component not shown in Fig. 2 is the "Press To Read" switch S_1. This is a normally-closed push-button or spring biased toggle switch, its function being to ensure that the gate of TR_1 is always connected to chassis when the capacitor to be measured is being coupled to the Test Terminals. Without this connection it would be possible for a static voltage to be passed to TR_1 gate when the operator's fingers touch the lower Test Terminal and, under certain circumstances, this could be sufficiently high to cause the gate-channel insulation of TR_1 to break down. The presence of S_1 also ensures that if a capacitor connected to the Test Terminals should happen to be charged, it can discharge via R_4 and the resistor selected by S_2. Without the short-circuit to chassis provided by S_1, a charged capacitor could also result in breakdown of the gate-channel insulation of TR_1.

Since S_1 carries out a very important function, it is desirable to emphasise the manner in which it is employed. This switch must only be pressed *after* the capacitor to be measured has been connected to the Test Terminals and *after* the operator's fingers have been taken away from these terminals. It follows from this that the capacitor being measured *must not* be handled whilst S_1 is pressed. These precautions do not incur any time-wasting procedure whilst taking a measurement. The capacitor whose value is unknown is initially connected to the Test Terminals. The operator removes his hands from the terminals, S_1 is pressed and C_1 is adjusted for balance. S_1 is next released, after which the capacitor under test can be removed from the Test Terminals. This approach is fairly fool-proof, since both hands will normally be required for connecting the capacitor to, or removing it from, the Test Terminals. When taking a measurement, one hand is then available to press S_1 whilst the other adjusts C_1. To prevent accidental pressure on S_1 whilst connecting up the capacitor under test, it would be a good plan to mount the switch on the side of the case in which the instrument is housed, with the Test Terminals on the front panel. Alternatively, it may be provided with a small protective hood. If the bridge is to be used by people other than the constructor, they should be advised of the correct procedure for using S_1.

Turning to the 3 kc/s generator, this appears to the right of the vertical

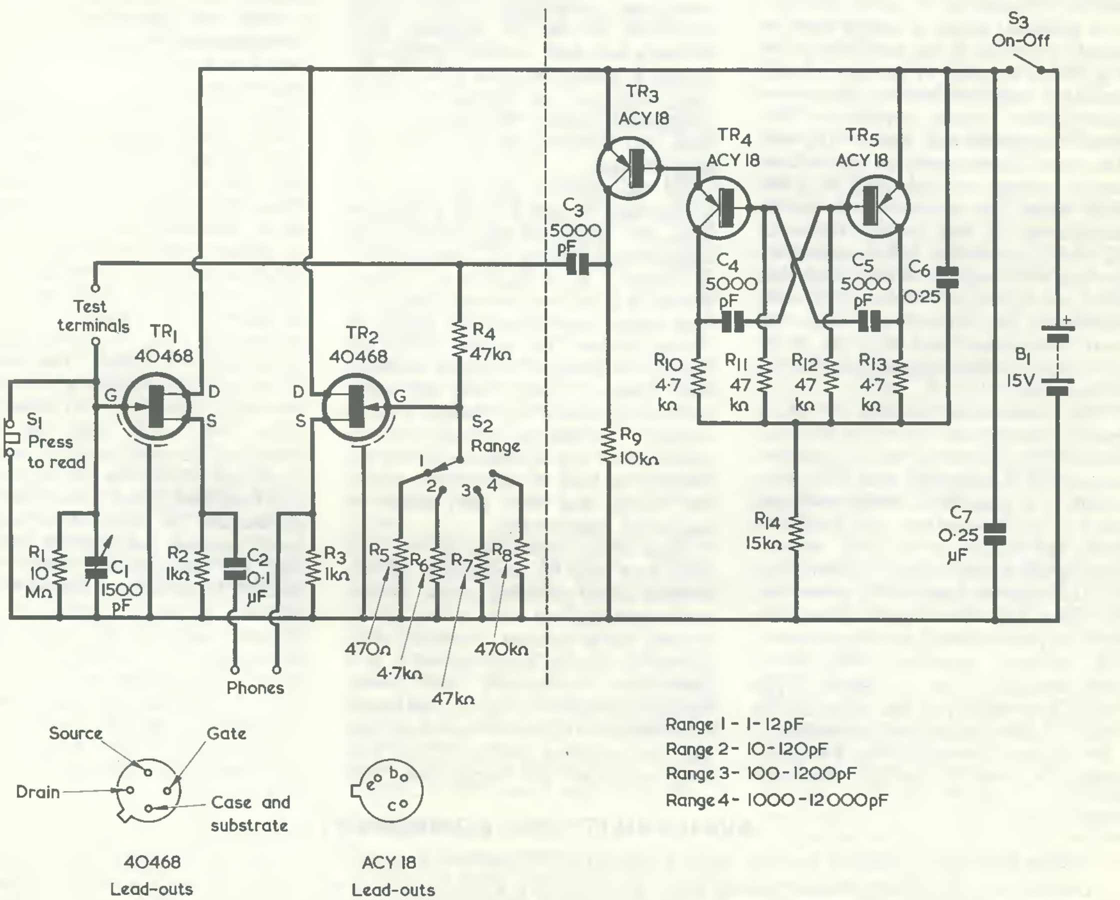


Fig. 3. The complete circuit diagram for the capacitance measuring instrument

Fig. 4. The Range 1 calibration given with the prototype. Readings are in picofarads

dashed line, and consists of the multivibrator given by TR_4 and TR_5, with the following amplifier TR_3. The supply to the multivibrator (which is drawn "upside-down" in Fig. 3 because the upper supply rail is positive) is dropped to some 3·5 to 4 volts by R_{14}, with C_6 functioning as bypass capacitor. The reason for running the multivibrator at less than the full 15 volts provided by the battery is that the maximum reverse base-emitter voltage for most small germanium transistors suitable for use in a multivibrator of this nature is of the order of 10 to 12 volts only, or even less. It has to be remembered that, in a multivibrator, the base of the transistor being cut off during the changeover in the cycle is momentarily driven in a reverse direction by the other transistor to a potential which is nearly equal to supply potential. If the multivibrator of Fig. 3 were supplied by the total 15 volts available from the battery, the reverse base-emitter voltage applied to TR_5 would approach this figure. TR_4 and TR_5 work comfortably at the reduced supply voltage available after R_{14}, and most small a.f. transistors should be satisfactory in this circuit. Capacitor C_4 and C_5 are a little low in value for a germanium transistor multivibrator and there is a very slight risk that, with some transistors, the multivibrator might not start. The author used ACY18's in the prototype and these caused no difficulties in this respect.

The base-emitter junction of TR_3 is inserted between the emitter of TR_4 and chassis, with the result that TR_3 switches on and off in sympathy with TR_4. As a result, it is possible to obtain a square wave of good waveform and amplitude from the oscillator of TR_3 without loading the multivibrator. Further, since R_9, the collector load of TR_3, is returned to the negative supply line, the peak-to-peak value of the square wave at TR_3 collector approaches the full 15 volts available from the battery. (The writer first employed this technique in "D.C. Voltage Multiplier", published in *The Radio Constructor* for February, 1968). TR_3 may be any a.f. transistor having a maximum collector voltage rating in excess of 15 volts, and in the prototype the writer used a third ACY18 here.

The output from TR_3 is passed, via C_3, to the bridge section of the instrument.

PRACTICAL POINTS

Construction should raise few difficulties, provided that care is taken to keep stray capacitances low in the bridge section to the left of the vertical dashed line. The components in the gate circuit of TR_1 should be spaced away from those in the gate circuit of TR_2 by some two inches or more. Both f.e.t. gates are at fairly high impedance and are liable to pick up stray 3 kc/s signal voltages, which will mask the null. The section to the right of the dashed line should preferably be screened from that to the left, although this is not entirely essential if the two sections are spaced well apart. The lead from C_3 into the bridge section should be kept well away from wiring connecting directly to the two gates.

The two Test Terminals need to be mounted on a piece of high-grade Paxolin, or similar, offering a high insulation resistance. The switch employed in the S_1 position must similarly have high insulation resistance. Switch S_2 should be of the Yaxley wafer type and not a miniature rotary component, since the latter varierty tend to exhibit rather high self-capacitances.

All the resistors may be $\frac{1}{4}$ watt or $\frac{1}{2}$ watt types. R_1, and R_9 to R_{14} inclusive, may be 10% carbon, whilst the remainder should be 5% high stability. In theory, if R_5 to R_8 were 1% types it should be possible to use one scale for all four ranges, multiplying the figures on this as required. The writer checked out this point in practice but found, however, that Ranges 1 and 4 did not agree sufficiently closely with Ranges 2 and 3 to merit this method of operation. In consequence, it is recommended that 5% resistors be used in the resistive side of the bridge and that each range be calibrated individually.

Field effect transistors of the type used here may be damaged if an unearthed mains soldering iron is applied to the gate lead-out when wiring up. To prevent static voltages damaging these transistors during construction it is a good plan to initially wire 4-way transistor holders into circuit first (white nylon holders available from Amatronix, Ltd. are suitable) and to fit f.e.t.'s to these after all the wiring has been completed and checked. Fig. 3 shows a chassis connection to the cases of TR_1 and TR_2. As may be seen from the lead-out diagram for the 40468, this connection also passes to the transistor substrate.

All the capacitors in the circuit may be paper or plastic foil types.

The headphones used with the bridge must be 2,000Ω types (i.e. two 2,000Ω earphones connected in series). Lower resistance phones, and especially single earpiece types, will probably not have sufficient sensitivity. Despite the fact that a high amplitude a.f. signal is fed into the bridge, there is a considerable degree of attenuation in the bridge arms, especially near the balance position, and the a.f. output is correspondingly reduced. It is also, of course, at a relatively high frequency. With the prototype, it was found possible to balance the bridge at all points of the four ranges when using 2,000Ω phones, the volume being more than adequate for use in a quiet room. It is possible that a crystal earpiece, with its enhanced higher frequency response, could be employed instead of the 2,000Ω phones, but this point was not checked by the writer.

With the prototype, the current consumption from the 15 volt supply was 4·5mA only.

CALIBRATION

As already mentioned, all four ranges are calibrated separately. This is not a difficult task if a small quantity of capacitors of known value are available, these being used singly or connected in series, in parallel and in series-parallel to provide calibration points. All null points should be sharp and easy to find.

The four ranges listed in Fig. 3 are nominal, and assume a minimum capacitance in C_1 of around 100pF and a maximum of 1,200pF. This restriction to the range ends allows a small amount of further travel in C_1 at either end in order that nulls may be reliably identified. Balance obviously cannot be confirmed unless one can approach the null from both sides! Nevertheless, there should still be some useful range "in hand" outside the nominal end limits, and the appropriate points can, if desired, be included in the calibration to provide a small degree of overlap between ranges. As an idea of what is to be expected, Fig. 4 shows the Range 1 calibration obtained with the prototype. It will be seen that the values are comfortably spaced out and that readings can, in practice, be obtained at as low a capacitance as 0·5pF.

AVAILABILITY OF COMPONENTS

We take the greatest care to ensure that the components specified in our articles are (a) correctly described, (b) of adequate rating and (c) currently available on the market. It occasionally happens however that some retailers run out of stock and find difficulty in obtaining immediate fresh supplies from the manufacturer—a waiting period of many weeks not being unusual. This is, of course, beyond our control and we regret any inconvenience caused to readers where this occurs.

QSX

by L. SAXHAM

(All times GMT)

A report on the stations – both amateur and broadcast – that may be logged by the s.w.l. on the various short wave bands; compiled by a Dx'er whose QTH is located near the S. Suffolk coast.

● TOPIC

"What's all this SINPO business?"

SINPO is a reporting code adopted by the Broadcast bands listener. Previous to this, the QSA/R code was used but was found to be totally inadequate to convey—when making a report—the necessary and required information to the station engineers. The QSA/R code, only conveys two points of information—signal strength and readability—it does not present sufficient material in which the station engineer would be interested. And in order to obtain the desired QSL card, as much information as is reasonably possible should be included in the report to the station.

As time went by, it became increasingly clear to Broadcast band operators that a different code to the QSA/R system would have to be adopted. Thus it was that the SINPO system came to be used by the world-wide brotherhood of broadcast bands listeners. The SINPO code conveys all the information required by an engineer when assessing the receivability of his transmitter signals at the particular location from which the report emanated.

The term SINPO is composed by the initial letters of the following headings under which the information is conveyed. Signal strength (QSA), Interference (QRM), Noise atmospheric (QRN), Propagation disturbance (QSB) and Overall merit (QRK). Under each of these headings there are five points of assessment which the listener must determine with as much accuracy as he is capable. For instance, it will be seen, from the SINPO Table—published in this issue on page 245—that under, for instance, the Signal strength heading (QSA) a progression from S1—barely audible, is made to S5—excellent. Similarly, the same progression, from 1 to 5, is made under the remaining four headings.

The use of this code has become almost universal within the last few years and it should be used by all Broadcast bands listeners if the desired QSL card is to be obtained from the station to which one is reporting. An example of the use of this code would be as follows:—33443, this imparting the information that the transmission was received Signal strength fair, Interference moderate, Noise slight, Propagation disturbance slight and the Overall merit fair.

SINPO is a shortened version of a more embracing code—SINPFEMO.

● Amateur Bands

Plenty of varied Dx has been apparent on the Amateur bands of late. There was a time when the choicest Dx to be heard was on the 14 Mc/s c.w. band but in recent years, however, the emphasis has changed to s.s.b. The writer personally regrets this change but it certainly makes Dx reception an easier matter for the phone only operator.

21 Mc/s

A recent foray on this band produced the following signals.

SSB: DU1FH, XW8AX, ZS6JF, 9K2CC and 9M2NR.

14 Mc/s

CW: CE9AT, CR6IV, HP1LR, KG6AAY, LU7FAL, PY2DQ, 2OU, 3AOF, TF3OJ, VK5KO, YS1XEE, 2RC, 2SJ, YV1AB, ZE1DB and ZL4CA.

SSB: CE1CN, HR1KAS, 1XAP, HV1CN (Vatican), KR6KN, 6NR, KV5FN, KZ5HE, LU1SE, 2CQ, 6DRB, OA4W, PY6AT, TG8IA, TI2EVA, VK2AJN, 3ALM, 3AXL, 3MO, 3WQ, 4KS, 6RU, 7GK, 7RX and VU2DKZ, 2LO.

7 Mc/s

Despite the remarks made under this sub-heading in the September issue, the writer was determined to have another try on this band—it being a favourite Dx haunt of pre-war years when there was far less commercial intrusion than there is at the present time.

CW: G16TK, GM3LOM, 3OXX, 3WOJ,

SSB: CM2DC, PY2EGA, 2EMD, 2ENR, 2GE, TG9VD, YV4OY, 5BPG and 9Y4KR.

1·8 Mc/s

The limited time spent on this band was entirely taken up with operation over the c.w. end, this produced a few thrills and spills and the following signals were noted.

CW: GI6TK, GM3LOM, 3OXX, 3WOJ, GW3XJC, OK1AWQ and OK2SSS.

● Broadcast Bands

There is always something of interest to hear on these bands and one never knows quite what to expect from one moment to the next. Recently, whilst idly tuning around one of the low frequency bands, Accra, Ghana, on 3350 kc/s was logged with the news in English and station identification at 2200. On another occasion, whilst tuning around the 5 Mc/s region, Lagos, Nigeria, on 4990 kc/s was heard with the talking drum interval signal followed by the news in English at 2100. The African talking drum must be heard to be believed!

3375 1950

CR6RZ, Radio Angola, Angola—with song programme.

4765 2030

Radio TV Congolaise, Brazzaville, Congo—with programme of African music.

4800 0230

YVMO, Radio Lara, Venezuala—station with identification.

4810 0355.

YVMG, Radio Popular, Venezuala—closing with National Anthem.

4872 0220

TGQH Radio Cruz, Guatemala—with sports commentary.

4890 0215

YVKB, Radio Dif. Venezuala—with station identifcation.

4923 0430

HCRQ1, Quito, Ecuador—with station identification.

4970 0115

YVLK, Radio Rhumbos, Venezuala—with station identification.

4972 2035

Radio Yaounde, Cameroon—with talk in French.

7200 2105

Kabul, Afghanistan—with programme of native songs. Kabul, the capital, is on the river Kabul (length 260 miles) which flows through Afghanistan to the River Indus at Peshawar. Kabul (alt. 6,900ft) is south of the Hindu Kush.

15325 0845

HCJB, Quito, Ecuador—with programme in English and station identification. Quito, the capital, is situated in the Andes 15 miles south of the Equator, altitude 9,402ft.

● Now Hear This

5052 1615

Radio Singapore, Singapore with programme of pop music and signing off with National Anthem at 1630. Singapore is situated at the extreme southern tip of the Malay Peninsular.

And This

4985 1600

Radio Malaysia, Malaysia—with 6 "pips", station identification and news in English. SINPO 33333.

● Last Look Round

Reader—"What receiver ancillary equipments do I need to obtain better reception and accurately log the low powered African and S. American Broadcast stations?"

Answer—"See QSX next time round—January issue".

NEWS . . . AND .

LOW-PRICED BATTERY CHARGER FOR TRANSISTOR RADIOS

A low-priced battery charging system called "Pencel" is announced by DCB Instrument & Lighting Company of Austin House, Croft Road, Crowborough, Sussex.

Following the outstanding success achieved by DCB Instrument & Lighting Company with rechargeable power supplies in the ophthalmic and medical fields, DCB have developed the "Pencel" battery charger to cover applications such as transistor radios, cameras, tape recorders, etc.

"PENCEL" CUTS BATTERY COSTS

The facility to recharge a cell, time and time again, at a fraction of the cost of the batteries spells an economy to the general public which cannot be overlooked. Recent field tests have demonstrated that the MN 1500, the popular battery in the transistor radio and photographic fields, can be recharged between ten and thirty times (depending upon operational conditions) by the "Pencel" Battery Charger.

As a replacement set of alkaline manganese 1500 type cells costs 11s. and has a limited life in a transistor radio, it is apparent that the initial outlay of 79s. 6d. which includes four alkaline manganese 1500 type cells, is soon recovered.

The "Pencel" Battery Charger is of all British design and manufacture and obtainable from DCB Instrument & Lighting Company.

COMBATING FLOOD DAMAGE

Permutit De-ionisers were in action recently in the flooded areas of Molesley, Esher, Tonbridge and Horley, offering free supplies of demineralised water.

A number of portable de-ionisers were put at the disposal of residents whose electrical equipment, tape recorders, hair dryers, vacuum cleaners, etc., were contaminated by flood waters.

One resident, Mr. Brian Matthews, of Hildenborough near Tonbridge, stated, "I have an expensive tape recorder which was under four feet of water and covered with slime for several hours. It is now working perfectly after cleaning with demineralised water. I have also cleaned and restored many valuable records by the same method."

Demineralised (purified) water produced by these ion exchange de-ionisers was in demand for washing the silt and sewage contamination from equipment and household electrical appliances which, if rinsed with ordinary tap water would have been affected by salts and damaging deposits left behind after drying out.

As the de-ionisers are completely portable the task was made easy and simple. Demineralised water is produced instantly by the action of raw water passing through the ion exchange resins in the de-ioniser.

Permutit Portable De-ionisers are used in laboratories and industry. Their larger counterparts produce millions of purified water daily for power stations, factories, steelworks and oil refineries all over the world.

BOUND VOLUMES

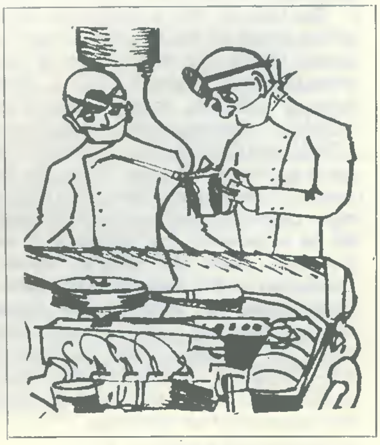
Year by year bound volumes of *The Radio Constructor* sell more quickly, and we regret that Volume 19 and all previous bound volumes are now out of stock.

Volume 21, covering the August 1967 to July 1968 issues, are now available from Data Publications Ltd., price 35s. plus postage 4s. 6d.

SNAP-IN 12 WAY MAINS CONNECTOR BLOCK

A Snap-in 12 Way Mains Connector Block now available from Carr Fastener Co. Ltd., of Stapleford, Nottingham, is designed to accept a 7/·064in max. diameter input cable. The connector block consists of a Nylon moulded body with a cadmium plated steel terminal strip. The input cable clamp is brass and incorporates a steel screw. The connector can be assembled with right or left hand cable entry and with red, blue or brown moulding. It is designed to snap-into pre-punched holes in 0·91mm (·036in) to 1·63mm (·064in) thick material. The terminal blades are for use with ·250in snap-on solderless connectors.

"For goodness sake can't you shut up! Nothing but torque, torque, torque."



. . . COMMENT

BRITAIN'S LIBRARY OF SOUND

The British Minister for the Arts, Miss Jennie Lee, has opened the new premises of Britain's first-ever national sound library.

In a BBC broadcast, Derek Blizzard made it clear that the Library—or to give it its proper name, the British Institute of Recorded Sound—is not something to appear suddenly out of the blue. It has, in fact, been in existence for more than a decade, quietly and persistently endeavouring to build up what Britain, unlike most Western countries, surprisingly did not possess—national sound archives. For a time, the Institute scraped along on meagre resources, dependent very largely on voluntary effort, until eventually the Government decided to provide the necessary financial support. Now, with its move to a permanent home in the museum area of London's fashionable Kensington, it has at last achieved public recognition.

The Institute at present has in its possession about 140,000 disc recordings, together with a large collection of tape recordings and folk-music cylinders. Many of these have come from private contributors in Britain and overseas—indeed about a thousand recordings a month are received in this way. The main British commercial record companies also present the Institute with all serious and some "pop" issues, and in addition copies are made of all material that goes into the BBC's own sound archives, which are still the largest sound collection in Britain.

The Institute's aim is to provide the general public, in particular students of languages, music, natural history and sociology, with a comprehensive sound reference library—what its Director, Mr. Patrick Saul, describes as a sound picture of our age. "We feel (he said) that there are valuable sounds, just as there are valuable books or valuable pictures or valuable buildings. And since the phonograph was invented, we ought to make use of it to enable posterity to hear all these things."

And just what are these valuable sounds that Mr. Saul speaks of? Well, they cover an immense range. Voices of famous personalities, many of them now dead; historic speeches; eye-witness descriptions of great events; theatrical and opera performances; animal sounds; street noises; examples of accents and dialects—an endless list. More, perhaps, than many of us realise, our world is captured and immortalised in sound. At the opening ceremony, the guests were given a vivid reminder of this fact, as a running tape recorder played through a succession of historic records from the Institute's collection. They heard, for example, the voice of the English poet, Robert Browning, reading a poem in 1888; a recording of Brahms playing one of his own works—an extremely rare piece copied from a cylinder once housed in a Berlin museum; the voice of Lenin addressing the third Communist International in 1919; and lastly, and most striking of all, the sound of the first-ever recording made by the inventor of the phonograph, Thomas Edison, in 1877.

The nucleus of a British national sound collection now exists. But of course the Institute is anxious to enlarge it by every means, and to make it as international in scope as possible. There seems no reason why, in the course of time, it should not vie with the British Museum as a cultural treasure-house of the British nation.

ELECTRONIC LABORATORY KIT

A.P.T. have introduced a new "Lektrokit" electronic construction kit for laboratory and educational use.

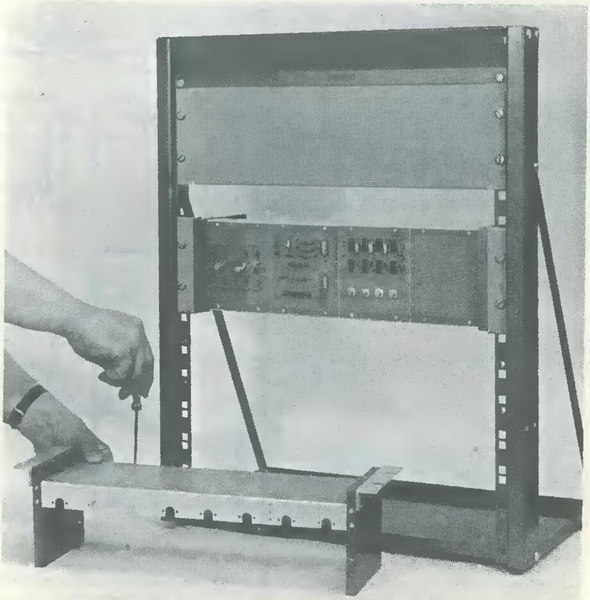
The kit consists of a bench rack with two chassis assemblies on which discrete components and integrated circuits can be mounted and wired. A front panel of grey enamelled aluminium alloy is also provided for indicator lamps, meters, switches, and other controls.

The base tray can be used to carry power supplies or other auxiliaries, and there is space for an additional chassis assembly or front panel if required.

This kit, known as "Lektrokit No. 6" enables laboratory experimental circuits to be neatly stacked vertically instead of the usual sprawl across the bench, and allows immediate "shelving" of a rig if a need arises to clear the bench space for other work.

These assemblies, if used generally in laboratories, will increase the utilisation of bench space, and create a uniform neat appearance of the work in progress.

The price of the Lektrokit No. 6 is £7 10s. (£7·50), and further details are available from the manufacturers, A.P.T. Electronic Industries Ltd., of Byfleet, Surrey.



One of the chassis units assembled for fixing into the completed rack kit

INEXPENSIVE INTERCOM SYSTEM

by
D. F. W. FEATHERSTONE

This article describes an intercom switching circuit which enables the amplifier to be permanently switched on with negligible load on its battery. Any amplifier with sufficient gain may be employed and a circuit is given for the simple transistorised unit used by the author

THE INTERCOM TO BE DESCRIBED OFFERS CLEAR reproduction, a call facility from main and extension positions and continual operation with negligible current drain from the battery. The amplifier may be of any type offering sufficient gain, and the circuit for that employed by the writer is discussed later.

SWITCHING CIRCUIT

The switching circuit external to the amplifier is given in Fig. 1. One loudspeaker is employed both for reproduction and as a microphone at the main position, and another at the extension position.

Switch S_1 is 4-pole 3-way and provides Stand-by, Listen and Talk. Switch S_2 is 2-pole 2-way and offers Normal and Call facilities. Rotary wafer switches can be employed for S_1 and S_2, and they must be of the break-before-make type to prevent feedback gurgles and other effects when switched from one position to the next. An alternative for S_2 would be a double-pole double-throw toggle switch spring-biased to remain at Normal. Switch S_3 is at the extension position, and may be an ordinary toggle switch. Since it is only closed for calling and for communication, some constructors may prefer to use a push-button here.

When the intercom is out of use, switch S_1 is at Stand-by, S_2 is at Normal and S_3 is at Off. The negative terminal of the 9 volt amplifier battery then connects, via $S_{2(a)}$ and $S_{1(d)}$, to the negative plate of the 50μF electrolytic capacitor at the extension position. The positive plate of this capacitor couples via the extension speaker to earth. Thus, there is a negligibly low flow of current from the battery, this passing through the 50μF electrolytic capacitor, the extension loudspeaker and the (now inactive) amplifier circuit.

On Stand-by, $S_{1(a)}$ and $S_{1(b)}$ couple the output of the amplifier back to the input via resistor R_x. This resistor has a value which, when the amplifier is brought into operation, causes it to oscillate at an audio frequency.

Let us next see what occurs when a call is made. If the main station wishes to call the extension station, S_2 is switched from Normal to Call. Contacts $S_{2(a)}$ connect the negative terminal of the 9 volt battery to earth, and the amplifier becomes operative. The amplifier output connects, via $S_{1(b)}$, $S_{2(b)}$, $S_{1(d)}$ and the 50μF electrolytic capacitor to the external loudspeaker. Since $S_{1(a)}$ and

(*continued on page 231*)

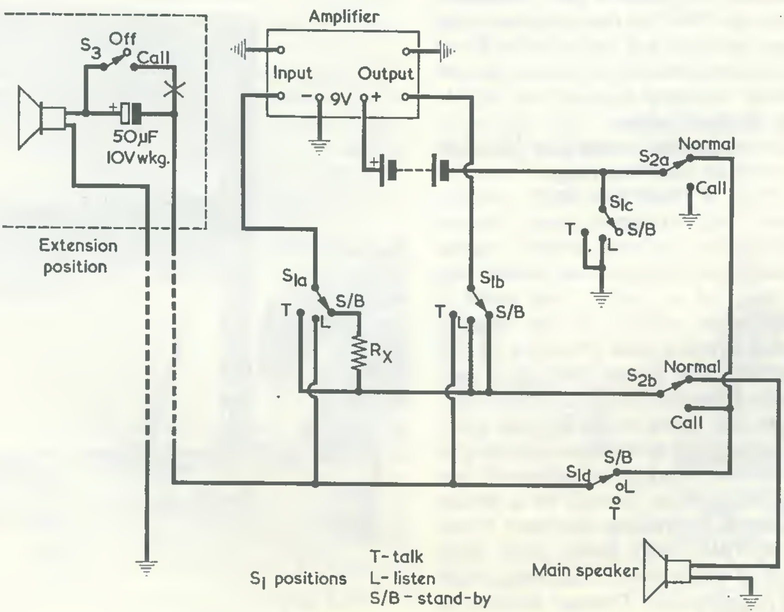


Fig. 1. The switching circuit for the intercom system

RC/DS/16

RADIO CONSTRUCTORS DATA SHEET 16

BINARY-DECIMAL CONVERSION TABLES

In binary numbers the radix is 2 (as compared with 10 in decimal numbers) with the result that digits, from right to left, represent the series 1, 2, 4, 8, 16, etc. Thus, binary 11001 represents a 1, no 2, no 4, an 8, and a 16, and is equal to $1+8+16=25$ in decimal.

Digits to the right of the binary point (equivalent to the decimal point) represent negative powers of 2. Thus, binary 0·101 represents $\frac{1}{2}$, no $\frac{1}{4}$, and $\frac{1}{8}=\frac{5}{8}=0{\cdot}625$ in decimal.

The Tables give series of binary and decimal equivalents for numbers below and above unity, illustrating also how the decimal equivalent is made up.

Numbers above unity

Binary number	Break-up into decimal	Decimal equivalent
0	0	0
1	1	1
10	2+0	2
11	2+1	3
100	4+0+0	4
101	4+0+1	5
110	4+2+0	6
111	4+2+1	7
1000	8+0+0+0	8
1001	8+0+0+1	9
1010	8+0+2+0	10
1011	8+0+2+1	11
1100	8+4+0+0	12
1101	8+4+0+1	13
1110	8+4+2+0	14
1111	8+4+2+1	15
10000	16+0+0+0+0	16
100000	32+0+0+0+0+0	32
1000000	64+0+0+0+0+0+0	64

Numbers below unity

Binary number	Break-up into decimal	Decimal equivalent
0·1111	$\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}$	0·9375
0·111	$\frac{1}{2}+\frac{1}{4}+\frac{1}{8}$	0·875
0·1101	$\frac{1}{2}+\frac{1}{4}+0+\frac{1}{16}$	0·8125
0·11	$\frac{1}{2}+\frac{1}{4}$	0·75
0·1011	$\frac{1}{2}+0+\frac{1}{8}+\frac{1}{16}$	0·6875
0·101	$\frac{1}{2}+0+\frac{1}{8}$	0·625
0·1001	$\frac{1}{2}+0+0+\frac{1}{16}$	0·5625
0·1	$\frac{1}{2}$	0·5
0·0111	$0+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}$	0·4375
0·011	$0+\frac{1}{4}+\frac{1}{8}$	0·375
0·0101	$0+\frac{1}{4}+0+\frac{1}{16}$	0·3125
0·01	$0+\frac{1}{4}$	0·25
0·0011	$0+0+\frac{1}{8}+\frac{1}{16}$	0·1875
0·001	$0+0+\frac{1}{8}$	0·125
0·0001	$0+0+0+\frac{1}{16}$	0·0625

RECENT PUBLICATIONS

ELECTRONIC COUNTING CIRCUITS. By J. B. Dance, M.Sc., B.Sc. 390 pages, $7\frac{1}{4} \times 9\frac{3}{4}$in. Published by Iliffe Books, Ltd. Price 85s.

It is a surprising fact that, despite the considerable importance of counting circuits in modern electronic equipment, there has not been, prior to the publication of the book under review, any single work devoted specifically to this subject. It is, indeed, the purpose of "Electronic Counting Circuits" to make good this shortage of literature in the counting field, and it presents an exceptionally comprehensive survey of the electronic systems which are currently in use in the world today.

The book assumes a reasonable knowledge of basic physics and of the operation of valves and transistors, and provides a description of functioning when more complex devices, such as tunnel diodes or Shockley diodes, are introduced. It is profusely illustrated with circuit diagrams (giving component values) together with 26 photographs of commercially manufactured counting equipment. Again, each chapter is terminated by a very extensive list of references.

"Electronic Counting Circuits" is intended for all people working with counting circuits, these ranging from service engineers to designers, and it also offers much of interest to the experimenter not directly employed on such circuits. It covers all aspects of the subject from electro-magnetic counters through gas filled counting tubes to valve and solid state scalers, ratemeters and nuclear counting instruments; and it can be confidently recommended as offering a reference work that is both all-embracing and authoritative.

FUN WITH SHORT WAVE RADIO. By Gilbert Davey. 64 pages, $7\frac{1}{2} \times 10$in. Published by Kaye & Ward Ltd. Price 16s.

"Fun With Short Wave Radio" is published for the youngster who has had little or no experience with short wave reception, and is written in a chatty style which gets the facts over easily and painlessly.

After an introductory chapter describing the results to be expected on the short wave bands, a second chapter discusses amateur radio and the R.S.G.B. Then follow details of a series of simple receivers suitable for construction by the reader, with valve designs predominating. Also dealt with are power units and short wave aerial and earth systems.

PRACTICAL WIRELESS CIRCUITS. Revised by the Technical Staff of *Practical Wireless.* 192 pages, 6 x 9in. Published by George Newnes Ltd. Price 17s. 6d.

This is the eighteenth edition of a book which first appeared, under the aegis of the late F. J. Camm, as "Twenty-five Tested Wireless Circuits" in 1931 and was subsequently reprinted in 1941 under its present title. This latest edition is completely revised and presents a number of circuits (58 are listed) for home-construction, these reflecting present-day techniques and interests.

The first 22 circuits are for receivers incorporating semiconductors and commence with two crystal diode circuits. All the remaining circuits in this section employ transistors, and the concluding circuit is for a 10-transistor dual-conversion communications receiver. Next follow 5 circuits for valve receivers, 5 circuits for transistor amplifiers, 6 circuits for valve amplifiers, 3 circuits for power supplies, 2 circuits for transmitters, 4 circuits for model control equipment and 9 circuits for test gear. A final 2 circuits, under the heading "Miscellaneous", are for a recording-level meter and an electronic timer.

In general, the circuits increase in complexity as one proceeds through each section, and they are accompanied by constructional information and layout and wiring diagrams. Where applicable, photographs of individual units after completion are also given.

INEXPENSIVE INTERCOM SYSTEM

(continued from page 228)

$S_{1(b)}$ have already switched feedback resistor R_x into circuit, the amplifier oscillates, and the resultant a.f. signal is heard over the extension loudspeaker. (The 50μF electrolytic capacitor offers very low impedance at the frequency of the a.f. signal.).

If the extension wishes to call the main position, switch S_3 is closed. The negative terminal of the 9 volt battery now conects, via $S_{2(a)}$, $S_{1(d)}$ and the low d.c. resistance of the extension speaker to earth, the amplifier is once more brought into use and it again oscillates. The amplifier output connects, via $S_{1(b)}$ and $S_{2(b)}$, to the main loudspeaker, which reproduces the a.f. signal.

For communication, S_1 is switched between the Talk and Listen positions as required. With S_1 at Listen, the extension speaker (now functioning as a microphone) couples, via S_3 (closed) and $S_{1(a)}$ to the amplifier input. The amplifier output connects, via $S_{1(b)}$ and $S_{2(b)}$ (at Normal) to the main speaker. The person at the extension point may then talk to the person at the main position. With S_1 at Talk the main loudspeaker couples, via $S_{2(b)}$ and $S_{1(a)}$ to the amplifier input, whilst the extension speaker couples, via S_3 and $S_{1(b)}$, to the amplifier output. In both the Listen and Talk positions, $S_{1(c)}$ connects the negative terminal of the 9 volt battery to earth, thereby keeping the amplifier operative.

Should the extension operator wish to call the main station, S_3 is set to Call for a few seconds and the a.f. call signal is heard from the main speaker. During the subsequent conversation, S_3 is held at the Call position and S_1 operated as previously. When the conversation is complete, S_1 is set to Stand-by and S_3 to Off. S_2 is already at Normal. The intercom is then ready for use at a later time.

In Fig. 1. separate earth symbols are shown at the main station to indicate earth returns, since this enables the switch circuit operation to be more readily visualised. In practice, all these earth points are connected together. They may also, if desired, be connected to a real earth. It will be noted that, when S_3 is closed, it directly short-circuits the charged 50μF electrolytic capacitor. If desired, s small resistor of around 3Ω may be inserted in the S_3 circuit at the point indicated with a cross. This will limit discharge current and extend capacitor life.

FINDING R_x

The value of R_x is found experimentally. Initially, S_1 is set to Stand-by and S_2 to Normal. A variable resistor of around 10kΩ is inserted in the R_1 position and its value gradually reduced until the feedback is sufficient to cause the amplifier to oscillate reliably whenever the extension leads are short-circuited. If oscillation does not occur, reverse the connections to the amplifier output transformer secondary. The value required in R_1 will vary widely for different amplifiers and it may be helpful to finish with a variable resistor lower than 10kΩ if R_x requires a low value. The variable resistor is finally replaced by a fixed resistor of the appropriate value.

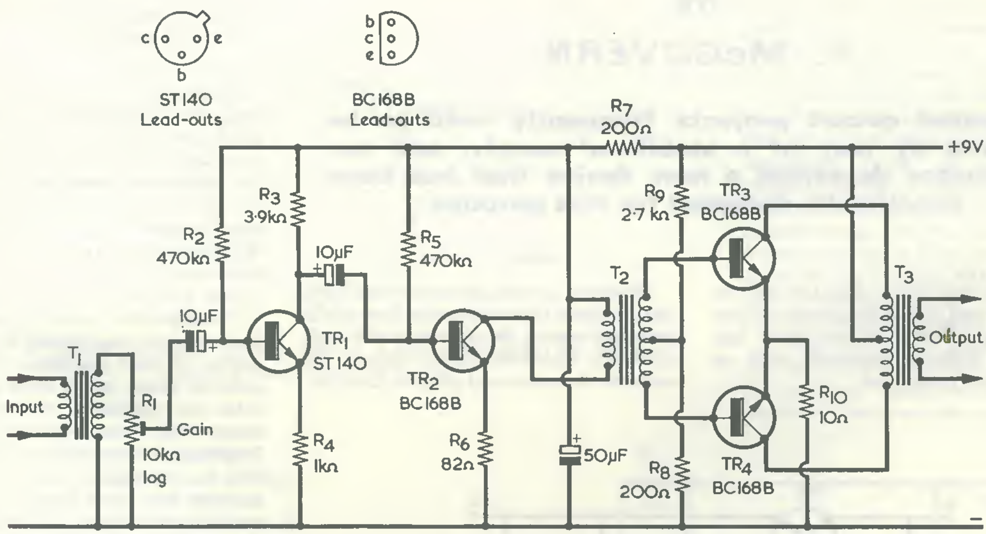


Fig. 2. The amplifier circuit employed in the prototype

Operation of the intercom may now be summed up in the following manner. If the intercom is not in use, S_1 is at Stand-by, S_2 is at Normal and S_3 is at Off. The only current flowing from the battery is leakage current in the 50μF electrolytic capacitor. If the person at the main position wishes to call the extension, S_2 is put to Call for a few seconds, whereupon the extension position is alerted by the a.f. signal from the extension loudspeaker. S_3 is put to Call and conversation proceeds with S_2 at Normal and S_1 switched between Talk and Listen, as appropriate.

All the wiring external to the amplifier is at low impedance so there are no layout problems. It is advisable to use different coloured wire for each section to avoid confusion and to aid checking when completed. The wire from the main station to the extension position can consist of any fairly low resistance twin cable. Take care to connect the extension wiring as shown in Fig. 1 so that the voltage across the 50μF electrolytic capacitor is of correct polarity.

Provided sufficient gain is offered, any amplifier with a low input impedance may be used. The circuit of the amplifier employed by the author is given in Fig. 2. This was built on a tagboard which fitted into a small case together with the main speaker, the battery, and switches S_1 and S_2. The transistors used were inexpensive types, and the BC168B's are available from Amatronix, Ltd. Other types more commonly encountered in a.f. amplifiers could be used in their place, using standard circuitry. Since the author used n.p.n. transistors, the earthy supply rail for the amplifier is negative. An alternative amplifier employing p.n.p. transistors would have the earthy supply rail positive, in which case both the battery and 50μF electrolytic capacitor of Fig. 1 should be reversed. Transformer T_1 is a single transistor output transformer for 3Ω speaker reversed, T_2 is a standard Class B driver transformer and T_3 a standard Class B output transformer. (A transformer designed to match a 3–8Ω speaker to transistor input for intercom purposes is the Type No. 759 from Henry's Radio, Ltd. T_2 and T_3 could be types LT44 and LT700 respectively, or similar.—EDITOR.). The amplifier volume control, R_1, follows T_1 secondary and is preset to provide the desired level of gain when the intercom unit is completed and installed. The adjustment of R_1 must, of course, be carried out before finding the required value for R_x of Fig. 1. The main and extension speakers can be any moving coil types from $2\frac{1}{2}$ to 6in having an impedance in the range 3Ω to 7Ω.

As a final point, no on-off switch is shown in Fig. 2 since, as already explained, current drain is negligible when the system is out of use. To keep Stand-by current at its minimum, the 50μF electrolytic capacitor of Fig. 1 should be a component of reliable manufacture with a high leakage resistance.

LINEAR I.C. VOLTAGE REGULATOR

by

P. McGOVERN

Integrated circuit projects frequently need to be powered by way of a stabilised supply, and our contributor describes a new device that has been specifically designed for this purpose

THE INCREASING AVAILABILITY OF linear and digital integrated circuits to the amateur experimenter has opened a hitherto restricted field of circuitry and equipment.

However, as with all new devices there are problems to be overcome. One of the principal ones is the provision of a high efficiency stabilised power supply. A number of circuits and projects covering power supplies have been dealt with in previous articles in this journal, but in many cases these have not been entirely suitable for use with integrated circuits either due to size and cost or because they do not meet the particular requirements of integrated circuit operation. A power supply for an i.c. is usually required to provide very good regulation, low ripple and of course fast response to any load or line changes.

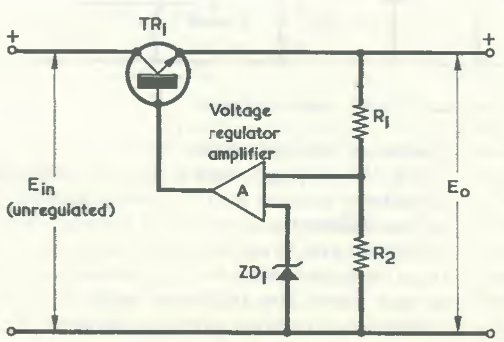


Fig. 1. Basic comparator circuit for a regulated supply

DIMENSIONS

To go back to size, it is quite a shock to discover when building a power supply using standard discrete components that it usually turns out to be of the order of ten times larger than the associated i.c. circuitry. It is difficult to justify the space required, apart from the question of appearance when such a power supply is compared to neat and very small i.c. circuit boards.

Consequently some semiconductor manufacturer was bound to provide an answer to these problems, the practical solution being in the form of a monolithic i.c. regulator. A device of this nature has been developed by the National Semiconductor Corporation, U.S.A., specifically for i.c. power supplies and allied uses. This has been available to industry for some time, but due to fairly high price it was not considered to be within the experimenter's budget. However, in recent months an epoxy encapsulated version in a package having approximately the same dimensions as a TO5 can has become readily available on the U.K. market under the N.S.C. type number LM300, and it is this device that will be described.

Briefly, a good voltage regulator should

(a) sense any change in output voltage no matter how minute;

(b) be able to amplify this change into a usable signal for fast corrective action, and

(c) provide the necessary circuit compensation to maintain a constant d.c. output voltage.

These requirements can be met by the basic comparator circuit shown at Fig. 1. The comparator samples the output voltage (E_o) and compares this sample to a constant reference voltage source represented by zener diode ZD_1. If there is a change in E_o from the design value an error signal appears at the output of the voltage regulator amplifier which changes the voltage on the base of TR_1. This causes a change in the current flow through TR_1, R_1 and R_2 which then brings E_o back to its previous value.

The LM300 contains the voltage reference source, comparator amplifier, and pass transistor all on one single monolithic silicon chip measuring 38 mil square. It consists in fact of a total of 12 transistors, 2 zener diodes, 1 diode and 8 resistors as illustrated in Fig. 2. Fig. 3 shows the lead-outs and it is important to note that this is a top view with the leads pointing *away* from the reader. (The numbers are in clockwise order when the leads point towards the reader). Terminal 8 is identified by a flat on the case.

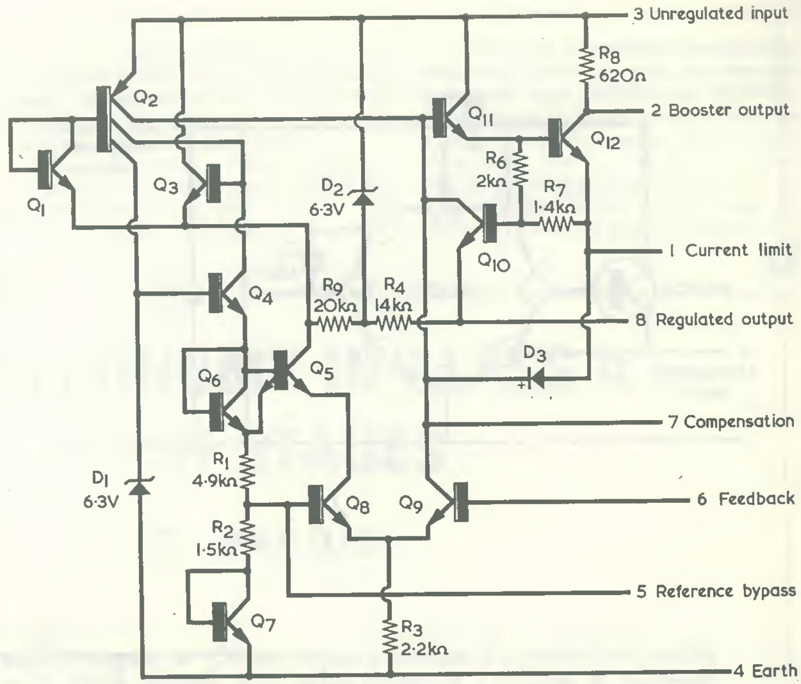


Fig. 2. Internal circuitry for the LM300, manufactured by the National Semiconductor Corporation

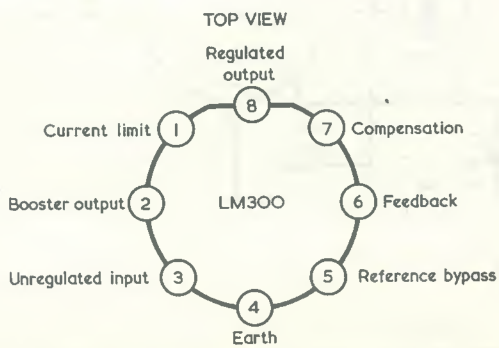


Fig. 3. LM300 terminal layout. This is a top view with the leads pointing away from the reader

The basic device can handle up to 20mA, and with the addition of external power transistors currents in excess of 5A are possible. A few typical applications are shown in Figs. 4, 5 and 6.

Fig. 4 illustrates the basic regulator circuit, suitable for currents up to 20mA. The output voltage is set by R_3 and the impedance "seen" by the feedback terminal should be approximately 2kΩ. The same basic circuit, with an external transistor type 2N2905 added to increase output current, is given in Fig. 5. The circuit of Fig. 5 is for a 300mA regulator. Fig. 6 illustrates a 2A regulator with feedback current limiting.

In Fig. 5, output voltage is set by R_1 and R_2, and Fig. 7 gives curves showing the optimum values required for these resistors. The curves also apply to Fig. 6,

GENERAL CHARACTERISTICS

General characteristics for the LM300 are:

(a) Input voltage range 8V minimum to 30V maximum.

(b) Output voltage adjustable from 2V to 20V.

(c) Load regulation 0·1% typical.

(d) Adjustable short-circuit current limiting.

(e) It can be used as either a linear or high efficiency switching regulator. (Only the linear application has been dealt with here.).

(f) Ambient temperature range 0 to 70°C.

(g) Maximum power dissipation 300mW.

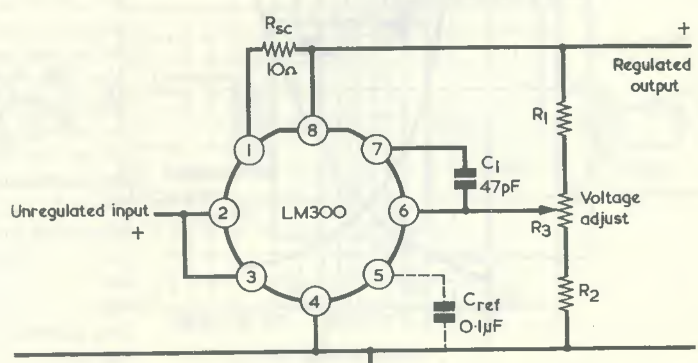


Fig. 4. Basic regulator circuit incorporating the LM300 on its own

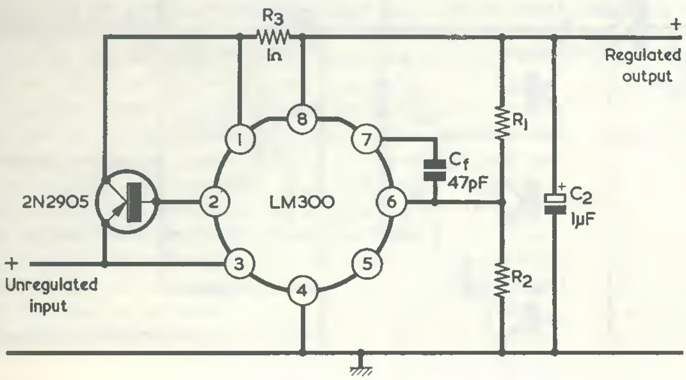


Fig. 5. Adding an external transistor increases regulated output current to 300mA

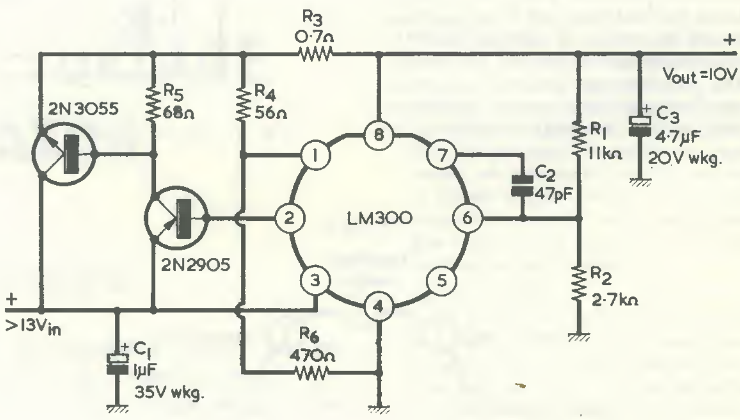


Fig. 6. A 2A regulator circuit

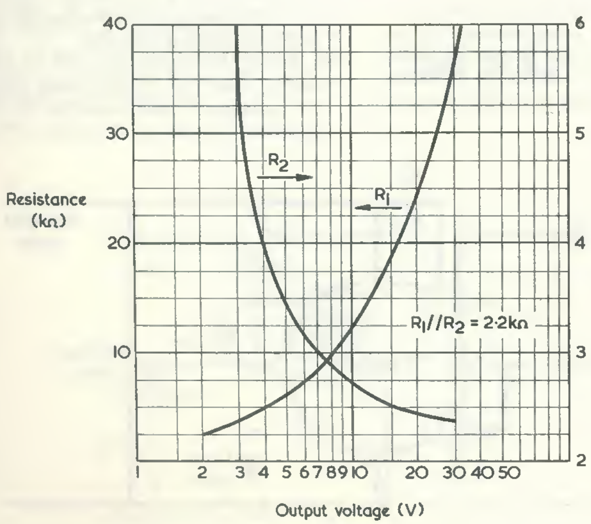


Fig. 7. Curves for evaluating R_1 and R_2. Ther vertical scale for R_1 is to the left and that for R_2 to the right

and to Fig. 4 when the resistance in R_3 above the slider is added to R_1 and the resistance in R_3 below the slider is added to R_2. In Fig. 6, component values are given for a 10V output. The resistor between terminals 1 and 8. (R_{sc} in Fig. 4) is a short-circuit current limiter.

AVAILABILITY

It has been the object of this short article to help keep the amateur in touch with the latest techniques in the integrated circuit field and to stimulate more ambitious projects which are, perhaps, not normally considered suitable for home construction.

The National Semiconductor Corporation is represented in the U.K. by Walmore Electronics Ltd., 11–15 Betterton Street, Drury Lane, London, W.C.2.

The LM300 is available directly from Walmore Electronics Ltd., as also are transistors type 2N3055 and 2N2905A (a version with better gain and leakage than the 2N2905) together with LM300 data sheets. The i.c. and the transistors can be obtained in quantities of 1-off or more, the price of the LM300 being, at the time of writing, slightly less than £3.

BATTERY ECONOMY IN CLASS A OUTPUT STAGES

by C. HARGIS

How to combine the advantages of Class A and Class B operation with the aid of "sliding bias". This varies the base bias of a Class A output transistor in proportion to output signal amplitude.

NOWADAYS ALMOST EVERY A.F. TRANSISTOR POWER output stage uses a Class B push-pull circuit. The well-known advantages of this type of stage are that the current taken from the battery when no signal is applied is very little and increases proportionally with the input signal, rising to its maximum value only with full power output. Also, the maximum theoretical efficiency is very nearly 80%, i.e. very nearly 80% of the battery power can be turned into a.c. output power.

The circuit of a typical Class B output stage (using input and output transformers for ease of explanation) is shown in Fig. 1. The output transistors TR_1 and TR_2, which must be well matched to avoid distortion, are biased by R_1, R_2 and R_3 to pass a very small standing current. The bias point for either transistor is at A in Fig. 2(a). The input signal is coupled to the stage by the driver transformer, which matches the higher impedance of the driver transistor collector to the low impedance of the output transistor bases. If we consider the operation of TR_1, shown graphically in Fig. 2(a), we see that on its own it would cause bad distortion, since it can only amplify negative-going signals at its base, and is completely cut off by positive half-cycles. However TR_2 is operated in an identical condition to TR_1, and is connected to the opposite end of the centre-tapped driver transformer, so that its own signals are 180° out of phase with those of TR_1. Thus whenever TR_1 is cut off by a positive half-cycle, TR_2 is conducting, and the signal is still amplified. The transistors are also connected to opposite ends of the output transformer, so that an increase in TR_2 current produces a similar signal in the loudspeaker speech coil to a decrease in TR_1 current. It may be seen, then, that the average current of the whole stage increases with an increase in output, and almost all of the battery current becomes a.c. output.

There are, however, a number of serious disadvantages with the Class B output stage as so far described. Apart from any problems incurred in matching the output transistors, the output transformer requires a relatively large core to provide a reasonable bass response, and the circuit does not as readily provide the richer and more mellow tone offered by valve output stages. Last but not least, biasing is critical, so that close-tolerance resistors and some form of temperature compensation are required. Single-ended push-pull stages obviate the output transformer, and complementary stages the driver

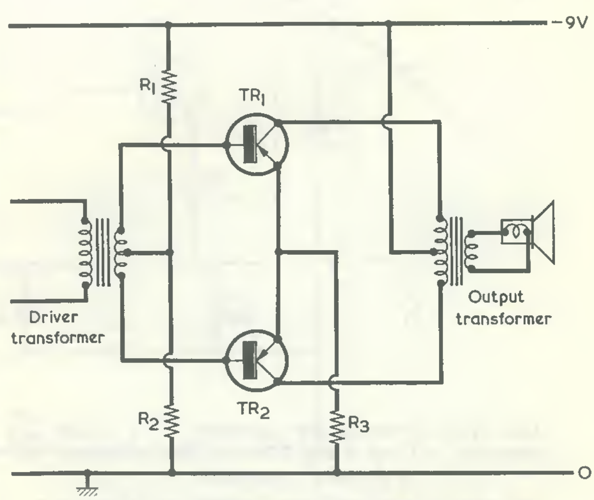


Fig. 1. The operation of a Class B output stage may be demonstrated by this basic transformer-coupled version.

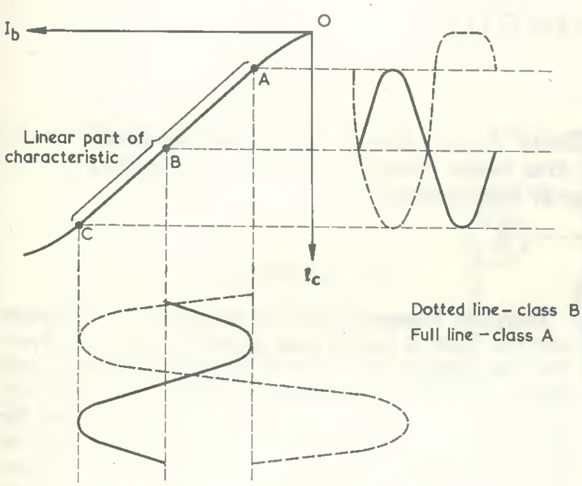
transformer as well, but these bring additional complications. A high impedance speaker is needed and, in many cases, a d.c. blocking capacitor of very large value.

CLASS A

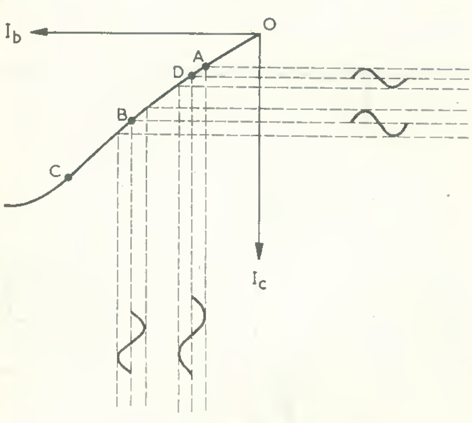
An alternative approach to transistor output stage design consists of re-examining the Class A circuit. A good starting point is the simple circuit shown in Fig. 3, which has appeared in an earlier issue of this journal*. Fig. 3 has slightly different resistor values to those in the previous circuit; also, the output transistor is now an OC29 and the preceding transistor an OC81D. The OC29 does not require a heat sink.

It was found that this circuit arrangement provides excellent quality for the absolute minimum of components but, as was stated by the previous writer, the standing current is very high because of the Class A operation. This is of little disadvantage when an accumulator is used, and with a mains power unit it is an advantage to have a constant current requirement, since a supply with poor stabilisation will not cause distortion as it would with a Class B stage. But the circuit is rather hard on small dry batteries, and the author decided to investigate the possibility of combining the advantages of both Class B and Class A circuits.

*Kenneth Jones, "2-Transistor Miniature A.F. Amplifier," *The Radio Constructor*, May, 1965.



(a)



(b)

Fig. 2(a). Showing the operation of a single transistor in Class B and Class A. Bias points are at A and B respectively.

(b) With a low-level input signal, the Class A amplifier will offer the same output at bias points B or D.

In Fig. 2(a) the operation of a Class A stage is shown. The transistor is biased to the centre of the linear part of its characteristic, and the maximum input swings the collector current between the lower limit A and the upper limit C. When in this condition, the circuit of Fig. 3 gives an efficiency approaching 50% as there is little to reduce it from the theoretical maximum, and this is quite acceptable. Unfortunately the condition of maximum signal input is rarely encountered in a.f. equipment, and in all other cases the efficiency is very low. Consider the typical small input signal shown in Fig. 2(b). The required collector current swing centred round B could perfectly well centre round point D, still allowing the signal to traverse a linear part of the characteristic and reducing the supply current considerably.

We require therefore a Class A amplifier which is biased normally at point A in Fig. 2, but whose bias increases whenever an a.c. input signal is applied by an amount equal to the peak value of the input signal. A circuit which achieves this is shown in Fig. 4. It will be seen that this is basically similar to Fig. 3, but with the addition of D_1, R_2, R_3, R_4, C_2, C_3, VR_1 and VR_2. VR_2 is in the circuit position occupied by R_2 of Fig. 3. VR_2 and R_1 bias the transistors to a low standing current. Since VR_2 of Fig. 4 will offer greater resistance than did R_2 of Fig. 3, the d.c. stabilisation will be impaired and it is desirable that R_2 of Fig. 4 be now included; though no harm can in fact be done to the power transistor due to the high resistance of the loudspeaker. If increased gain is required it should prove beneficial to bypass R_2 of Fig. 4 with an electrolytic capacitor of at least 1,000μF at 3V wkg., although such a component is naturally rather bulky.

The requisite increase in d.c. current with a.c. signal is provided in the following manner. A.C. is taken from TR_2 collector via C_2 and applied to diode D_1. R_3 provides a d.c. path to earth. The negative d.c. output from D_1 is filtered off a.f. by C_3, and fed back to the base of TR_1 via preset potentiometer VR_1. Thus, whenever an a.c. signal appears in the output, the negative bias on the transistor pair increases, the d.c. current increases, and the signal is accommodated.

C_3 has a rather critical value. A low value causes an almost instantaneous increase in current with signal, but it enables rectified, and therefore distorted, low frequencies to be fed back to the input, causing distortion to appear in the output. However too high a value causes a time delay before the sliding system responds to a signal, resulting in bad transient distortion. In any case transients cannot exceed the maximum power output of 500mW, and the value shown presented a reasonably good compromise.

Diode D_1 is also a little critical. An ordinary OA81 was quite unsuccessful, since it tends to have a "delay voltage" of about 0·4V before it conducts sufficiently in the forward direction. If an attempt is made to cure this effect by increasing the standing bias, it is merely cut off even further, and no advantage is given. However, a low voltage power diode works very well, and the author used a GJ7M (available from Henry's Radio, Ltd.). Any small germanium diode designed for high current at low voltage should prove satisfactory. Resistor R_4 is a later addition, providing extra a.c. negative feedback.

CONSTRUCTION

The physical layout is not at all critical. The circuit lends itself well to printed circuit construction, and possibly Veroboard could be used with the power transistor mounted separately. The prototype was built into a cough capsule tin measuring $3\frac{1}{4}$ by $2\frac{1}{2}$ by $\frac{3}{4}$in, and the power transistor was bolted straight to the tin, which then became "live" at collector potential.

The tin was painted black and marked in white ink, but an attractive appearance is not necessary due to the unit's small size, reliability if well built, and absence of controls. Little trouble should be experienced in tucking it away out of sight somewhere. The dissipation in the power transistor is less than 1 watt, so that no heat sink is, in fact, required, giving the circuit a great deal of flexibility.

During the building of the amplifier the usual rules of construction apply. When soldering the transistors and diode use a heat shunt of some sort, and do not bend the leads too close to the body. Colour-coded wires should be fitted to the GJ7M, or if a printed circuit is used it can be bolted directly to the board by the anode, this also forming the connection. Remember that all miniature components are fragile and ruined by heat, so make quick, efficient soldered joints. The electrolytic capacitors must be connected round the right way, and if the input is taken from the collector of the transistor in a pre-amplifier or from some other source with a negative d.c. potential superimposed, the input capacitor C_1 must be reversed. A reversible electrolytic would be useful here for a general purpose amplifier, but is rather bulky.

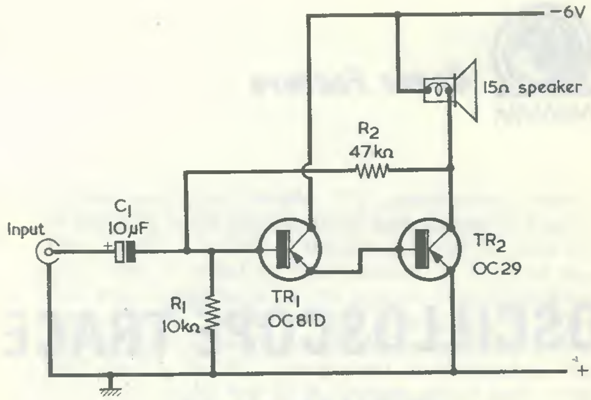


Fig. 3. A basic Class A amplifier.

SETTING UP

The amplifier needs a little adjustment before it can be used, and for this a simple multimeter is required. Connect the amplifier to a 6V battery, remembering that damage to the transistors may be caused if it is connected with incorrect polarity. The battery should preferably be one of large capacity, since if one of high internal resistance is used distortion will be caused on peaks. An Ever Ready type 996 "Lantern" battery was used with the prototype, and gives a long life. A PP1 battery was not found satisfactory.) A miniature silver-zinc or Deac accumulator might also be used. As the circuit is quite well stabilised

(*continued on page* 246)

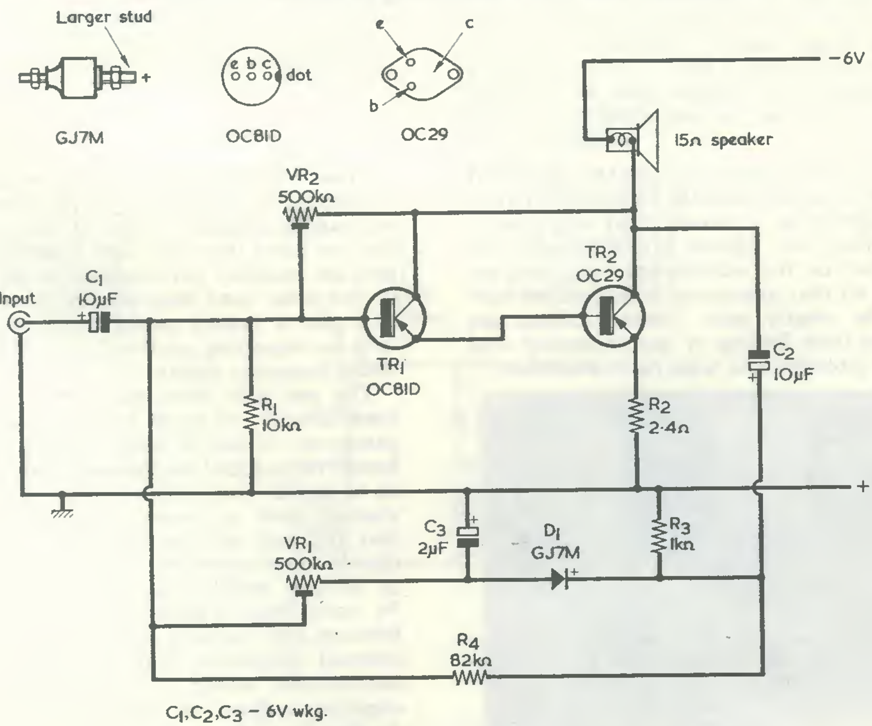


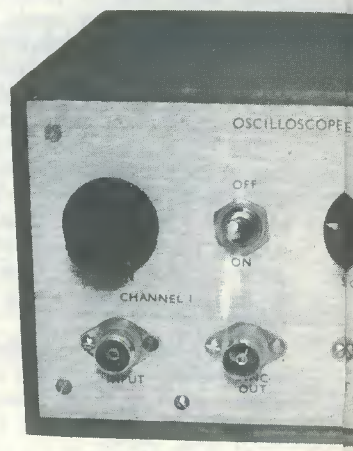
Fig. 4. The Class A amplifier of Fig. 3 with "sliding bias" components added. VR_1 and VR_2 may be skeleton potentiometers.

Cover Feature

OSCILLOSCOPE TRACE DOUBLER

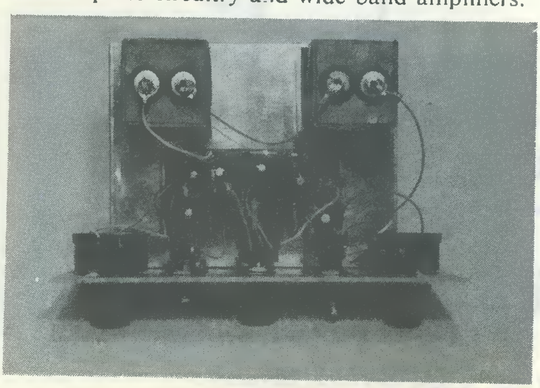
by

W. KEMP



Capable of being fitted into a case measuring only $8\frac{1}{4}$in wide, $4\frac{1}{4}$in high and $5\frac{1}{2}$in deep, this completely self-contained unit will give trace doubling for input waveforms up to 2 Mc/s or more. To prevent possible interaction with some input signals, two trace switching speeds are provided

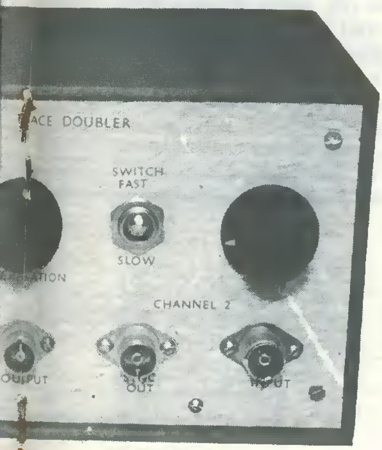
An oscilloscope trace doubler makes it possible to simultaneously view two separate input signals on a conventional single beam instrument. The two signals are displayed one above the other on the oscilloscope tube, and are phase related so that any phase difference between signals can be clearly seen. These facilities are essential when fault finding or experimenting with modern pulse circuitry and wide band amplifiers.



Top view with batteries in place and connected up

Trace doublers are not widely available commercially, and the few types that do exist can be roughly classed in one of two categories. On the one hand there are very expensive types which give an excellent performance in all respects, and on the other hand there are fairly inexpensive types that give a limited performance and are of little help for inspecting anything other than fairly simple audio frequency signals.

The unit that forms the basis of this article has been designed to fit in between these two general categories. It can be built for about £8, yet it can handle input signal frequencies ranging from a few c/s up to several Mc/s. Circuit "frills" have been eliminated as much as possible and, on the assumption that the unit will be used mainly for inspecting signals from transistor circuits, it has been designed to directly handle maximum input signals up to 14 volts peak-to-peak only. Larger signals can, however, be handled with the aid of a simple external attenuator; and this measure results in a considerable saving in building costs. The input impedance direct to each channel of the trace doubler is of the order of 100kΩ, but this can be increased to 1MΩ or so by using the external attenuator.



The unit incorporates a built-in infinitely variable attenuator in each channel, provides two alternative switching or gate speeds to suit all operating conditions, has a Trace Separation control, and gives a low impedance external sync drive signal from each channel. The unit should meet the needs of all but the most fastidious of electronics enthusiasts.

Basic Principles Of Operation

The basic principles of operation of the trace doubler are quite simple. The operational "heart" of the unit is the simple diode gate shown in Fig. 1. Here, input 1 is fed to the junction of D_1 and R_1 and input 2 is fed to the junction of D_2 and R_2. The gate is operated by the square wave gate-drive signal which varies between zero and 10 volts positive, but when this signal is a.c. coupled to the gate via C_3 the d.c. component is eliminated and the signal at the top of R_3 swings about zero volts as shown. Thus, on high points of the gate signal the top of R_3 is 5 volts positive, and on low points it is 5 volts negative.

Now, when the top of R_3 is 5 volts positive, D_1 is forward biased and forms an effective short circuit, so that R_1 is virtually connected direct to R_3 and input 1 to the output terminal. At the same time D_2 is reverse biased and effectively open-circuit, so that no part of the input 2 signal appears at the output. By potential divider action, the output signal is imposed on a potential of 2.5 volts positive. Thus, under this condition the output consists of input 1 plus a bias potential of 2.5 volts positive.

When, on the next square wave half-cycle, the top of R_3 goes 5 volts negative, D_1 is reverse biased and isolates input 1 from the output, whilst D_2 is forward biased and connects input 2 to the output. In this case, however, the output signal is imposed on a potential of 2.5 volts negative, so that under this condition the output consists of input 2 plus a bias potential of 2.5 volts negative. Thus, the composite output signal of the gate consists of input 1 above input 2, as shown in the diagram, the two signals being separated by a potential proportional to the magnitude of the gate-drive signal.

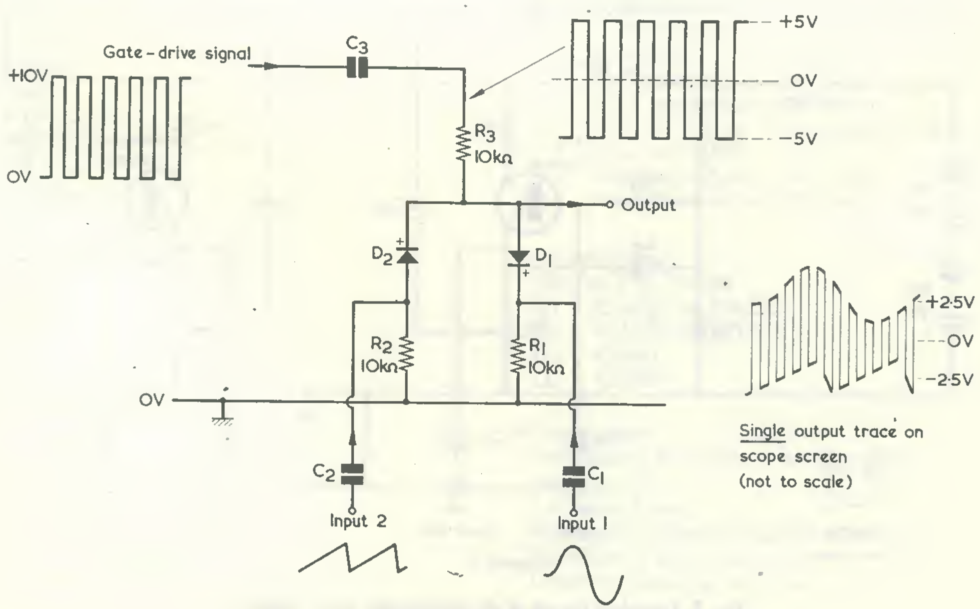


Fig. 1. The basic diode gate circuit employed in the trace doubler

In the diagram, the frequency of the gate-drive signal is shown as being higher than that of the input signals, and the output is only a *single* trace as it would appear on an oscilloscope screen. In practice a train of traces will be displayed and, if the frequencies of the input and drive signals are not harmonically related, the gate "dashes" will appear at different points on each successive sweep and will seem to "run" across the screen. If the harmonic relationship between the input and gate signals differs by greater than some 50 c/s the gate dashes will "run" so fast that the eye cannot follow them, whereupon they will disappear completely, leaving a clean impression of input 1 above input 2. Because of this illusion, it is not necessary to select special gate speeds, and the gate frequency can even be considerably lower than that of the input signal without adversely effecting the clarity of the oscilloscope trace. Indeed, the only point of importance in this respect is to ensure that the gate and input speeds are not harmonically related, and this can be simply accomplished by making two alternative switching speeds available.

The Practical Circuit

The full circuit diagram of the trace doubler is shown in Fig. 2. Here, TR_1 and TR_2 form a free-running multivibrator which gives an approximately square wave signal at TR_2 collector; D_1 and D_2 prevent emitter-base reverse voltage breakdown on TR_1 and TR_2 and improve oscillator stability. S_1 enables either Fast or Slow operating frequencies to be selected. It is shown in the Slow position. The approximate square wave from TR_2 collector

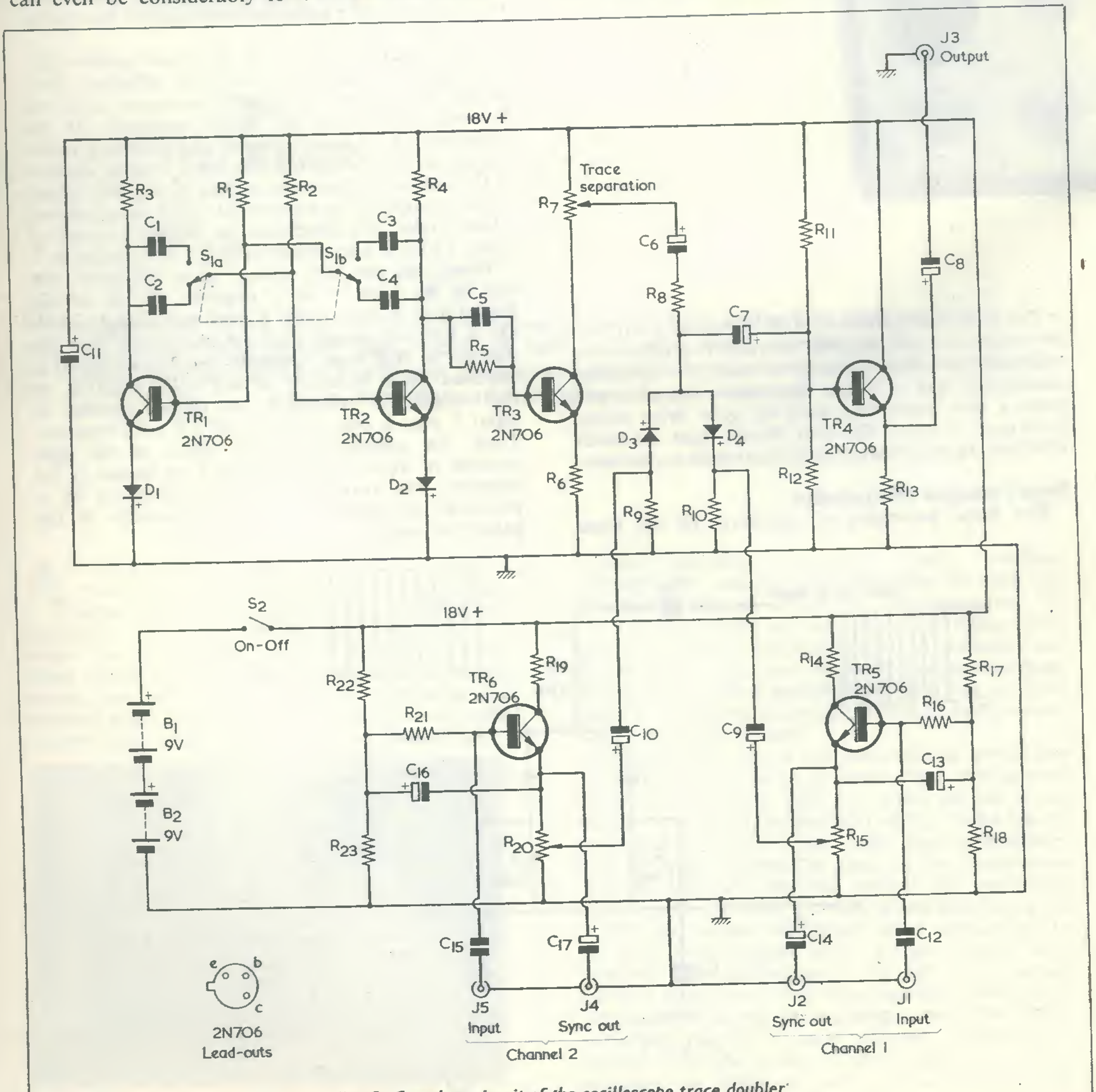


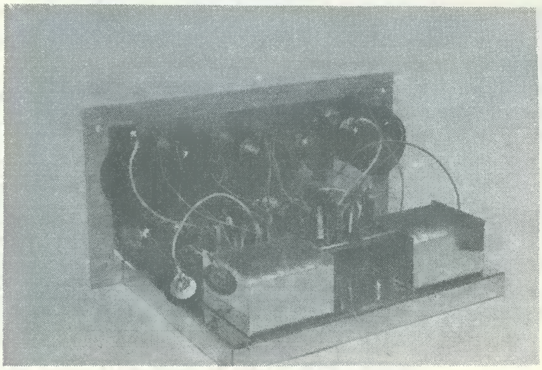
Fig. 2. Complete circuit of the oscilloscope trace doubler

is direct coupled to TR_3, which sharpens up the waveform and passes it on to the diode gate circuit (D_3 and D_4) via R_7, which serves as a Trace Separation control. The output of the gate is fed to socket J_3 via emitter follower TR_4, giving a low impedance output drive to the external oscilloscope.

Inputs to the trace doubler are fed to bootstrap emitter followers TR_5 and TR_6, which each give input impedances of approximately 100kΩ. The 5kΩ emitter loads of these circuits serve as infinitely variable attenuators which pass the input signals on to the gate at a low impedance. The signals at the emitters of TR_5 and TR_6 are also fed, at low impedance, to sockets J_2 and J_4 respectively, to provide input 1 or input 2 synchronisation for the oscilloscope timebase. The 470Ω resistors in the collectors of TR_5 and TR_6 introduce a small degree of Miller feedback to prevent instability in the bootstrap circuitry.

The complete unit is powered by two 9 volt batteries in series, giving 18 volts total. Total current consumption of the unit is about 10mA.

Before proceeding to a description of construction, one important point has to be emphasised. This is that C_{12} and C_{15} *must* be low-leakage types, or damage to the transistor circuitry may result. Polyester or Mylar capacitors should be used here, and the working voltage should be adequate for any input it is intended to apply to the unit.



Rear view, showing the general assembly. The batteries are not fitted here

Construction

The general layout of the unit, which can be fitted into a simple $8\frac{1}{4}$ x $5\frac{1}{2}$ x $4\frac{1}{4}$in cabinet, is shown in

COMPONENTS

Resistors
(All fixed values $\frac{1}{4}$ watt 10%, unless otherwise stated)

R_1	82kΩ 5%
R_2	82kΩ 5%
R_3	4.7kΩ
R_4	4.7kΩ
R_5	4.7kΩ
R_6	680Ω
R_7	5kΩ potentiometer, linear
R_8	18kΩ
R_9	8.2kΩ
R_{10}	8.2kΩ
R_{11}	82kΩ
R_{12}	120kΩ
R_{13}	5.6kΩ
R_{14}	470Ω
R_{15}	5kΩ potentiometer, linear
R_{16}	47kΩ
R_{17}	22kΩ
R_{18}	56kΩ
R_{19}	470Ω
R_{20}	5kΩ potentiometer, linear
R_{21}	47kΩ
R_{22}	22kΩ
R_{23}	56kΩ

Sockets
J_1 to J_5 Coaxial sockets

Batteries
B_1, B_2 9-volt batteries type DT_7 (Exide)

Switches
$S_{1(a)(b)}$ d.p.d.t. toggle
S_2 s.p.s.t. toggle

Capacitors

C_1	0.001μF Mylar or polyester
C_2	0.005μF Mylar or polyester
C_3	0.001μF Mylar or polyester
C_4	0.005μF Mylar or polyester
C_5	0.05μF disc ceramic
C_6	10μF electrolytic, 25V wkg.
C_7	6.4μF or 8μF electrolytic, 25V wkg.
C_8	10μF electrolytic, 25V wkg.
C_9	10μF electrolytic, 25V wkg.
C_{10}	10μF electrolytic, 25V wkg.
C_{11}	40μF electrolytic, 25V wkg.
C_{12}	0.25μF Mylar or polyester, 100V wkg. (see text)
C_{13}	8μF electrolytic, 15V wkg.
C_{14}	10μF electrolytic, 25V wkg.
C_{15}	0.25 μF Mylar or polyester, 100V wkg. (see text)
C_{16}	8μF electrolytic, 15V wkg.
C_{17}	10μF electrolytic, 25V wkg.

Semiconductors
TR_1 to TR_6 2N706

D_1	OA200 or OA202
D_2	OA200 or OA202
D_3	OA90
D_4	OA90

Miscellaneous
Veroboard, 0.15in matrix, $4\frac{1}{8}$ x $2\frac{1}{8}$in (see Fig. 3)
3 control knobs
Material for chassis, panel, case, etc.
4 rubber or p.v.c. grommets
Insulated sleeving, wire, etc.

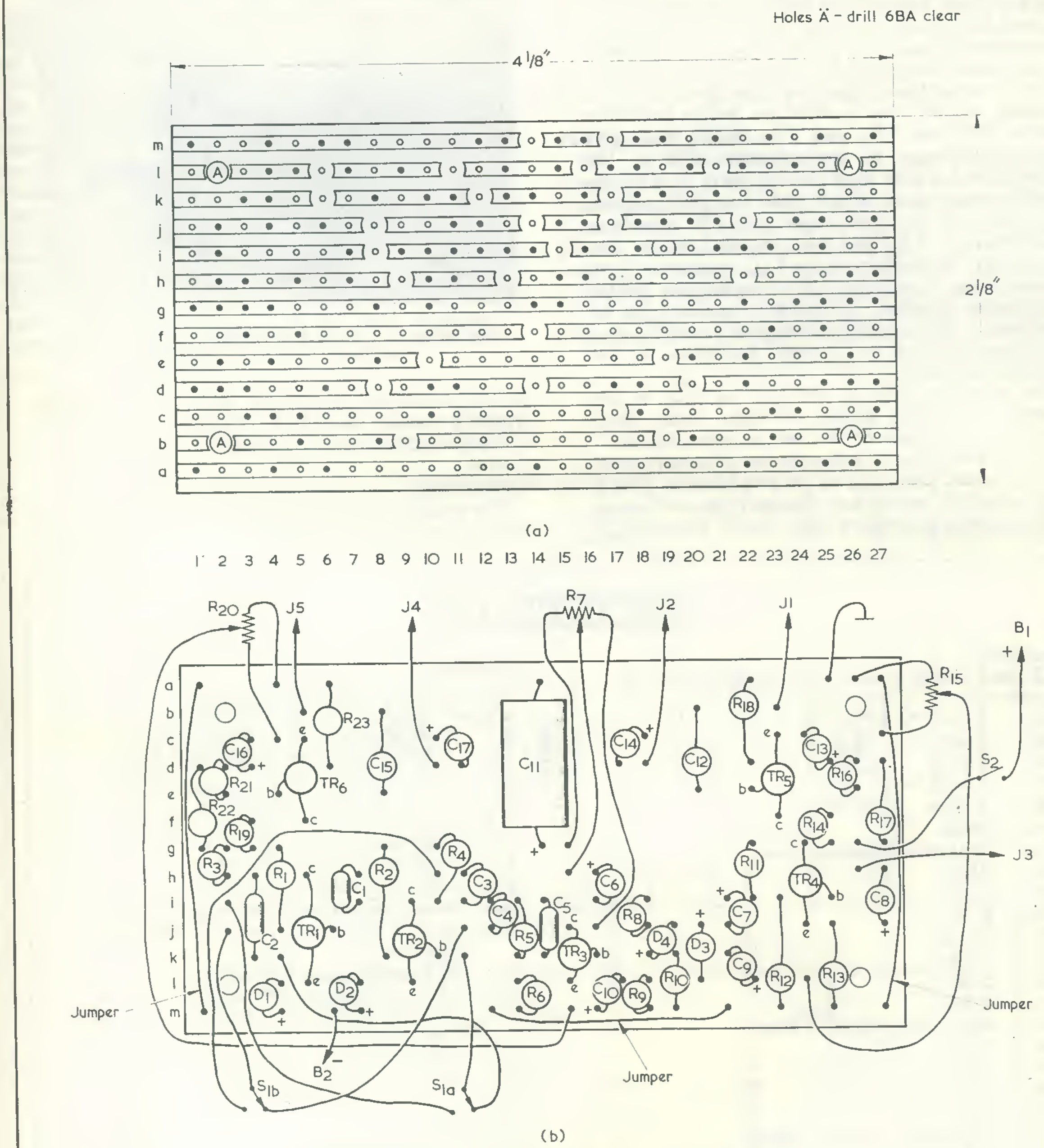


Fig. 3. The copper and component sides of the Veroboard panel

the accompanying photographs.

Start construction by cutting the Veroboard panel to size, as shown in Fig. 3, and then break the copper strips, with the aid of a small drill or the special cutting tool that is available, where indicated. Now drill the four small mounting holes, to clear 6BA screws, in the positions shown, and cut back the copper around them to prevent short circuits occurring when the panel is finally secured to the main chassis.

The components, connecting leads, and wire jumpers can now be mounted on the plain side of the panel, as shown in the lower view of Fig. 3, and soldered in place. The component layout of this unit is rather critical, and that illustrated must be adhered to. Note that all components other than C_{11} are mounted vertically on the panel, and that insulated sleeving should be used where there is any danger of component leads short-circuiting against one another.

Once assembly of the Veroboard panel is complete, make up the front panel and the main chassis, using a medium gauge aluminium, as shown in Figs. 4 (*a*) and 4 (*b*). Also required are two battery holders. These are made from light gauge aluminium, as shown in Fig. 5. Now cover the front panel with Fablon or a similar self-adhesive plastic material, mount all controls and sockets in place, and then bolt the two battery holders and the front panel assembly to the main chassis.

The Veroboard assembly can now be mounted to the main chassis by placing four small rubber or p.v.c. grommets under the Veroboard mounting holes, these acting both as spacers and insulators, and then bolting the panel to the main chassis with four 6BA screws. The final wiring up of the unit

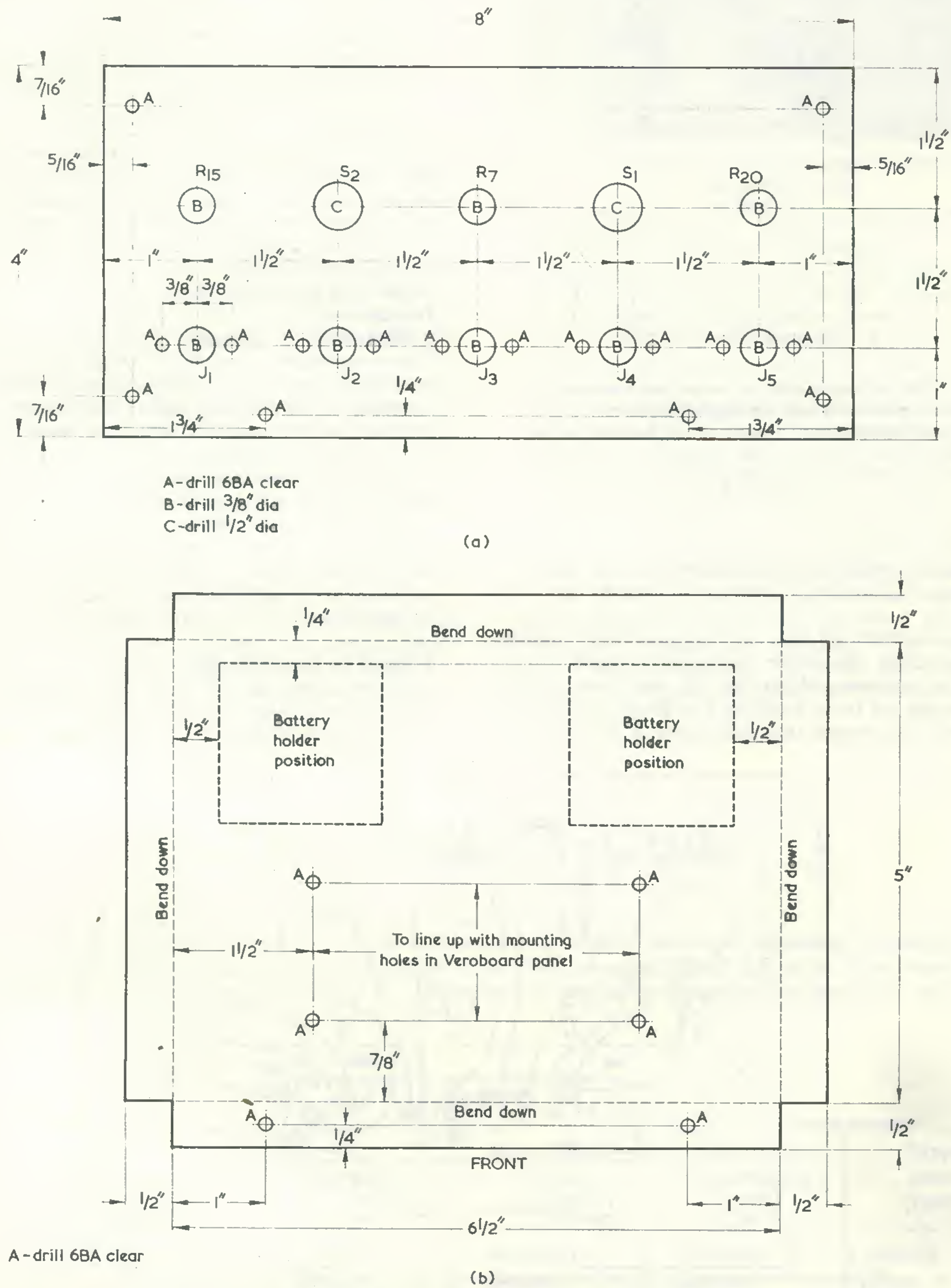


Fig. 4 (a). Details of the front panel. The material may be medium gauge aluminium sheet. The four 6BA clear holes at the corners are intended for mounting the unit in a cabinet
(b). The main chassis. This may employ the same gauge of aluminium sheet as is used for the panel

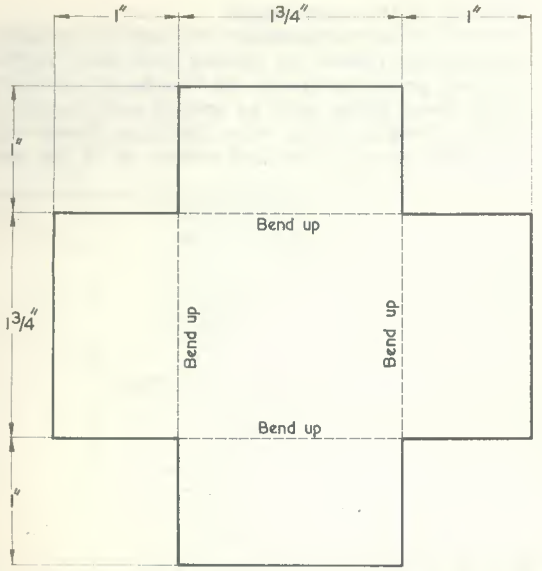


Fig. 5. The battery holders, of which two are required. These may be made with light gauge aluminium. They are bolted to the main chassis in the positions shown in Fig. 4 (b). The bolt holes required can be at any convenient points in the bottom of the holders, and are not shown here

can then be completed, as shown in Fig. 6. Note that strip "a" of the Veroboard is nearer the front panel.

Once assembly of the unit is complete, it can be given a series of simple functional checks in the following manner. With the Y amplifier of the oscilloscope set for a sensitivity of about 100mV/cm or 1 volt full screen diameter, switch on the trace doubler and connect the output of J_3 to the oscilloscope input terminals, using screened cable. Set the oscilloscope for Internal Sync and adjust the timebase to check that a good square wave output is obtained from the doubler. Check also that the square wave amplitude can be adjusted by means of the Trace Separation control, and that a good square wave, with negligible rise and fall times, is obtained for both the Fast and Slow settings of S_1. If satisfactory, adjust the oscilloscope for External Sync, increase the timebase speed and check that the square wave on the oscilloscope tube changes into two plain lines, positioned one above the other. Now connect suitable inputs to J_1 and J_5 on the trace doubler, connect the External Sync terminal of the oscilloscope to either J_2 or J_4, and check that the two test signal traces can be obtained on the screen and that sensitivity and trace spacing can be adjusted by means of the front panel controls. If satisfactory, the unit can next be fitted in a suitable cabinet and transfer markings applied to the front panel. The trace doubler is then complete and ready for use.

Should any "trouble shooting" of the circuit prove necessary, the only voltage tests that need be carried out are on TR_4, TR_5 and TR_6. These transistors should be checked to ensure that their emitters are at a potential of roughly 9 volts, i.e. half supply line voltage.

Note that coaxial sockets are used for all front panel connectors, and that it is important that all input and output connecting leads be fully screened when using the unit. Otherwise, peculiar results may be obtained due to interaction of input and output signals. It is particularly important to employ screened wire for the Sync Output connections.

Using The Trace Doubler

When using the trace doubler, the oscilloscope Y amplifier should be set to about the 100mV/cm range and connected to the J_3 Output socket. The

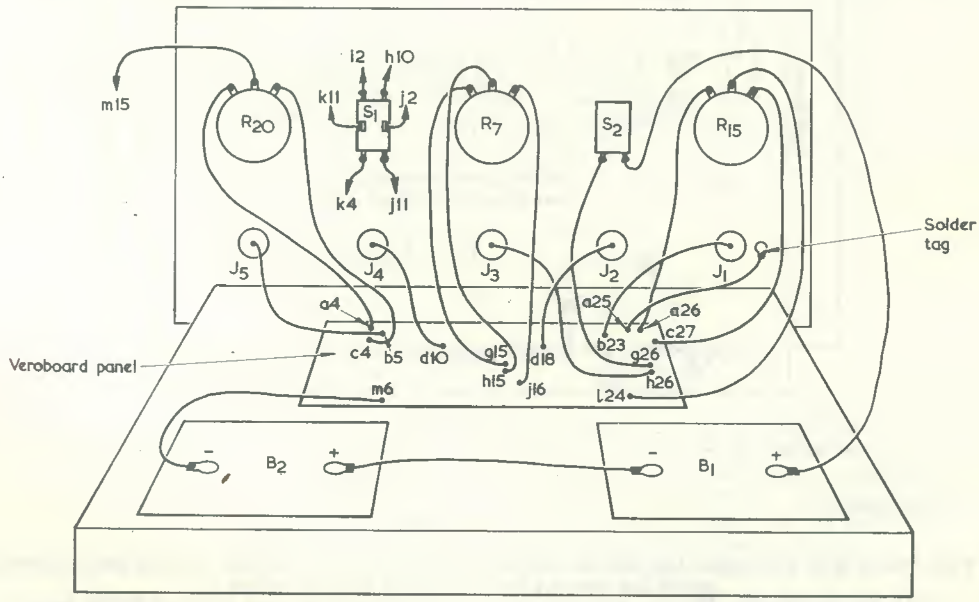


Fig. 6. Final wiring details. For reasons of clarity, only the battery holder outlines are illustrated

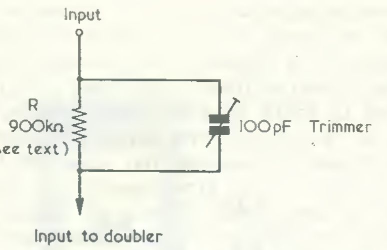
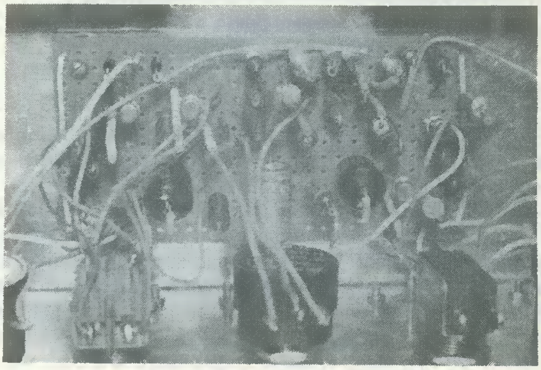


Fig. 7. A simple external attenuator. This allows inputs up to 140 volts peak-to-peak to be inspected



Detail illustrating the component side of the Veroboard panel

oscilloscope should be switched to External Sync, this being obtained from either the J_2 or J_4 Sync Output socket. With no inputs connected to the trace doubler two plain lines should now appear on the oscilloscope tube, one above the other. The distance between these lines can be adjusted by the Separation control; set this control so that the top line is about a quarter of the way down from the top of the tube and the lower line is about a quarter of the way up from the bottom. Now connect the two signals to be observed to the inputs (J_1 and J_5) of the trace doubler, and adjust the Gain controls (R_{15} and R_{20}) so that each trace occupies about a third of the screen. The channel 1 signal will be the upper trace on the screen. Select either Switch Fast or Slow for the best overall trace, with the switching square waves barely noticeable.

Do not try to superimpose the two traces on the screen, as this will result in distortion. A minor snag with the unit is that there is slight interaction between the two traces; if there is a large signal at channel 1 and none at channel 2, a breakthrough of about 5% will show up on channel 2 on the screen. Against this snag is the advantage of the very good frequency response of the unit; signals up to several Mc/s can be handled.

Signal phase shifts can be easily checked. If the two signals are displayed with the individual cycles directly opposite each other there is zero phase shift. A shift of $\frac{1}{4}$ cycle between the upper and lower traces means a phase shift of 90°, a shift of $\frac{1}{2}$ cycle means a phase shift of 180°, and so on.

If input signals greater than 14 volts peak-to-peak are to be inspected, the signals should be connected to the trace doubler via a simple attenuator probe, this comprising a fixed resistor and a 100pF trimmer capacitor in parallel, as illustrated in Fig. 7. The 900kΩ resistor, R, will enable signals up to 140 volts to be inspected, the 100pF trimmer being adjusted for a good response from a square wave input. If the a.c. input signal to the trace doubler is to be taken from a d.c. potential greater than 100 volts, increase the ratings of C_{12} and C_{15} to suit. Always make sure that only very low leakage capacitors are used in these two positions.

The SINPO Code

This code is reproduced here for the benefit of those readers who are interested in listening and reporting to short wave Broadcast band stations—see QSX on page 225 of this issue. This code may be removed from the magazine, pasted on to stiff card and placed in a convenient position near to the receiver.

SINPO

	Signal Strength (QSA)	Interference (QRM)	Atmospheric Noise (QRN)	Propagation Disturbance (QSB)	Overall Merit (QRK)
1	Barely Aud.	Extreme	Extreme	Extreme	Usable
2	Poor	Severe	Severe	Severe	Poor
3	Fair	Moderate	Moderate	Moderate	Fair
4	Good	Slight	Slight	Slight	Good
5	Excellent	None	None	None	Excellent

BATTERY ECONOMY IN CLASS A OUTPUT STAGES

(continued from page 237)

it should be possible to use a 9V or 12V battery to obtain increased output, though here trouble may be experienced from the d.c. flowing in the louspeaker speech-coil.

With the multimeter in series with the battery, first set VR_1 at maximum resistance and adjust VR_2 to give a standing current of 100mA or so. Apply a suitable low impedance a.f. source, such as the output immediately after the volume control of a transistor superhet, and ensure that a good quality signal is obtained from the speaker up to a large volume. If not, there is a fault which must be traced and corrected before work proceeds. When all is well use VR_2 to reduce the standing current to about 10 mA. When a signal is now applied distortion will result at a very low volume. It should however be found that by reducing VR_1 this distortion can be removed. Gradually increase the a.f. input and keep VR_1 in the position where distortion just ceases. Occasionally it will be found necessary to disconnect the a.f. source and readjust VR_2 to give the original standing current, as VR_1 has a certain effect on it.

Eventually a point is found where VR_1 can no longer prevent the distortion. Leave it at the optimum setting, and the adjustment is now complete. In the prototype the maximum output was very great. The d.c. input current at maximum output was 260mA, corresponding to a d.c. input of about 1·5W. Assuming the perhaps rather optimistic value of 40% for the efficiency this gives an output of 600mW or, at least, 0·5W.

The method of adjustment just described is rather crude. It may be found that with certain combinations of components it is impossible to eradicate distortion at a standing current of 10mA, whereupon it may have to be increased to 15mA or even 20mA. Ideally, adjustment should be carried out with a low distortion sine-wave generator and oscilloscope, but these are luxuries not everyone can afford. However, if the constructor is satisfied in himself that there is no distortion, there is little point in reducing it by an inaudible amount.

In connection with quality, the question of loudspeakers may be considered. The prototype was used with two 3Ω and two 5Ω loudspeakers in series. A small 15Ω loudspeaker may cause trouble with the heavy d.c. current, but a large type which would do justice to the quality obtainable should handle it with little difficulty.

The amplifier of Fig. 4 is not perfect, of course. Transient response definitely suffers, and it should be remembered that the efficiency cannot exceed 50% in any case. The prototype just manages full output from a 3-transistor tuner, but if it is to be used in a battery record player pre-amplification is necessary. It must be remembered that input impedance is low. Valve equipment will give inferior results unless a cathode-follower or emitter-follower is interposed. On the other hand, the low impedance means that it will be possible to use long lengths of unscreened cable to the input without fear of hum pick-up.

This amplifier is by no means the only possible application of the "sliding bias" system, but it does seem to offer the only useful power range at which a standard low impedance loudspeaker can be d.c. coupled into the collector circuit of the output transistor.

NEW U.H.F. AERIALS AT CRYSTAL PALACE

An important phase in the improvement and expansion of television transmissions in the London area was completed during August, 1968, when a new U.H.F. transmitting aerial was brought into service on the BBC 645 foot tower at Crystal Palace.

This new aerial, designed and supplied by EMI Electronics, now radiates BBC-2 programmes and will later transmit the BBC-1 service duplicated in the U.H.F. band. A similar aerial currently being installed at Crystal Palace for I.T.A. programmes duplicated in the U.H.F. band will be brought into service concurrently with the start of the BBC-1 duplicated service.

The aerials are mounted co-linearly on a 63 foot extension to the 645 foot tower and enclosed in a 5 foot diameter glass fibre reinforced plastic cylinder. Each aerial consists of four tiers of three Emislot panels mounted on a lattice spine. This arrangement produces an omidirectional radiation pattern and a nominal aerial gain of sixteen.

The Crystal Palace site is situated in a densely populated area. As a consequence, the BBC required the aerial contractor to meet a stringent specification for the vertical radiation pattern to ensure that viewers adjacent to and further from the transmitting site, alike, obtained good reception. Performance tests show that this specification is being met.

The new aerials are each able to radiate two programmes with maximum e.r.p's approaching 1000 kw when fed by transmitters producing peak vision powers of 80 kw per programme plus associated sound signals.

Delivery of the aerial in June 1968 was within 12 months of the placing of the contract with EMI. The difficult installation and commissioning has since been completed, using the erection services of British Insulated Callender's Construction Co. Ltd., without interruption to programme services from Crystal Palace.

This important aerial is the tenth high power U.H.F. aerial supplied to the BBC and ITA by EMI Electronics who are currently engaged in the construction of a further nineteen transmitting aerials for the expansion of the U.H.F. television services in the United Kingdom.

RC/DS/17

RADIO CONSTRUCTORS DATA SHEET 17

SPEAKER TRANSFORMER RATIO TABLE

Optimum load impedances for a.f. amplifier output stages vary over a wide range. Lowest figures appear in transistor output stages and highest figures in push-pull valve output stages (e.g. the 24kΩ anode-to-anode impedance required by two 6AM5 valves in Class AB1).

The Table gives worked examples of speaker transformer step-down ratios for output stage load impedances from 30Ω to 30kΩ. Results are to two significant figures and it would, in most instances, be satisfactory to use a transformer having a ratio within some 20% of the figure given.

Each ratio is the square root of the corresponding primary impedance to secondary impedance ratio.

Output load impedance	Speaker impedance			Output load impedance	Speaker impedance		
	3Ω	8Ω	15Ω		3Ω	8Ω	15Ω
30Ω	3·2:1	2·0:1	1·4:1	4kΩ	37:1	22:1	16:1
50Ω	4·1:1	2·5:1	1·8:1	5kΩ	41:1	25:1	18:1
75Ω	5·0:1	3·1:1	2·2:1	6kΩ	45:1	27:1	20:1
100Ω	5·8:1	3·5:1	2·6:1	7kΩ	48:1	30:1	22:1
150Ω	7·1:1	4·3:1	3·2:1	8kΩ	52:1	32:1	23:1
200Ω	8·2:1	5·0:1	3·7:1	9kΩ	55:1	34:1	24:1
250Ω	9·1:1	5·6:1	4·1:1	10kΩ	58:1	35:1	26:1
300Ω	10:1	6·1:1	4·5:1	12kΩ	63:1	39:1	28:1
400Ω	12:1	7·1:1	5·2:1	14kΩ	68:1	42:1	31:1
500Ω	13:1	8·0:1	5·8:1	16kΩ	73:1	45:1	33:1
600Ω	14:1	8·7:1	6·3:1	18kΩ	77:1	47:1	35:1
700Ω	15:1	9·4:1	6·8:1	20kΩ	82:1	50:1	37:1
800Ω	16:1	10:1	7·3:1	22kΩ	86:1	52:1	38:1
900Ω	17:1	10:1	7·7:1	24kΩ	89:1	55:1	40:1
1kΩ	18:1	11:1	8·2:1	26kΩ	93:1	57:1	42:1
2kΩ	26:1	16:1	12:1	28kΩ	97:1	59:1	44:1
3kΩ	32:1	19:1	14:1	30kΩ	100:1	61:1	45:1

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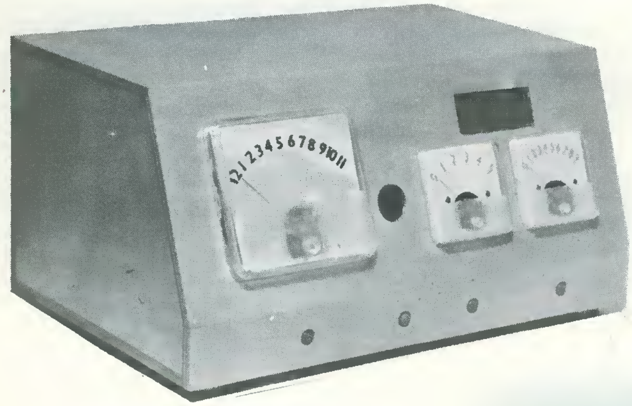

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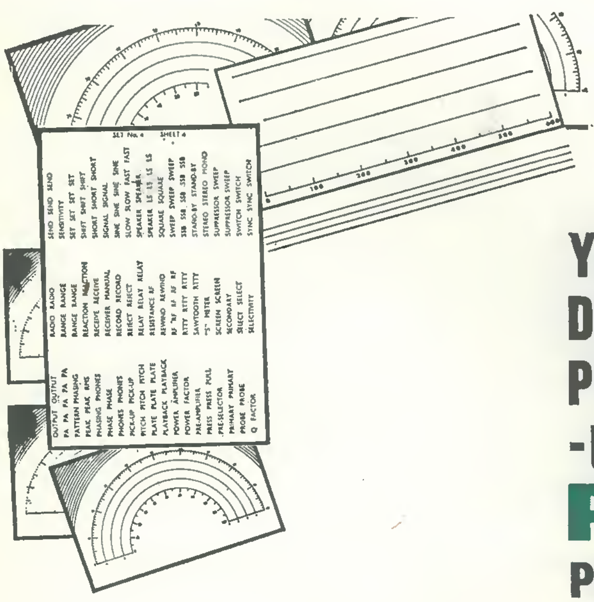

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I.F. AMPLIFIER AND DIODE DETECTOR

by W. G. Morley

In last month's article in this series we concluded our discussion of the frequency changer, and then introduced the i.f. amplifier. We examined a typical i.f. amplifier (without automatic gain control) as would be encountered in a domestic a.m. valve superhet, and saw that it employed a single pentode only. We also examined basic i.f. transformer design for receivers of this nature.

We now continue with the i.f. amplifier, after which we shall turn to the detector stage.

I.F. AMPLIFIER DESIGN

The i.f. amplifier we saw last month employed a single pentode, and was suitable for domestic a.m. valve receivers intended for long, medium and short wave reception. This single pentode, in conjunction with the i.f. transformers in its grid and anode circuits, provides adequate sensitivity and selectivity for domestic entertainment requirements.

The use of one valve only in the i.f. amplifier offers an interesting economic advantage from the point of view of overall receiver design. A typical domestic valve receiver can have its individual valves form the progression shown in Fig. 1. The first valve in Fig. 1 is a triode heptode frequency changer, this comprising a triode local oscillator and a heptode mixer. The second valve is the i.f. amplifier pentode. The third valve is a double diode triode, in which the diodes are used for detection of the i.f. signal whilst the triode gives voltage amplification of the a.f. signal obtained after detection. The fourth valve is the output valve, and this can be a pentode.

If we examine the individual valves in terms of the frequencies which appear in their anode circuits, we commence to see the advantage which accrues from having a single i.f. amplifying valve. The anode circuit of the triode in the frequency changer handles the local oscillator frequency only. The anode circuit of the heptode handles the intermediate frequency, together with unwanted signal and oscillator frequencies. The anode circuit of the i.f. pentode carries the intermediate frequency only, whilst the anode circuits of the voltage amplifier triode and output pentode handle the detected audio frequency signal only. Thus, no more than any two anode circuits share a signal at the same frequency. Because of this, the amount of decoupling required in the h.t. supply to the valves does not have to be at all elaborate. In practice, it is possible to dispense with decoupling altogether and to feed *all* the anode circuits from a common h.t. supply which is bypassed by one single electrolytic capacitor! The resulting h.t. circuit is shown in Fig. 2 (*a*). Since the single electrolytic capacitor is also the h.t. smoothing capacitor for the power supply section of the receiver, the quantity of components required for h.t. supply is virtually the minimum possible.

A slightly modified approach which enables a small further economy to be achieved is shown in Fig. 2 (*b*). Here, the anode circuit of the output valve is returned to the h.t. reservoir capacitor, whilst the remainder of the anode circuits (and the output valve screen grid) are run from the smoothing capacitor. (We saw, in detail, how it was possible to feed the output valve anode in this manner in the issue for October, 1967. The article in that issue also described an improved version of Fig. 2 (*b*) in which the rectifier cathode connected to a tap in the output transformer primary in order to further reduce the ripple level passed to the loudspeaker.). Since the output anode current is usually greater than the sum of the anode currents of all the other stages, the method of h.t. supply shown in Fig. 2 (*b*) allows a lower current to flow in the smoothing resistor (or choke), and thereby eases h.t. smoothing requirements.

The simple h.t. circuits of Figs. 2 (*a*) and (*b*) have been used in a very large number of commercially produced domestic a.m. receivers. In these, the smoothing capacitor normally has a value of the order of 16μF to 32μF. Theoretically, it is usual to assume that an electrolytic capacitor, due to its construction, offers a significant impedance at radio frequencies and is not, in consequence, as good a component for r.f. bypass purposes as a non-electrolytic component. In practice, however, an electrolytic capacitor functions adequately enough as an r.f. bypass to enable the h.t. supply circuits of Figs. 2 (*a*) and (*b*) to be quite acceptable for commercial manufacture. They are both very economical and are feasible when a single pentode is employed in the i.f. amplifier section.

It must be stated, before concluding on this particular point, that the h.t. supply circuits of Figs. 2 (*a*) and (*b*) can allow *some* unwanted coupling between the i.f. amplifier and mixer anode circuits to take place, this being particularly true if relatively long wiring couples these circuits to the smoothing capacitor. This unwanted

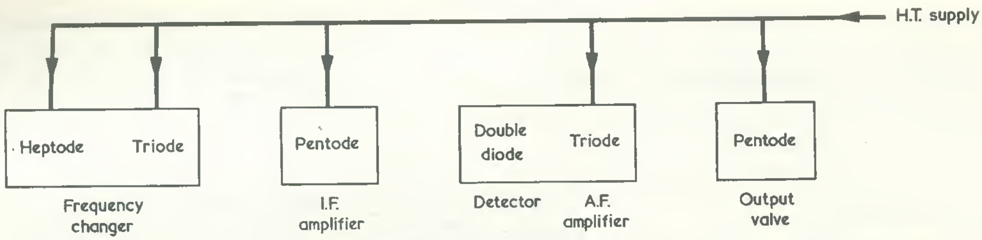


Fig. 1. H.T. supply arrangements for the anode circuits of a conventional domestic a.m. superhet

coupling does not result in actual instability in the receiver, but it can sometimes cause difficulty in obtaining a truly symmetrical overall response from the i.f. transformers. Where expense is of less consequence, as occurs in, say, a home constructor design, it is frequently beneficial to add a single h.t. decoupling circuit at either the mixer anode circuit, the i.f. pentode anode circuit, or both. Fig. 2 (*c*) shows such a circuit added to the h.t. feed to the i.f. amplifier anode. The extra decoupling provided here makes it easier to obtain a good i.f. response and the improvement, even if marginal, is often worthwhile.

I.F. amplifiers intended for valve f.m. receivers normally have two valves and operate at an i.f. of 10·7 Mc/s. The higher frequencies involved, and the fact that more than one i.f. valve is employed, makes it necessary to use individual decoupling circuits in the h.t. supplies to all r.f. and i.f. anodes.

In valve a.m./f.m. receivers the i.f. amplifier operates at a frequency in the range of 450 to 475 kc/s when receiving a.m. signals, and at 10·7 Mc/s when receiving f.m. signals. A.M./F.M. switching arrangements vary but it is usual to have a single pentode as i.f. amplifier for both frequencies, with the a.m. mixer functioning as a preceding i.f. amplifier valve when f.m. signals are being received. The relative complexity of the circuits employed make it necessary to have individual h.t. decoupling for all r.f. and i.f. anode circuits.

DIODE DETECTOR

We introduced the diode detector and described its operation in detail in the issues for May and June, 1965, the discussion at that time being mainly in terms of its use in t.r.f. receivers. It is not proposed to repeat the full description given in these earlier issues but, for the benefit of readers who do not have the appropriate copies to hand, a summary of the points made will now be given.

Fig. 3 (*a*) shows a standard diode detector, as would be applicable to t.r.f. receiver design. The r.f. input to the tuned circuit is at signal frequency and may come from a preceding tuned r.f. amplifier having its tuning capacitor ganged with that in Fig. 3 (*a*), or directly from an aerial. Detection takes place because the diode functions as a rectifier, allowing positive half-cycles of the received r.f. signal to be passed to C_1. C_1 has a capacitance which offers a high reactance at a.f. and a low reactance at r.f. It functions in a similar manner to the reservoir capacitor following a diode power supply rectifier, becoming charged on each alternate half-cycle peak and discharging (via the resistors which follow it) between these peaks. To prevent distortion, its rate of discharge must always be greater than the rate at which r.f. amplitude falls during a cycle of high level modulation at the higher audio frequencies. Fortunately, it is not difficult to provide a value for C_1 which avoids such distortion under normal conditions of a.m. reception.

An r.f. "ripple" exists across C_1 and this is removed by the filter given by R_1 and C_2. R_2 is the load resistor across which the detected a.f. signal finally appears. Representative values for the components just discussed could, in a valve circuit, be 100pF for C_1 and C_2, 15kΩ for R_1 and 220kΩ for R_2.

Appearing across C_1 is a direct voltage having nearly the peak value of the r.f. half-cycles. Part of this direct voltage appears across R_2. R_1 and R_2 form a potentiometer, and the direct voltage across R_2 is equal to that appearing across C_1 less the direct voltage dropped across R_1. Since R_1 is usually much smaller in value than R_2, the direct voltage across R_2 is only a little lower than that across C_1. With the diode connected in the manner shown, the upper end of R_2 is positive with respect to chassis.

Since the detected signal across R_2 will, under normal circumstances, be passed to a following a.f. voltage amplifier, it is necessary to remove the direct voltage across this resistor as it could otherwise upset the biasing arrangements for the voltage amplifier. The direct voltage is, in consequence, blocked by C_3 which has a low reactance at a.f. and which, typically, is given a value of around 0·01μF. The following resistor, R_3, can be the grid resistor of the voltage amplifier.

The introduction of C_3 and R_3 introduces a complication which must next be considered. So far as d.c. is concerned, the load presented to the diode is given by R_1 and R_2 in series. Because R_1 is much lower in value than R_2 we can, for the immediate discussion which follows, assume that the "d.c. load" presented to the diode is given by R_2 on its own. Speaking in terms of the detected audio frequency (and again ignoring R_1) the diode load is given by R_2 and R_3 in parallel because C_3 can be considered to offer negligible reactance to audio frequencies. R_2 and R_3 in parallel are, in consequence, referred to as the "a.c. load". Obviously, the d.c. and a.c. loads cannot be exactly the same, and it can be shown that this factor may cause distortion, the distortion becoming more severe as modulation depth increases. The distortion becomes more severe, also, as the difference between the values of the two loads increases. The only practicable method of keeping the difference between the d.c. and a.c. loads as low as possible is to make R_3 considerably higher in value than R_2, with the consequence that the a.c. load given by R_2 and R_3 in parallel then becomes closer in value to the d.c. load given by R_2 on its own. In practice, it is normal to make R_3 some four or more times greater than R_2, and this results in neglibible distortion with broadcast a.m. transmissions of normal modulation depth.

It is necessary to have an a.f. volume control in a receiver and this can be conveniently inserted at the detector stage; whereupon either R_2 or R_3 may be changed to a potentiometer as illustrated in Figs. 3 (*b*) and 3 (*c*) respectively. The circuit of Fig. 3 (*b*) has the advantage that when the volume control slider is at a low setting on its track the additional a.c. loading given by R_3 is much lower than when the slider is at the upper end of the track. It is common for the volume controls in domestic receivers to be adjusted to a fairly low setting for normal listening, with the result that the circuit of Fig. 3 (*b*) ensures that the ratio between d.c. and a.c. loads is close to unity at such settings, with consequently reduced risk of distortion. Even so, it is still good practice to make R_3 some four or more times greater than R_2 when the latter is a volume control.

A disadvantage with having R_2 as the volume control arises from the fact that the direct voltage due to signal rectification appears across it. When a volume control track becomes worn with use the resistance tapped off by the slider as it rotates does not vary smoothly but changes in small discrete steps. If R_2 is the volume control, there will then be similar discrete changes in the d.c. voltage applied to C_3, these being reproduced by the loudspeaker as a "rushing" noise when the control is adjusted. The effect is absent when the volume control is in the R_3 position, as in Fig. 3 (*c*), because there is no d.c. voltage across this resistor. The overall result is that a volume control in the R_2 position is liable to become "noisy" in operation earlier in its life than does a volume control of similar construction in the R_3 position. This disadvantage does not necessarily outweigh the advantages offered by having R_2 as the volume control, but it does emphasise the point that a good quality component should be used in the R_2 position if a long life is to be assured.

When the volume control is in the R_3 position it merely functions in the same manner as the volume control in any a.f. amplifier. Whichever position is chosen for the volume control, it should have a "log" track.

SUPERHET DETECTOR

The circuits we have considered in Fig. 3 are based on a consideration of the diode detector when it is connected, in obvious manner, between the source of r.f. signal and the load circuit. The principles involved are simple to follow, because the diode circuit is very similar to the familiar rectifier circuit used for h.t. supply. The circuit is also of the type which would be encountered when initially examining t.r.f. receivers. In such receivers the tuned circuit supplying the diode has one end connected to chassis because this is the most convenient method of connecting its manually operated tuning capacitor.

For valve superhet use it is desirable to slightly rearrange the detector components, and a suitable circuit is shown in Fig. 4 (*a*) where the diode follows the last i.f. transformer of the i.f. amplifier. The circuit of Fig. 4 (*a*) functions in the same manner as does Fig. 3 (*a*) and the resistors and capacitors have the same identifying numbers. The first

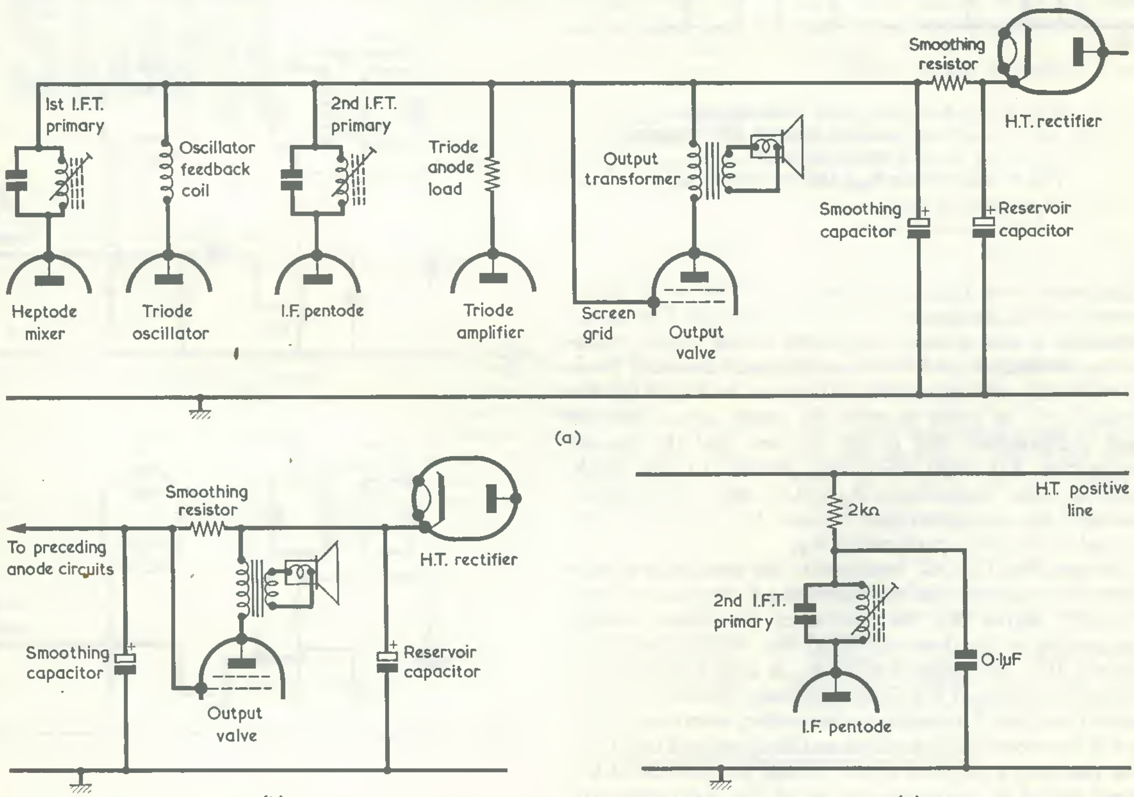


Fig. 2 (a). An a.m. superhet incorporating a single i.f. pentode may operate without any anode decoupling filters, the smoothing capacitor acting as a bypass for all anode circuits
(b). An alternative method of providing an h.t. supply for the output valve
(c). Adding an anode decoupling circuit to the i.f. amplifier pentode

(c). Adding an anode decoupling circuit to the i.f. amplifier pentode

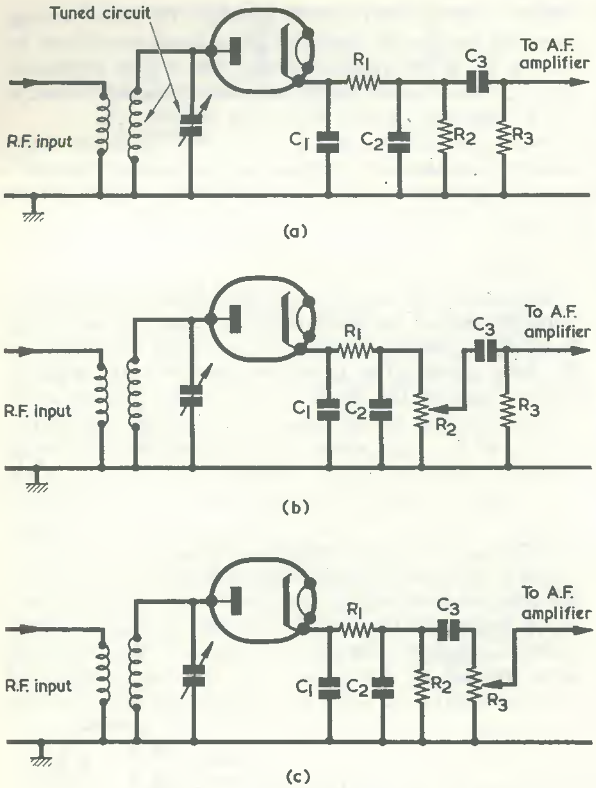


Fig. 3 (a). A simple diode detector circuit
(b). Adding an a.f. volume control by changing R_2 to a potentiometer
(c). In this version R_3 is the volume control

thing to notice in Fig. 4 (*a*) is that neither side of the tuned circuit feeding the diode is at chassis potential. The tuning capacitor is now a fixed component across the i.f. transformer secondary, and there is no physical necessity for it to have one side connected to chassis. In Fig. 4 (*a*) the diode is still in series between the tuned circuit and the load components, and it can be seen that the chassis connection has been effectively shifted to the diode cathode. Filter components R_1 and C_2 once more appear, and they are now interposed between the i.f. transformer secondary and the upper end of R_2.

As with Fig. 2 (*a*), C_1 functions in the same manner as a reservoir capacitor, and the detected a.f. appears, without "ripple", across R_2. So also does the direct voltage component of the detected signal, but it is important to observe that the upper end of R_2 is now *negative* with respect to chassis. (The diode will only conduct on half-cycles from the i.f. transformer secondary where the upper end of the secondary is positive and the lower end negative). The fact that a negative direct voltage is available at the upper end of R_1 makes the circuit of Fig. 4 (*a*) attractive for use in a valve superhet because, as we shall see later, that negative voltage may be employed for automatic gain control and for tuning indicator circuits.

Another advantage offered by the arrangement of Fig. 4 (*a*) is that the diode cathode is at chassis potential. In valve superhets the diode detector is usually combined with the following a.f. voltage amplifier in a single envelope, both sharing the same cathode. That cathode can then be at chassis potential for both triode and diode.

The same points concerning d.c. and a.c. loads apply, in Fig. 4 (*a*), as in Fig. 3 (*a*). To prevent distortion R_3 should be some four of more times larger in value than R_2.

Fig. 4 (*b*) shows the rearranged form of Fig. 3 (*b*), in which R_2 is the volume control. Similarly, Fig. 4 (*c*) shows the rearranged version of Fig. 3 (*c*), in which R_3 is the volume control. Again, the same comments apply as for the previous diagrams.

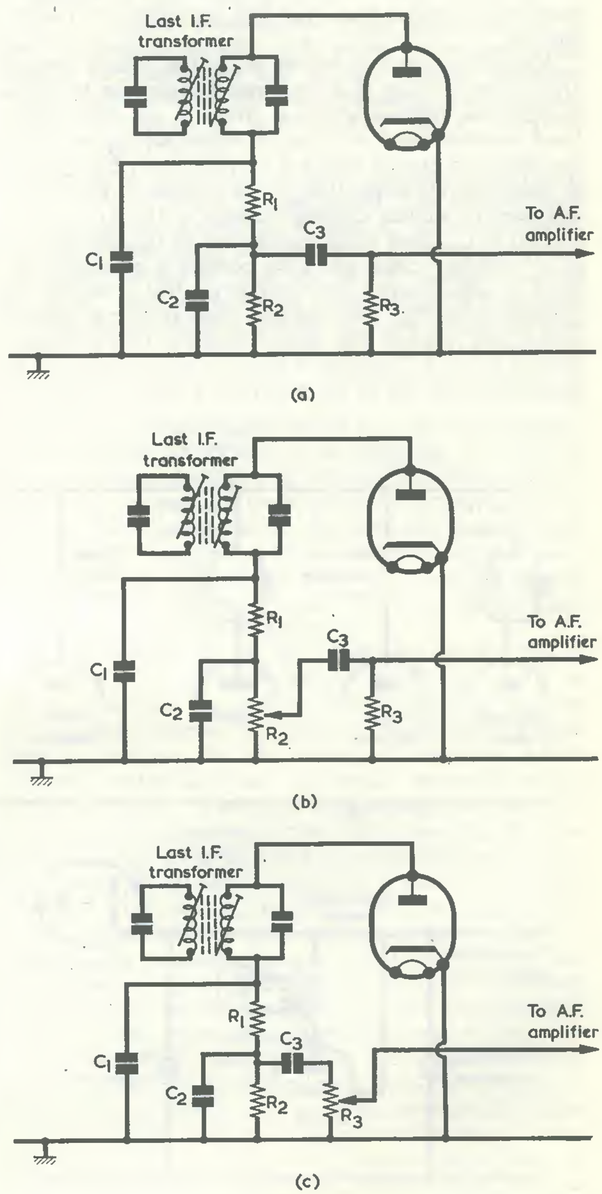


Fig. 4 (a). A rearranged version of Fig. 3 (a), suitable for a valve superhet detector stage
(b). The superhet version of Fig. 3 (b)
(c). The rearranged circuit having R_3 as volume control

In last month's issue it was stated that, due to the loading introduced by the diode detector, it is desirable for the two windings of the last i.f. transformer to be positioned slightly closer together to provide the same critical coupling response as is given by the i.f. transformer which feeds the i.f. amplifier pentode. It may now be seen that this loading is caused by the necessity to charge C_1 on each alternate i.f. half-cycle.

NEXT MONTH

In next month's issue we shall continue with the detector circuit and then carry on to automatic gain control.

In your work-shop

Life presents difficulties which are common to all of us, and this month's episode finds Dick grappling with one of the most universal problems which beset mankind. Fortunately, a discussion of the latest hints received from readers not only helps him to momentarily forget his troubles but it eventually enables him to overcome them completely

"Smithy!"

"Hallo!"

"What's the time now?"

Irritably, Smithy the Serviceman glanced at his wrist watch.

"It's twenty past nine".

"Ta".

Dick took out his wallet, extracted a card from this and studied it intently. He then returned the card to the wallet, and replaced the wallet in his jacket.

The Workshop fell silent again. Smithy concentrated on the faulty television receiver on his bench, whilst Dick prodded listlessly at a small transistor radio chassis in front of him. It was evident that Smithy's assistant was greatly preoccupied with matters other than electronic.

READERS' HINTS

Suddenly, Dick put his test prods down on the bench and once more took his wallet from his pocket. He gazed unhappily at the card it contained.

"Smithy!"

"What is it now?"

"Is that watch of yours correct?"

"Of course it's correct".

"Then what time does it say at the moment?"

Smithy snorted.

"Is this", he growled irately, "a gag something?"

"Of course it's not", returned Dick aggrievedly. "It's just that I wanted to know what the time is now".

"Hell's teeth", snarled Smithy. "You've done nothing else but ask me the time ever since you came in to work this morning. I must have looked at my watch at least twenty times".

"Seeing", replied Dick, using the condescending tone of one who explains an obvious point to an idiot, "that the Workshop clock is in for repair and you're the only person with a watch, I've got no option, have I? Anyway, what *is* the time?"

"If you must know," said Smithy ungraciously, "It's half-past nine".

"Then, said Dick, looking once more at his card. "I've got another fifty minutes to go".

"Fifty minutes to go before what?" snapped Smithy. "And what the dickens is that scrap of paper you keep looking at?"

"What you refer to as a 'scrap of paper'", returned Dick indignantly, "is a very important document".

"All right then, but what is it?"

"It's my appointment card".

"Appointment card?"

"For my dentist", explained Dick with dignity. "And it tells me that I'm due to see him this morning at 10.30 sharp, which means that I'll have to leave the Workshop at 10.20. I should add that my dentist gets very narky, too, if I don't turn up on time".

"Well", conceded Smithy, somewhat mollified by this explanation, "it's always a sensible policy to maintain good terms with your dentist. Have you got toothache or anything?"

"Oh no", said Dick. "I've just got to go for a routine check-up".

"I see", remarked Smithy thoughtfully. "Funnily enough, your talking about the dentist has just reminded me of something".

"What's that?"

"It's reminded me about the readers' hint sessions we have every now and again. It so happens that I've received several hints recently which are loosely connected, in one way or another, with dentistry".

A light of interest gleamed in Dick's eye.

"It's quite a long time since our last sesh on readers' hints", he remarked eagerly. "Have you got many new ones on hand?"

"As a matter of fact", replied Smithy, "I've collected quite a few".

The Serviceman directed a critical glance towards his assistant, then decisively turned back to the TV chassis he had been examining and switched it off. He next opened a drawer in his bench and extracted a sheaf of letters.

"It's quite evident", he remarked, "that the chances of your doing any useful work between now and 10.20 are just about negligible, and so this period *would* be a good time to devote to readers' hints. Come on over to my bench, Dick, and have a look at the ones I've got here".

Delighted, Dick promptly carried his stool to Smithy's side whilst that worthy examined the letters he had taken from his drawer.

"Here's a good one to start off with", he said, picking out one of the letters. "And it takes advantage of discarded

Fig. 1. The internal ink reservoir tube of a ball point pen may be readily converted for use as a trimming tool

ball point pens".

"Oh yes", remarked Dick, settling himself down comfortably. "What do you make from those?"

"Trimming tools", replied Smithy. "You first extract the inner ink reservoir tube and flatten the brass end containing the ballpoint in a vice. The small flat end thus obtained can then be fitted in the slots of iron dust cores in i.f. transformers and the like, filing it if necessary to get the final dimensions desired. There's a sketch of the finished job supplied with the letter".

Smithy showed Dick the sketch. (Fig. 1).

"Since", he went on, "the tube part is made of polythene it is non-metallic, which means that it won't alter the inductance of any windings it passes through. The ink reservoir tubes which are best for this application are those having an overall diameter not greater than ⅛ inch, and these are slim enough to pass through really small access holes".

"That's a smart idea", said Dick approvingly. "I'm always in favour of schemes which give you something for nothing!"

Smithy noticed, with interest, that his assistant had already forgotten his forthcoming encounter with the dentist.

"Here's another useful idea", remarked the Serviceman cheerfully, "and it offers a warning when a transistor radio is not properly switched off".

"That's something that's always cropping up", commented Dick. "People turn the volume control on their transistor radios to minimum without properly switching them off, and then wonder why the batteries run down so quickly!"

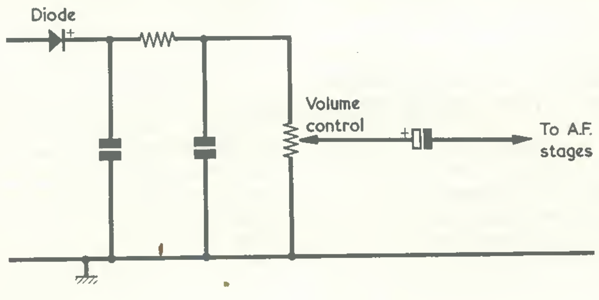
"True enough", agreed Smithy. "Well, the very simple idea I've got here guards against that sort of thing very neatly. Take a look at these two circuits".

Dick leaned over and examined the circuits in the letter Smithy was holding.

"Now", said Smithy, "the normal volume control arrangement in a transistor radio is basically like the first circuit here. (Fig. 2 (*a*)). The a.f. output from the diode appears across the volume control track and the slider taps off the desired proportion which is to be passed to the a.f. stages. As you can see, the set can be silenced completely by turning the volume control to minimum. In many cases, this can also occur even when the volume control is ganged with the on-off switch, and the set can still be completely silenced without being actually switched off. What the present dodge consists of is the insertion of a low value resistor in series with the earthy end of the volume control track. (Fig. 2 (*b*)). Provided the receiver is tuned in to a station, as it normally will be, it then becomes impossible to silence it completely. A few milliwatts of output will still be heard with the volume control at minimum, giving a warning that the set has not been switched off. The great advantages of this idea are that it is easy to apply, that it doesn't alter operating conditions in the receiver, and that it doesn't cause extra battery consumption as would any other type of on-off indicating device".

"What value", asked Dick, "should the additional resistor have?"

"About 47Ω will give the required result with most receivers", replied Smithy. "But you can, of course, experiment a little with the value to get just exactly the minimum volume level you require".



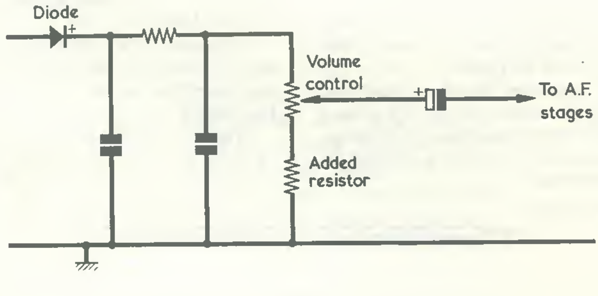


Fig. 2 (a). The basic diode and volume control circuit of a transistor radio
(b). Adding a low value resistor ensures that the receiver cannot be completely silenced without actually switching off

METER PROTECTION

Smithy extracted another letter from the sheaf on his bench and read it carefully.

"Here's another simple idea", he said. "The writer of this letter has a testmeter on which the range selector switch positions for the 10 volt and 50μA ranges are side by side. Because of this, the 50μA range has been inadvertently selected on several occasions, nearly causing the needle to get wrapped around its end-stop. To overcome this problem, an 8BA hole was drilled and tapped at the 50μA switch position on the testmeter panel. An 8BA bolt was then fitted, thereby preventing the pointer knob of the switch being accidentally set to this range. (Fig. 3). Since the knob turns through more than 180° it was also necessary to file a step in its other end to clear this screw. It is only occasionally necessary to use the 50μA range, and when this is required all that needs to be done is to remove the 8BA screw".

"I've got a similar sort of problem with my own testmeter", announced Dick musingly. "It mightn't be a bad idea to fit a little guard screw to it on its low current range as well".

"It would be a jolly *good* idea", returned Smithy, fixing a basilisk glare on his assistant. "Judging by the way *you* handle testmeters, I've often thought of issuing you with one which had no current ranges below 1 amp!"

"Now, don't be like that, Smithy", said Dick soothingly. "Let's get on to the next hint".

"Very well, than", said Smithy, dismissing with an effort his perennial irritation at Dick's cavalier treatment of the Workshop test equipment. "Let's see what the next letter says".

Smithy's expression brightened as he quickly scanned the letter, and he gave a little chuckle.

"This one really *is* neat", he grinned. I'll read it out to you. 'The large size Steradent denture tablet containers made of aluminium are just the right size for holding two No. 8 batteries. The container has a push-on plastic cap, with the result that all that is required for the positive connection is a flat-headed screw fitted to the centre of this cap. The result is a convenient 6 volt battery pack, which is just the job for transistor receivers and other transistor gear'".

"That *is* neat", confirmed Dick.

"Incidentally, talking of denture tablets has just reminded me. What's the time now, Smithy?

"It's five to ten", replied Smithy, consulting his watch. "You've got plenty of time to go before your dental appointment. You don't half seem worried about it".

"I am a bit", admitted Dick ruefully. "It's the thought of that high-speed drill of his that gets me. Blimey, Smithy, you can hear it screaming away even as you walk up to the surgery!"

"You should be jolly lucky", returned Smithy sternly, "that you live in a generation whose dentists have *got* high-speed drills. In my time they used low-speed drills coupled up to a treadle wheel by way of a cord running on pulleys. The pressure on the drill in your mouth used to vary in sympathy with the pressure of the dentist's foot on the treadle!"

"Gosh", shuddered Dick. "But what do you mean by 'in your time'? Don't you still have to get a filling done occasionally?"

"Not nowadays", replied Smithy smugly. "If there's anything wrong with *my* teeth, then I just lean back in the chair and natter with the dentist whilst he makes any adjustments they need in another part of the room. Smashing, it is!"

Dick stared at Smithy. This was a feature of the Serviceman which he had not before even considered.

"Blimey", he remarked, impressed. "You've got false teeth, then".

"I wear", said Smithy, primly correcting his assistant's terminology, "dentures".

Dick gazed at the Serviceman with morbid fascination.

"Top", he continued, "*and* bottom?"

"The full set", replied Smithy proudly. He raised his hand to his mouth.

"Would you like to have a look at them?"

"Ye gods, no", retorted Dick with revulsion. "Phew, you must look *horrible* when you go to bed at night".

"Nonsense", said Smithy equably. "There's just a slight change in the facial contours, that's all. And, after a good night's sleep, I come down in the morning, snap the old plates back into position again, and I'm all set for anything from pork crackling to a fried egg sandwich!"

"Ugh", said Dick.

"What was that?"

"Nothing", replied Dick hastily. "Can we get on to another hint, please?"

"As you like", said Smithy obligingly. "Well, now, let's see what we've got next. Ah, this is a good one, and it has to do with soldered connections to switches. The writer of the letter I've got here says that some types of miniature switch, including in particular slide switches, can introduce peculiar circuit faults if they are overheated during soldering. It seems that these faults are caused by the nature of the switch insulation when this consists of resin-impregnated paper. If there is excessive heat on the tags when they are being soldered, the resins in the insulation apparently run over the contact surfaces and form a partially insulating film. The result is that the switch either goes open-circuit, becomes intermittent, or presents a high contact resistance".

"That's an awkward one", commented Dick. "You don't expect snags like that, especially if the switch is a brand-new component".

"True enough", agreed Smithy. "I should imagine that, if over-heating during soldering is causing the trouble, there's a possibility that the resin could well be coming from the core of the solder as well as from the switch insulation. At any event, the cause doesn't affect the suggested method of overcoming the difficulty. Which is, quite simply, to keep switches of this nature on their side when soldering to them, so that the tags project horizontally. This ensures that hot solder cannot run down the tag, and it eradicates the risk of hot solder blobs falling on to the insulation. If soldering heat is applied to the ends of the tags only, the risk of resin flowing over the contact surfaces becomes negligible".

NOVEL KNOBS

"That's something I must bear in mind for the future", observed Dick.

"It's worth remembering", agreed Smithy. "I must admit that some of the little slide switches I bump into these days have a construction which could readily allow resin to flow over the contact surfaces if they are overheated during soldering, and it would certainly be worthwhile soldering them with the tags horizontal to avoid this risk. Now, let's see what we've got next".

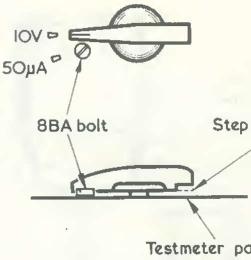


Fig. 3. A simple means of preventing an infrequently used low current range in a testmeter being selected by accident

Smithy once more inspected his sheaf of letters.

"Here's an idea which is *right* in the do-it-yourself category", he announced, as he selected a letter. "This one is concerned with making your own control knobs".

"That", remarked Dick, "sounds like a very knobby idea".

Smithy cast a suspicious glance at his assistant's guileless face, then returned to the letter.

"The writer of this letter", he resumed, "says that after building an oscilloscope he needed some small knobs that would complement the trouble he had gone to in making the front panel attractive. His local radio shop had some very smart knobs in stock but, as they asked 2/6d each for them and he needed quite a large quantity, he thought he'd try something else. He'd heard of toothpaste

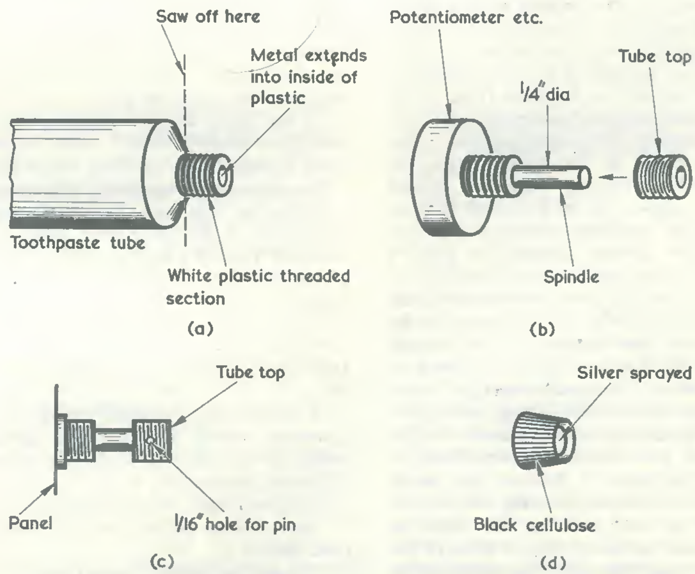


Fig. 4. A method of obtaining attractive and very cheap control knobs. The individual steps in making up the knobs are described in the text

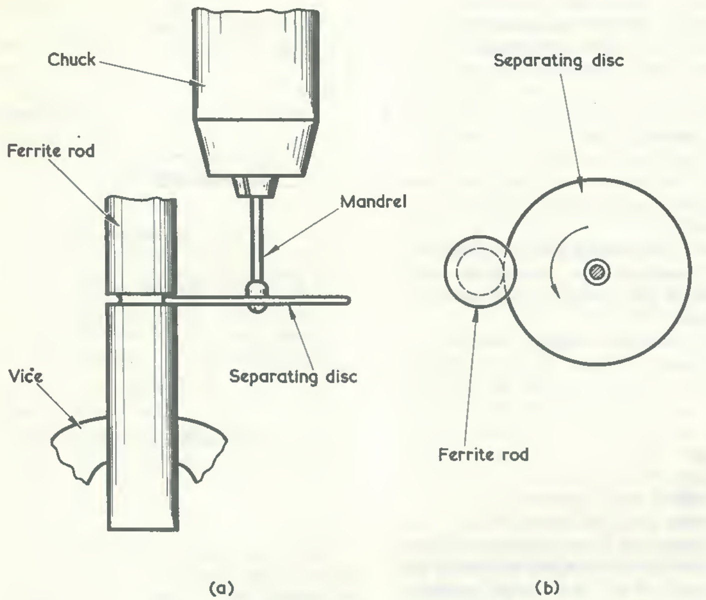


Fig. 5 (a). Cutting a ferrite rod on a bench drill with the aid of a separating disc, as used by dental mechanics
(b). The ferrite rod is moved gently around the disc to enable a continually deepening groove to be cut. Only light pressure against the disc should be employed

caps being used for knobs before, but he'd never seen a satisfactory method of attaching them to the spindles. In consequence, he devised the scheme which he now describes in this letter".

Smithy showed Dick the letter, which included a number of sketches (Fig. 4), then proceeded to read from it.

"'Most toothpaste tubes nowadays have a soft metal body, the thread for the cap being bonded plastic with a metal core. The internal diameter of this metal core happens, in most cases, to be a quarter of an inch. The top of the tube is sawn off with a hacksaw (Fig. 4 (*a*)) after which any toothpaste that's left in it is washed out. The control spindle is then cut to length in the normal way, the threaded toothpaste tube top placed over it, and a $\frac{1}{16}$in hole drilled through the whole assembly. (Figs. 4 (*b*)) and (*c*)). The drilling process is quite a simple matter with an electric drill. A panel pin of $\frac{1}{16}$in diameter is next pushed through the hole and trimmed to lie flush with the bottom of the plastic thread. All that remains to be done is to screw on the toothpaste cap tightly and the knob is complete. It was found that knobs made up in this manner didn't unscrew, even when they were fitted to rotary switches. If desired, the knobs can be finished by spraying the sunken part silver and painting the knurling with black cellulose. (Fig. 4 (*d*)). In the writer's case, the silver was given by an aerosol bought at Woolworth's whilst the black cellulose was car touch-up paint. Incidentally, ordinary paint is not satisfactory here since it tends to chip in use when applied to plastic!"

Smithy finished reading the letter and placed it on the bench.

"How", asked Dick, "do you know if a particular toothpaste tube has a $\frac{1}{4}$in hole down the threaded bit?"

"I think you'll find the majority of makes have", replied Smithy. "What you have to do is to take a pot up to the bathroom and pop its spindle down the nozzle of all the toothpaste tubes you can find there! That'll soon tell you whether they're $\frac{1}{4}$in or not".

"If my family caught me doing that", said Dick firmly, "they'd have me put away, mate".

A sudden frown creased his forehead.

"Blow me", he said, "we don't seem to be able to get away from teeth this morning. First, it's denture cleaner, then it's toothpaste! What's the time now, Smithy?"

Gravely, Smithy consulted his watch.

"Eight minutes past ten", he announced. "You've got plenty of time yet".

"I won't half be glad", said Dick gloomily, "when I've got this dental check-up business over and done with".

Smithy gazed at his assistant.

"Do you know", he remarked chattily, "I think you're really *scared* of seeing your dentist".

"I'm not just scared", said Dick, "I'm *petrified*! For goodness' sake, Smithy, let's get on to another hint".

"As you like", replied the Serviceman serenely. "Now there are two quite useful hints in the next letter. The first concerns the use of an electric drill on a painted metal case or cabinet. In instances of this nature, it's very easy for the chuck to get pushed forward and scrape the finish around the hole when the drill breaks through. This problem can be avoided by the simple process of winding masking tape around the chuck and the shank of the drill".

"That's a crafty wheeze", remarked Dick interestedly, once more temporarily forgetting his impending trip to the dentist.

"Yes, isn't it?" agreed Smithy. "It's one of those quick dodges which can save a considerable amount of grief later on. The other hint in this letter is concerned with cutting the copper strips on Veroboard. Some people who only use Veroboard occasionally may not have available the special rotary cutting tool that is intended for this job, and may attempt to use alternative methods. One possible idea here is to cut the strips with a knife, but this is not always successful as it can result in a whole strip being lifted from the board. The best solution is to countersink at the hole where the cut is to be made with an ordinary twist drill. This method is quite efficient and the board looks just as neat as if the proper tool had been used".

Smithy returned the letter to his bench and perused the next one in the sheaf. A gleam came into his eye.

"Ah", he announced with satisfaction. "Now, we have a really excellent hint here. Tell me, Dick, how do you normally cut ferrite rod?"

"Do you mean", queried Dick in return, "how do I obtain a short length from a long rod?"

"That's right".

Dick frowned.

"The ability to shorten lengths of ferrite rod accurately", he remarked plaintively, "has been something which has eluded me over all the years I've been playing around with radio. At any event I don't *cut* the rod because, so far as I know, ferrite rod just can't be cut. I usually put the rod in a vice and bash it with something, hoping that it will break at the top surface of the vice jaws. It doesn't always, though, and even if it does the end where it's broken always looks rough".

"What you've just described", commented Smithy, "represents general experience. As the hint I now have here points out, however, it *is* possible to cut ferrite rod, and it can be done easily and reliably. The process is carried out with a special separating disc, as used by dental mechanics for cutting chrome wires. The ferrite rod to be cut is first of all mounted in a machine vice and held loosely on the supporting plane of a bench drill. Mounted in the drill chuck is a mandrel carrying the separating disc, this being at the level at which section is required. (Fig. 5 (*a*)). The ferrite rod is then held lightly against the edge of the separating disc and moved gently round to cut a groove which becomes steadily deeper until the rod is cut through. (Fig. 5 (*b*)). The pressure on the disc must not be great because it is only made of plastic with dispersed carborundum. This cutting method is completely satisfactory and gives a beautifully clean end to the rod. It will, for instance, easily cut ½ inch rod".

CHANGE OF HEART

"Blimey, Smithy, that's the best idea I've heard for ages", exclaimed Dick. "As I said just now I'd never even realised that ferrite rod could be cut. Why, this solves *all* my future problems with ferrite rod. There must be stacks of other people, too, who'll take advantage of this particular hint".

"I'm sure there will be", agreed Smithy. "Look, here's a sample of a piece cut from a ½ inch rod".

Smithy removed a thin disc which had been stuck to the letter with Sellotape and passed it over to his assistant. Dick examined it, then excitedly snatched up a steel rule from Smithy's bench.

"Corluvaduk", he gasped. "Do you know, Smithy, this slice of ferrite material is less than a sixteenth of an inch thick! And yet it's not chipped in any way and both the sides are perfectly clean and parallel. This idea for cutting ferrite rod really *is* something!"

He avidly examined the slice of ferrite material once more, then turned to the Serviceman.

"How", he asked, "do you obtain the separating disc and mandrel?"

"As I just mentioned", replied Smithy, "the separating disc is an item used by dental mechanics. Its full description is 'flat double side ⅞ inch plastic based high speed separating disc'. At the same time, the mandrel on which it's mounted is a standard item used by dental mechanics. You should be able to get both of these from any dental supplier, of which there should be one in most large towns. Or you could get them from any dental mechanic you happened to be friendly with".

Smithy glanced at his watch.

"And", he continued artlessly, "after having once again reminded you of dental topics, I can forestall your next query by saying that the time is 10.18 exactly".

"Is it?" said Dick enthusiastically. "That's fine, then. I'll get ready to go right now".

Smithy's jaw dropped open.

"I thought you were *dreading* this visit of yours to the dentist", he said. "How come the sudden change of heart?"

"I *was* dreading it", admitted Dick, "but not now. My dentist is bound to have a dental mechanic which means that, for the first time ever, I've got means of access to a tool which is capable of actually cutting ferrite rod. If my dentist can assure me a future supply of separating discs and mandrels he can do just what he likes with my teeth. I won't complain even if he whips them all out and I go on to false choppers just like you!"

And with these words Dick hastily snatched up his raincoat from its peg and rushed out of the Workshop door.

As the echoes died away, Smithy collected the letters and returned them to the drawer in his bench. He noted that there were several still left unread. Thoughtfully, he decided that he had better not leave it too long before he and his assistant had a further discussion based on Hints from Readers.

EDITOR'S NOTE

The hints described in this episode of 'In Your Workshop' were submitted, in the order in which they appear, by W. D. Graham, W. Smith, C. P. Finn, R. C. Lea, T. E. Millsom, M. Francis, D. J. Tate and W. H. Bond.

Further hints for this feature are welcomed, and payment is made for all that are published.

THE "TRIPLE-S" 3-TRANSISTOR RECEIVER

by SIR DOUGLAS HALL, K.C.M.G., M.A.(Oxon)

Readers may recall our contributor's successful and popular "Simplicity and Sensitivity" receiver designs based on an ingenious 2-transistor reflex circuit. The "Triple S" is a further development of the "Simplicity and Sensitivity" approach. It incorporates modern silicon transistors, which enable an even better performance to be achieved

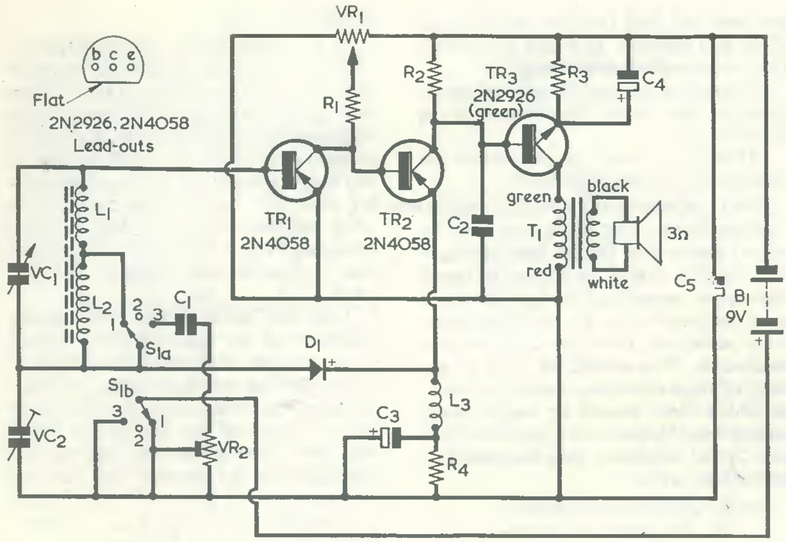
THE AUTHOR HAS DESCRIBED TWO simple receivers in this magazine under the title of "Simplicity and Sensitivity". The first of these (April, 1964) was an earpiece receiver, employing two transistors, and the second (November, 1965) a loudspeaker version covering two wavebands and using three transistors.[1] Judging from correspondence it would seem that these designs—particularly the latter—have been built in considerable numbers and, indeed, are still being constructed.

This article describes a revised version of the circuit using modern silicon transistors. "Simplicity and Sensitivity with Silicon" equals "Triple S." The opportunity has also been taken to improve on two weaknesses in the earlier designs—a rather pronounced pulling between the tuning and volume controls, and a limited wave coverage on the medium wave band. A further improvement is that variations in transistor characteristics are now looked after by two preset controls, one for each waveband, which are adjusted once and for all. Finally, sensitivity, previously good, is now further enhanced and the design is particularly suitable for those who live in difficult reception areas, whether the difficulty arises from the absence of local stations or from local screening. In such areas many readers may have found that the usual small and simple transistor portable is of little practical use.

TRIPLE S CIRCUIT

The circuit of the Triple S receiver is shown in Fig. 1. Reaction is no longer controlled by a variable resistor in the tapping circuit but by varying the collector current of TR_1 and TR_2 by means of a potentiometer across the battery. By using a 9 volt battery, as against 3 or 4½ volts in the earlier version, the resistance in the collector circuit of TR_1 can be increased. This steps up the r.f. gain of both TR_1 and TR_2. A.F. gain is also increased, especially by TR_3 which can now produce more voltage gain due to the comparatively large load presented by the primary of T_1—about 1·2kΩ as against the previous 80Ω. A further advantage which comes from using silicon transistors is that the larger

[1] Sir Douglas Hall, "Simplicity and Sensitivity with 2 Transistors", *The Radio Constructor*, April 1964; "Simplicity and Sensitivity with 3 Transistors", *The Radio Constructor*, November 1965.



S_1 positions: 1 - M.W
2 - Off
3 - L.W.

Fig. 1. The circuit diagram of the Triple-S receiver. L_1 and L_2 form the ferrite aerial

voltage required between base and emitter with these devices means that there is more voltage available between collector and emitter of TR_1 than when germanium transistors were used. This, again, results in improved sensitivity. In fact, increased overall gain is such that transformer coupling between TR_2 and TR_3 is now no longer necessary or desirable. In the present receiver, D_1 is a comparatively low resistance diode. The OA73 specified gives better results with this circuit than a higher resistance type such as the OA81.

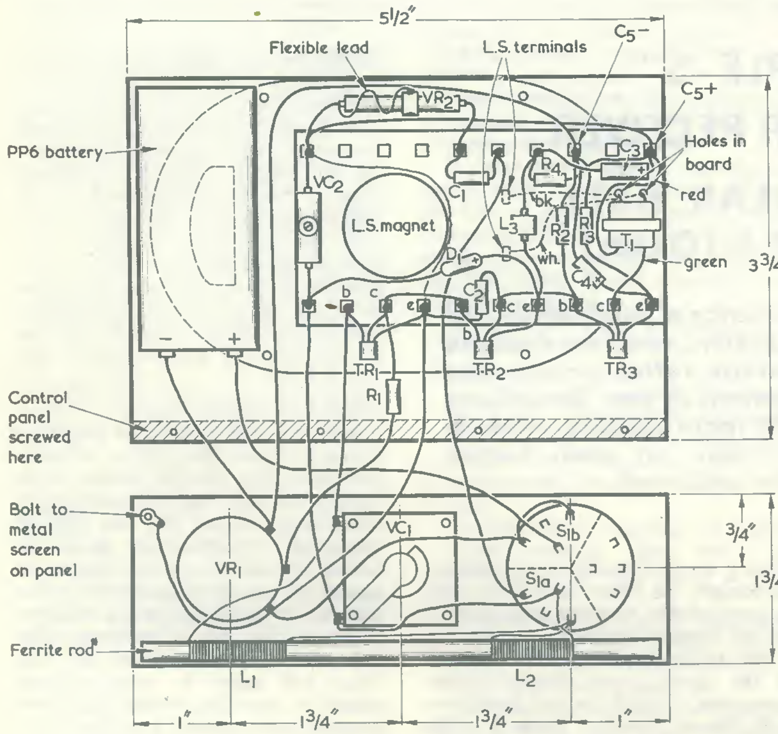


Fig. 2. Wiring and layout diagram. The control panel is shown separate from the board on which the loudspeaker is mounted. The body of C_5, which fits under the tagboard, is not shown

COMPONENTS

Resistors
(All fixed values ¼ watt 10%)
R_1 22kΩ
R_2 1kΩ
R_3 27Ω
R_4 680Ω
VR_1 1MΩ potentiometer, log, Radiospares "Moulded Track", Cat. No. VR18B (Home Radio)
VR_2 1kΩ preset potentiometer, Radiospares "Slider", Cat. No. VR101 (Home Radio)

Capacitors
C_1 0·003μF
C_2 0·1μF
C_3 250μF electrolytic, 2·5V wkg.
C_4 250μF electrolytic, 2·5V wkg.
C_5 640μF electrolytic, 10V wkg.
VC_1 500pF variable, solid dielectric, Ivory Electric, Cat. No. VC79A (Home Radio)
VC_2 60pF trimmer, mica

Inductors
L_1 See text
L_2 See text
L_3 2·5mH r.f. choke, Type CH1 (Repanco)
T_1 Output transformer, Type LT700 (Eagle)

Semiconductors
TR_1, TR_2 2N4058
TR_3 2N2926 green spot
D_1 OA73

Switch
S_1 3-pole 3-way rotary (see text)

Battery
B_1 9-volt battery Type PP6 (Ever Ready)

Speaker
3Ω, 5in by 3in, Elac.

Miscellaneous
Tagboard, Radiospares 18-way "Standard", Cat. No. BTS10 (Home Radio)
Ferrite rod, 5in × ⅜in dia., (G. W. Smith & Co., 3 Lisle St., London, W.C.2.)
Knobs, as required
Battery connectors
Hardboard, plywood, Paxolin, etc.

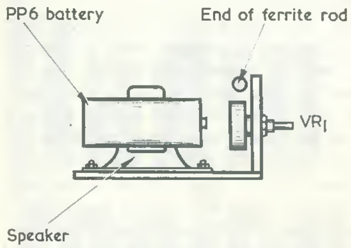


Fig. 3. Side view, from the battery end of the receiver, illustrating how the board on which the loudspeaker is fitted and the control panel assemble together

As readers who have studied the earlier versions may remember, TR_1 acts as a common emitter r.f. amplifier followed by TR_2 as a common collector amplifier. Demodulation is carried out by D_1 and the coupling is such that any a.f. which may be fed back from TR_2 emitter is out of phase with that developed at TR_1 base, with complete a.f. stability resulting. All three transistors give a.f. amplification by the common emitter mode.

SETTING UP

To set up for medium waves it is necessary to adjust VC_2. If this provides too much capacitance, it will prove impossible to receive, say, Radio 3 on 194 metres, and selectivity will be poor. If VC_2 provides too little capacitance it will prove impossible to obtain oscillation at the low frequency end of the band. On long waves, variations in the characteristics of TR_1 and TR_2 are looked after by VR_2. A position should be found for the slider of VR_2 which gives smooth control of reaction throughout the band by means of panel control VR_1. If VR_2 inserts too much resistance in circuit oscillation may prove impossible over all of the band. At the same time, if too little resistance is in circuit the high frequency end of the band will be cut off, Radio 2 coming in near the minimum capacitance position of VC_1, or even being lost altogether, and oscillation will tend to start with VR_1 advanced only a short distance from minimum.

TR_1 and TR_2 are identical transistors which are especially designed to give a high amplification (100–400) at only 100μA collector current. They are p.n.p. devices. TR_3 is a high amplification (235–470) n.p.n. transistor.

The current consumption of the complete receiver from its 9 volt battery is between 8 and 12mA, depending on the state of the battery and the setting of VR_1.

LAYOUT

The layout shown in Fig. 2 has proved satisfactory and it allows the use of a 5in by 3in speaker, which will give better quality and volume than a smaller one in what still remains a very small receiver.

A panel of hardboard or Paxolin, about $\frac{1}{8}$in thick and measuring $5\frac{1}{2}$ by $3\frac{3}{4}$in, is cut out. A suitable aperture for the speaker is next made in this panel, and the speaker mounted by means of countersunk bolts and nuts. An 18-way standard size Radiospares tagboard is next cut so that 10 pairs of tags remain. A circular hole is cut in this to fit over the speaker magnet as shown in Fig. 2, and the board is held in position by being secured with adhesive to the magnet. This provides a firm and practicable method of mounting and it may be of help if a turn or two of insulating tape or Sellotape is initially wound on to the magnet to ensure a tight fit. Readers who would prefer to employ some form

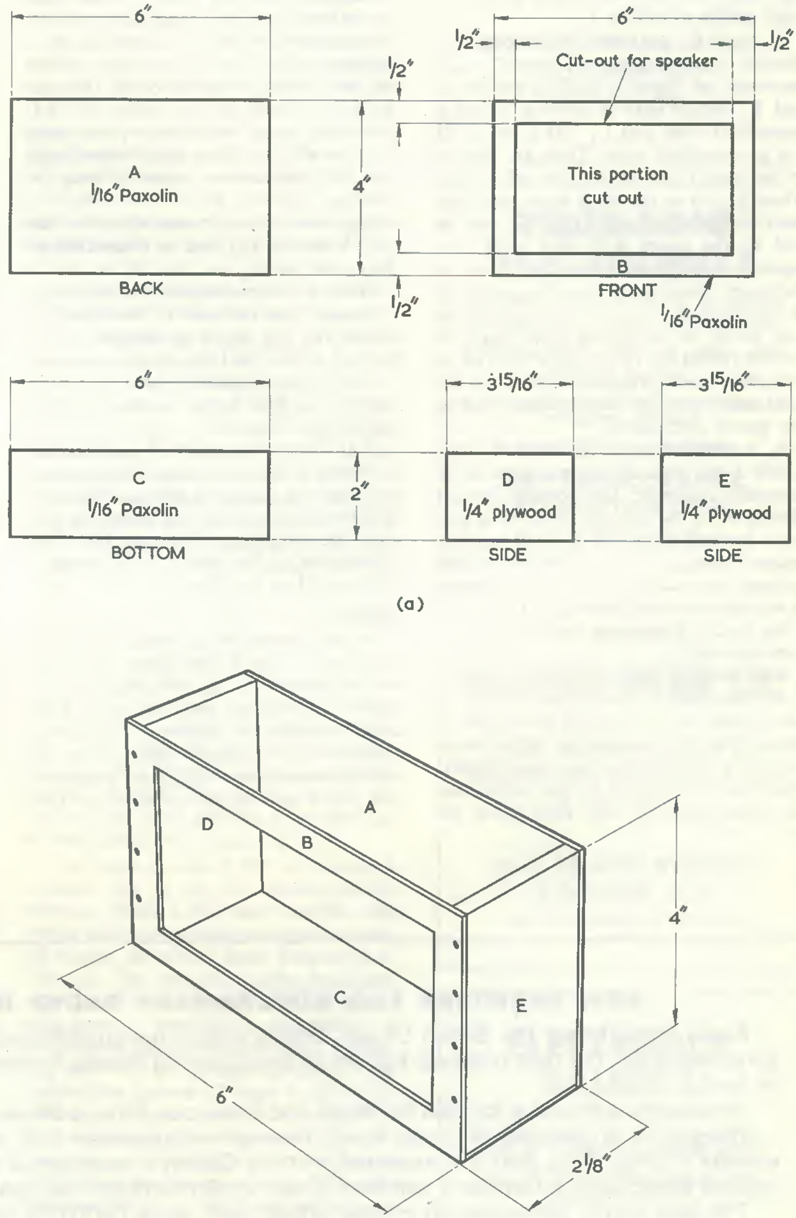


Fig. 4 (a). The five parts used for making the cabinet (b). The cabinet completed. The assembly of Figs. 2 and 3 is dropped in from the top, with expanded metal inserted between the speaker board and the cut-out in the front of mounting bracket for the board may, of course, do so. It is convenient to mount the components on the board, and to apply "Contact" or similar material to its back, before fitting this in position. Note the connections, in Fig. 2, from T_1 to the speaker. T_1 may be secured to the board with adhesive.

The control panel is made of ¼in plywood and is cut to the dimensions shown in Fig. 2, the three controls being mounted as illustrated. The edge of the panel secures to the shaded section of the 3¾in by 5½in board, so that the two are at right angles as in Fig. 3.

L_1 and L_2 are both closewound on sleeves made from "Contact" and mounted on opposite ends of the ferrite rod. L_1 should have 60 turns of 32 s.w.g. enamelled wire and L_2 150 turns of 38 s.w.g. enamelled wire. They are wound in the same direction on the rod so that, when $S_{1(a)}$ is in the long wave position, their inductances add. The rod can be tied to the panel with thin cord, this passing through suitable small holes in the panel. There is no room for grommets at the ends of the rod; alternatively, a few turns of insulating tape may be wound round the two ends of the rod to provide a good gripping surface for the cord and to prevent the windings fouling the panel underside.

S_1 is specified as a 3-pole switch, since 2-pole 3-way switches do not seem to be generally available. The volume control should be of the moulded type or it will soon become noisy, as a small current passes through it. It is wired such that volume increases as its knob is turned in an anticlockwise direction. This, with a log track, gives very smooth control over reaction.

Both sets of plates in VC_1 are alive to r.f. currents, so that it is wise to cover the outside of the control panel with a piece of aluminium foil or thin metal sheet to avoid hand capacitance effects. Holes must be drilled in this screen for the three controls and care must be taken to see that the screen does not touch the bush or holding nut of VC_1. Connection from the screen to the positive supply line is taken by way of a 6BA bolt and nut as shown in Fig. 2. R_1 should have its leads covered with insulated sleeving, and insulated connecting wire should be used throughout.

The red and green leads of T_1 should be connected temporarily only during construction. When the receiver is later checked out it may be found that a.f. stability is better with these leads connected one way round rather than the other. If present, the effect will be most noticeable as oscillation point is approached at the high frequency end of the medium wave band. In the unlikely event of instability at a.f. persisting, it can be stopped by removing C_4. This will introduce negative feedback and will, of course, cause a drop in volume.

Capacitor C_5 is mounted *under* the board (below T_1) and is connected as illustrated in Fig. 2.

When wiring is complete the insulating "Contact" on the rear of the board is added and the board is secured to the magnet, whilst the large panel is screwed to the control panel. There is ample room for a PP6 battery at the position indicated in Fig. 2.

If an alternative make of loudspeaker is employed the constructor should make sure that the magnet is not so large as to foul terminals on the tag board. It will also be necessary to modify the dimensions of the cabinet if the speaker is deeper than the Elac.

CABINET

The prototype uses a simple case made as shown in Fig. 4. The front, back and bottom are all of thin paxolin, and are screwed to the two plywood sides with small countersunk screws. The case is covered with "Contact" and a piece of expanded metal speaker gauze is slipped into place in front of the speaker. The control panel will form the top of the case, and the thin metal screen will need covering with a piece of suitable material on which wavelengths, etc., may be marked. Small knobs, in keeping with the size of the receiver, should be used.

As to results, sensitivity will be found to be unusually high for a small, simple design. On the long wave band sensitivity is quite exceptional, and at the author's home in S. Devon, four alternative programmes are available on this band at excellent strength, during daylight hours as well as after dark. These include Radio 2 and three Continental stations. Selectivity is quite reasonable though not so good as with, say, the "Spontaflex" S.A.4[2], and a powerful local station can cause trouble if it is in line with, and close in wavelength to, the signal it is wished to receive. But in many cases the directional properties of the ferrite aerial can be used to overcome any difficulty. As already stated, the design is particularly intended for bad reception districts, but if selectivity proves a problem in more favourable areas it can be improved by using two separate ferrite rods for L_1 and L_2, each say about 1½in long. There will then, of course, be some loss of sensitivity and it may be necessary to increase the number of turns on L_1 and L_2 to obtain proper waveband coverage.

EDITOR'S NOTE

Since the original "Simplicity and Sensitivity" circuits were published in *The Radio Constructor,* basically similar receiver circuits have appeared from other sources. Our contributor wishes to point out that this present receiver is developed from no other source than his own original published designs. It is not derived from any other circuit.

[2]Sir Douglas Hall, "The 'Spontaflex' S.A.4. Transistor Portable," *The Radio Constructor*, May, 1968.

NEW PREMISES FOR GOVERNMENT RADIO IN HONG KONG

Radio Hong Kong, the British Crown Colony's government radio station, will have its own building early next year. The new building, known as Broadcasting House, is expected to be ready for occupation in April.

Broadcasting House is located in "Radio and Television City," a 50-acre site in north Kowloon.

The television centres of Hong Kong Television Broadcasts Ltd. and Rediffusion (H.K.) Ltd. are already located there, and it is expected that the Colony's commercial radio station, Hong Kong Commercial Broadcasting Company will have a new studio centre in the area by autumn next year.

The four-storey Broadcasting House, which cost some £400,000 to build and equip, will have 16 studios and recording rooms, and these, together with main engineering control rooms, maintenance workshops, record and tape libraries, offices and staff canteen, will occupy a floor area of 52,000 square feet.

Equipment will be installed at Broadcasting House commencing this month and installation is expected to be completed by next March.

Radio Topics

By Recorder

THE TROUBLE WITH BEING electronically minded is that one is liable to get quite finicky about shortcomings in radio and TV performance which other people take for granted. I definitely suffer from this finicality (yes, it *is* in the dictionary) myself and, for example, go through periods of intense agony when one of those little square wave generators which the general public refer to as "transistors" is suddenly turned on at full blast in some previously peaceful country retreat.

My finicalness (so's *that* one, too!) was recently strained to the limit; not by an over-run transistor portable, but by a solidly built mains-driven valve radio belonging to a friend I visited some time ago. This set played quietly in the background all the time that I was there, and the quality of the music it reproduced was quite pleasant. But, and it is a big but, the music was accompanied by what to my ears was the father and mother of all mains hums. This hum rumbled away ponderously and at a fantastically high level, yet nobody in the family seemed to even notice it. Not being one to actually solicit work I refrained from remarking on the hum, but I was jolly glad to get out in the street and give the 100 c/s section of the Recorder ear mechanism a chance to settle down to rest again.

PROBLEMS WITH HUM

After this experience I turned a critical ear to all the other domestic radios I encountered in my normal travels. Most families retain a mains-operated valve receiver and I found that nearly a third of those I checked had hum levels which ranged from being just audible in the absence of programme to being strong enough, in my estimation, to be really objectionable. In consequence, it occurred to me that I could profitably devote some space this month to the problem of hum in these receivers and how to clear it. There are plenty of valve radios knocking around with years of life still left in them, and there's no reason why they shouldn't be brought into good working order.

I'll deal mainly with commercially-made receivers in which the hum level has increased over the years, whereupon the attack on the hum is really a straightforward servicing project whose purpose is to bring the receiver back to the state which it left the factory.

At the outset, however, it must be stated that many mains-driven radio receivers have been manufactured which produced quite a noticeable level of hum even when new. Knowledge of what a particular make and model can offer in this respect can only be acquired by experience but, in general, the hum level in any set of reasonably good design should be such that, at worst and so far as the ear can judge, it is not significantly louder than general "background noise" in the absence of signal.

I mentioned the frequency of 100 c/s just now when referring to the hum I encountered in my friend's radio. This is because the sound we usually refer to as "mains hum" frequently has a high 100 c/s content. Both the human ear and the smaller type of speaker fitted to domestic radio receivers have a reduced response at 50 c/s, and it is possible for a surprisingly high level of pure 50 c/s hum to be present at the receiver output without it being subjectively annoying. It is possible, for instance, to touch the cone of a speaker fed by a sine wave 50 c/s tone and actually *feel* it vibrating, and yet find that the apparent 50 c/s sound level is hardly perceptible. Much depends here, incidentally, on the usefulness, as a baffle, of the receiver cabinet in which the speaker is housed. With normal cabinet dimensions, a 50 c/s tone will be more audible if the speaker is more effectively "boxed-in".

The main source of 100 c/s hum in a receiver lies in the h.t. power supply circuits. With a full-wave rectifier the ripple across the reservoir capacitor has, of course, an actual basic frequency of 100 c/s. The nominal ripple frequency with a half-wave rectifier is 50 c/s, but its non-linear waveform supports a flourishing family of harmonics, including the 100 c/s second harmonic. An alternative source of hum is given by unwanted coupling to the a.f. amplifier circuits from any wiring or components carrying a.c., the most likely offender here being the heater wiring. Although this coupling is at 50 c/s any subsequent non-linearity can produce harmonics and, in any case, the 50 c/s fundamental will itself become audible if it is at a sufficiently high amplitude.

When checking a receiver with a high hum level the first thing to do is to see whether this varies as the volume control is adjusted. If it does, and if the hum can be reduced to a negligibly low level with the volume control at its minimum setting, then the hum pick-up is occurring in the circuits preceding the volume control and this part of the receiver should be checked for unwanted couplings to a.c. wiring and components. If the hum does not vary with volume control adjustment—or, if it does, is still very audible at minimum volume control setting—then the fault either lies in the stages after the volume control or is common to the a.f. circuits on either side.

Assuming the second case, the general cause of the hum has to be located. When spares are available, it is a good plan at this stage to try replacement valves in the a.f. stages, and in the rectifier stage as well if this is a valve. This replacement procedure is not recommended because the valves are the most likely offenders but simply because the process of changing them can be carried out so quickly! Should the hum clear when a new a.f. valve is fitted a final check should be made to ensure that, if its control grid is supplied from a preceding anode via a blocking capacitor, that that capacitor is not leaky. A leaky anode-grid capacitor may have been the root cause of the previous valve becoming faulty. If a new rectifier valve clears the hum, check that the overall h.t. current is not excessive and that neither the reservoir nor smoothing capacitors is drawing excess current. Also, if it is a full-wave rectifier ensure that there are no open-circuits in the mains transformer h.t. secondary circuits to both its anodes.

The next step, should results not be satisfactory so far, is to check the reservoir and smoothing capacitors for loss of capacitance by temporarily connecting a capacitor of about the same value across each in turn. If either of these has low capacitance the reduction in hum will be dramatic when the additional capacitor is connected across it. A faulty capacitor located in this manner must always be taken out of circuit and a new capacitor fitted. Don't forget that there are some relatively high voltages along the h.t. line and that all appropriate precautions against shock must be taken.

UNWANTED COUPLINGS

When hum is not caused by faulty valves or low capacitance h.t. filter capacitors, it is most likely that there are unwanted couplings to a.c. wiring in the amplifier stages. It is helpful here to try and locate the stage at which the hum pick-up is occurring. If the volume control check I mentioned earlier hasn't already done this, try short-circuiting the grid leak of the output valve to see if the hum clears. If it does, then the hum is being picked up at this grid circuit or in a previous stage. Repeat the procedure at the grid of the preceding a.f. valve. If the hum remains the pick-up is occurring after that grid. These simple checks can soon pin-point the circuit position where the unwanted coupling is appearing.

Typical causes of hum in the unwanted coupling category are given by disconnections to screened lead braiding, poor chassis connections to volume control metal cases, and bad connections to chassis in the older sets when these are made via solder tags rivetted, eyeletted or bolted to the metal chassis. In some receivers one side of the heater supply is fed via the chassis itself, whereupon one may encounter a single chassis tag carrying heater current to a valve as well as providing a chassis return for a.f. circuits. A tag of this nature is particularly suspect because it only needs to develop a small resistance to chassis for the heater current to produce a really sizeable 50 c/s voltage across that resistance. A little digging with a screwdriver so that part of the blade is on the chassis and the other part on the tag will soon locate any miscreants here.

Should you suspect, but are not entirely certain, that hum is being picked up from the heater circuit, a useful dodge is to fix up the set so that the heater circuit can be temporarily open-circuited, at its non-earthy end, either at the mains transformer or at the heater dropper as applicable. After this switch on the set and let it get well warmed up, then break the heater circuit. The valves will continue to run for a while before their cathodes cool. If the hum clears when the heater circuit is opened, then this is obviously producing the hum.

In these notes I haven't mentioned *all* possible causes of hum, but I have referred to those most likely to be found in equipment which was previously satisfactory in this respect. The hints I've given apply, by the way, to valve a.f. amplifiers and oscilloscope Y amplifiers as well. And please let me emphasise that all precautions against shock *must* be observed, particularly if the receiver or other equipment being dealt with has a live chassis connected to one side of the mains.

Happy hum hunting!

BRAKE LIGHT WARNING

If you have the issue for April, 1968 to hand, you may be interested in re-reading the article "Brake Light Warning Device" by T. R. Balbirnie, B.Sc., which appeared at that time. The warning device employed a relay in the circuit given in Fig. 1. When the car stop light switch is closed, current flows in opposing directions through the two halves of the relay coil with the result that, if both stop lights are serviceable, the relay does not energise. If, however, one of the stop lights has burnt out, current flows through one half of the relay coil and it operates. Its contacts then cause the panel light to be illuminated, warning the driver that he is running with only one stop light in

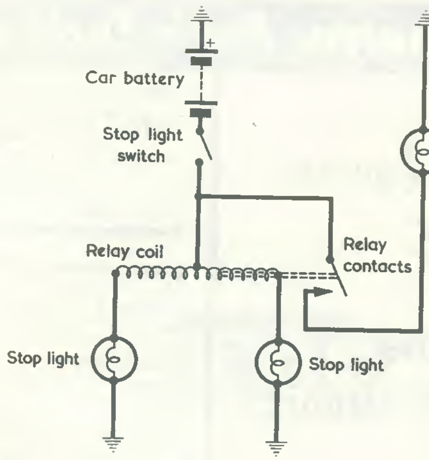


Fig. 1. Circuit of the brake light warning device which was described in the April 1968 issue

operation.

The circuit of Fig. 1 is not, of course, intended to give a warning should both lamps fail, and Mr. N. J. Tubb, of Crawley, Sussex, has sent us a useful design which covers this point, albeit at the cost of an extra relay. Mr. Tubb's circuit appears in Fig. 2 and it works in the following manner. When the brake pedal is depressed current flows to both relays which, being in series with the stop lights, will only energise if the lamps function. If either or both relays do not operate, current is passed via the appropriate normally-closed relay contacts to the panel light, which then becomes illuminated to indicate a failure. The circuit of Fig. 2 has the further advantage that it will reveal any failure in the stop switch or panel light itself by virtue of the fact that the panel light will normally flash when depressing the brake pedal, thus showing the circuit is in order.

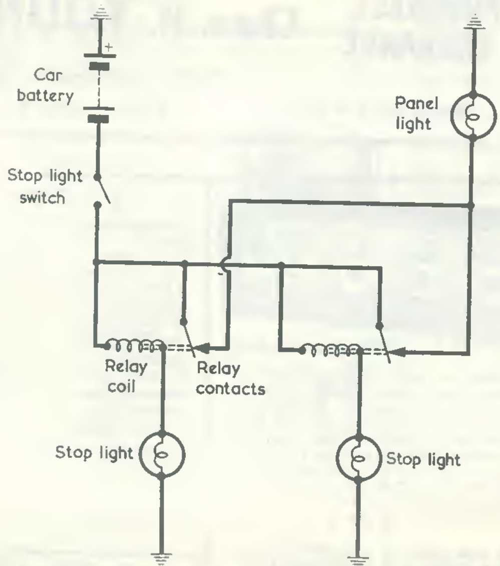


Fig. 2. An alternative circuit which indicates failure of one or both lights, as well as giving automatic checking of the device itself

As with the relay in the original article, the two relays in Fig. 2 need to have their coils rewound. Some 40 to 50 turns of 22 s.w.g. wire should be satisfactory for most standard relays.

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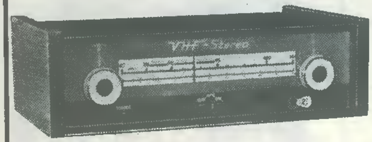

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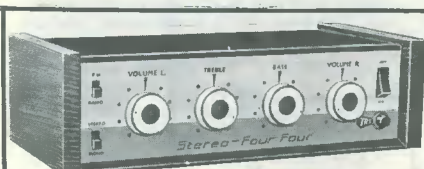

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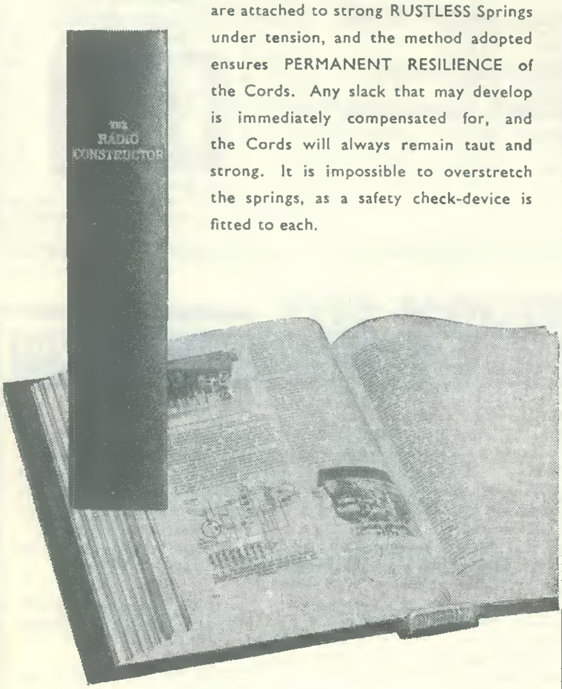

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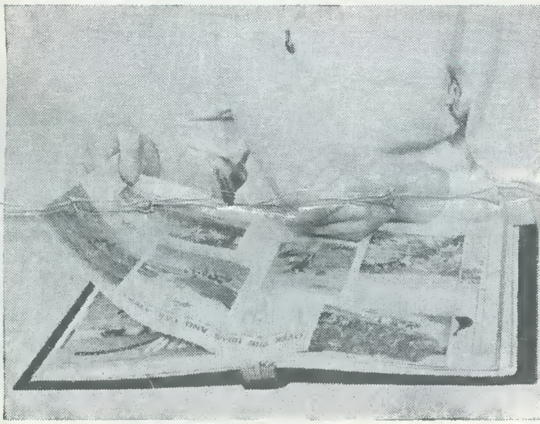

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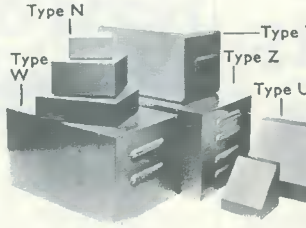

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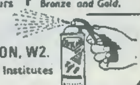

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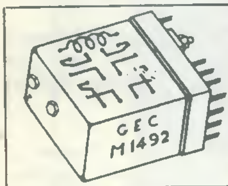

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