

THE

RADIO CONSTRUCTOR

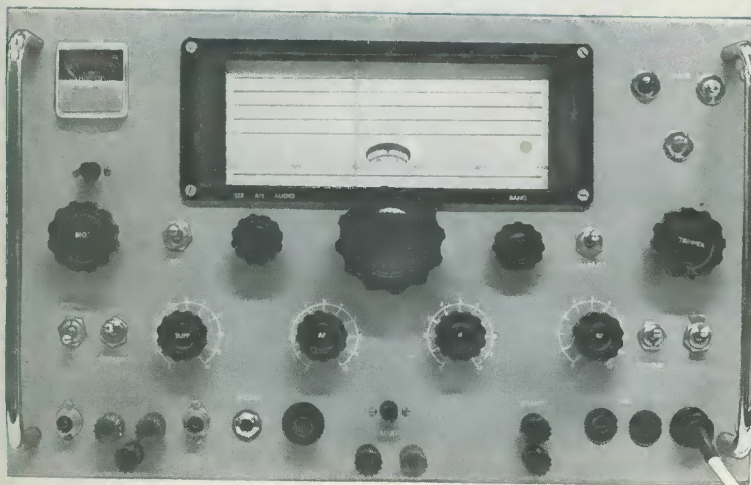
Vol. 21 No. 12

JULY 1968

3/-

A DATA PUBLICATION

RADIO · TELEVISION · ELECTRONICS · AUDIO



**High
Performance,
Double
Conversion
Communications
Receiver—
Part—1**

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Voltmeter**

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Stethoscope**

**Sensitive
Crystal Set**

Plus Vol.21 Index and Data Sheet

Scottish Insurance Corporation Ltd

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A "Scottish" special policy for Television Sets, Receivers and Short Wave Transmitters provides the following cover:

- (a) Loss or damage to installation (including in the case of Television Sets the Cathode Ray Tube) by Fire, Explosion, Lightning, Theft or Accidental External Means at any private dwelling-house.
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IM-17 Kit £12.10.0 pp 4/6



Solid state circuitry FET input. 4 Silicon transistor, 1 diode. 4 A.C. voltage ranges. 4 d.c. voltage ranges. 4 ohm ranges. 11M ohm input d.c. 1M ohm input on a.c. 4½ in. 200µA meter. Battery powered. Rugged Polypropylene case, self cover and handle. Space for storage of test leads. Easy circuit board construction.

Just right for the householder, hobbyist, boaters, model builders. Amateur radio den, sophisticated enough for the radio and TV service engineer. Does hundreds of everyday measurements at low cost. Battery powered so will work anywhere.

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Kit £28.6.0 incl. P.T. p.p. 10/6

Ready-to-Use £35.4.0 incl. P.T. p.p. 10/6



Automatic playing of 16, 33, 45 and 78 rpm records. All transistor—cool instant operation. Dual LP/78 stylus. Plays mono or stereo records. Suitcase portability. Detachable speaker enclosure for best stereo effect. Two 8in x 5in. special loudspeakers. For 220-250V a.c. mains operation. Overall cabinet size 15½ x 3½ x 10½in.

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Kit £23.18.0 Ready-to-Use £31.18.0 p.p. 9/-

5" GEN-PURPOSE OSCILLOSCOPE. Model 10-12U. An outstanding model with professional specification and styling. "Y" bandwidth 3Hz-4.5 MHz +3dB. T/B 10 Hz-500 kHz.

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MULTIMETER. Model MM-1U. Ranges 0-1.5V to 1,500V a.c. and d.c.; 150µA to 15A d.c.; 0.2Ω to 20MΩ. 4½" 50µA meter.

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R.F. SIGNAL GENERATOR Model RF-1U. Up to 100 MHz fundamental and 200 MHz on harmonics. Up to 100mV output. Kit £13.18.0 Rdy-to-Use £20.8.0 p.p. 6/-

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OS-2



IM-13U



V-7A



RF-1U

Complete your motoring pleasure with this outstanding CAR RADIO, Model CR-1

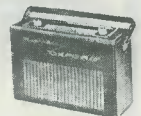


Will give you superb LW and MW entertainment wherever you drive. Tastefully styled to harmonise with any car colour scheme. Available for your convenience in two separate parts, RF Amp. Kit £1.15.0 incl. P.T. IF/AF Amp. Kit £11.3.6.

Total Price Kit (excl. Loudspeaker) £12.18.6 incl. P.T.
p.p. 9/6. 8" x 5" Loudspeaker £1.16.1 incl. P.T.

TRANSISTOR RADIOS

OXFORD LUXURY PORTABLE. Model UXR-2. Specially designed for use as a domestic or personal portable receiver. Covers L. and M. Wave bands. 7 transistor, 3 diode, circuit. 7" x 4" loudspeaker for big set sound. Heathkit now offer choice of Brown or Black real leather case. Excellent value at only £15.10.0 Kit inc. P.T. p.p. 6/-



UXR-2

TRANSISTOR PORTABLE, Model UXR-1. Now available in modern colours or real leather case. 6 Transistor, 1 diode circuit for reliability. Pre-aligned I.F. transformers. Covers L.W. and M. Wave bands. 7" x 4" loudspeaker for generous sound. Case available in colours Navy Blue, Coral Pink, Lime Green or Brown Real Leather. Please state second choice. Kit £12.8.0 Colour incl. P.T. p.p. 4/6.



UXR-1

Kit £13.8.0 Real leather incl. P.T. p.p. 4/6.

STEREO TRANSISTOR FM TUNER

(Mono version also available)

14 transistor, 5 diode circuit. Tuning range 88-108 MHz. Designed to match the AA-22U Amplifier. Available in separate units, can be built for a total price.



TFM-IS Kit (Stereo) £25.2.6 incl. P.T. p.p. 6/-

TFM-IM Kit (Mono) £21.3.6 incl. P.T. p.p. 6/-

Cabinet extra £2.5.0.

FM Tuner

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12 × 12 watts output.

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Cabinet £2.5.0 extra

Ready-to-Use £38.0.0 incl. cabinet p.p. 10/6



FOR THIS SPECIFICATION

- 17 transistors, 6 diode circuit • $\pm 1dB$, 16 to 50,000 Hz at 12 watts per channel into 8 ohms • Output suitable for 8 or 15 ohm loudspeakers • 3 stereo inputs for Gram, Radio and Aux. • Modern low silhouette styling • Attractive aluminium, golden anodised front panel • Handsome assembled and finished walnut veneered cabinet available • Matches Heathkit models TFM-1 and AFM-2 transistor tuners.

Full range power . . . over extremely wide frequency range. Special transformerless output circuitry. Adequately heat-sinked power transistors for cool operation—long life. 6 position source switch.

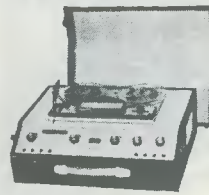
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LATEST! STEREO TAPE RECORDER, STR-1

Fully portable—own speakers

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FOR THIS SPECIFICATION

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Versatile recording facilities. So easy to build—so easy to use.

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WORLD LEADER IN QUALITY KITSETS

The instruction manual shows you how to build the model.



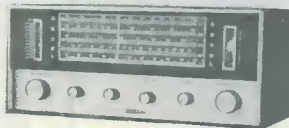
SHORTWAVE 4 BAND RECEIVER, GR-64 E

Offers you the exciting world of Shortwave

Covers 550 kHz to 30 MHz incl. broadcast plus 3 SW bands. 4 valve superhet circuit plus 2 silicon rectifiers. Own 5" speaker. Illuminated 7" slide-rule dial with logging scale. Signal strength indicator.

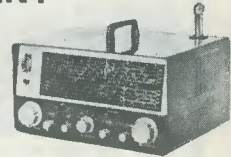
Variable BFO control. Built in AM rod antenna. Circuit Board construction. Headphone jack. Attractive charcoal grey cabinet with black dial panel with green/white markings. Assemble in a few hours. Hear live broadcasts from around the Globe.

Kit £22.9.0 pp 9/- Ready to use £29.9.0 pp 9/-



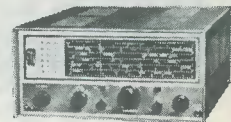
"AMATEUR" EQUIPMENT

THE "MOHICAN" GENERAL COVERAGE RECEIVER. Model GC-1U. With 4 piezo-electric transmitters, variable tuned B.F.O. and Zener diode stabiliser, this is an excellent fully transistorised general purpose receiver for Amateur and Short wave listeners. Printed circuits, telescopic aerial, tuning meter and large slide-rule dial. Kit £37.17.6 Ready-to-Use £45.17.6 p.p. 10/6



GC-1U

AMATEUR BANDS RECEIVER. Model RA-1. To cover all the Amateur Bands from 160-10 metres. Many special features, including: half-lattice crystal filter; 8 valves; signal strength "S" meter; tuned R.F. Amp. stage. Kit £39.6.6 Ready-to-Use £52.10.0 p.p. 9/-



RG-1

160-10M TRANSMITTER. Model DX-100U. Careful design has achieved high performance and stability. Completely self-contained. Kit £81.10.0 Ready-to-Use £106.15.0 p.p. 10/6

COMMUNICATIONS TYPE RECEIVER. Model RG-1. A high performance, low cost receiver for the discriminating listener. Frequency coverage: 600 kHz 1.5 MHz and 1.7 MHz-32 MHz. Kit £39.16.0 Ready-to-Use £53.0.0

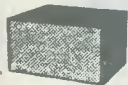


SSU-1

SPEAKER SYSTEMS

HI-FI SPEAKER SYSTEM, Model SSU-1

Ducted-port bass reflex cabinet in the white: Two speakers, vertical or horizontal models with legs, KIT £12.14.6, p.p. 7/6 without legs, KIT £12.0.0 incl. P.T. p.p. 7/6



AVON MINI SPEAKER SYSTEM

6 $\frac{1}{2}$ " Bass, 3 $\frac{1}{2}$ " Treble speakers and crossover unit. Kit £5.2.0 incl. P.T. Beautiful Walnut veneered fully-finished cabinet, £8.18.0, Total price Kit £14.0.0 incl. P.T. p.p. 10/6



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4 OA10 Diodes Mullard	10/-	

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UNIUNION

UT46, Eqvt. 2N2646.
Eqvt. T1S43. BEN3000

7/6 EACH

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50	2/-	3/-	4/6 9/6
100	2/3	3/6	6/- 15/-
200	2/6	4/6	6/6 20/-
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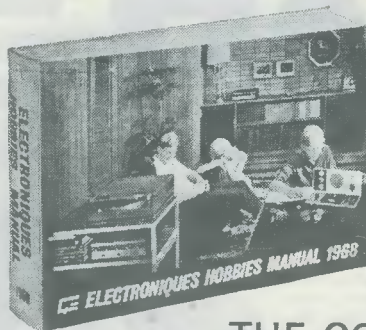
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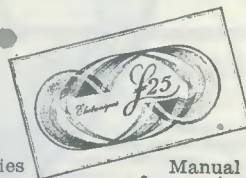
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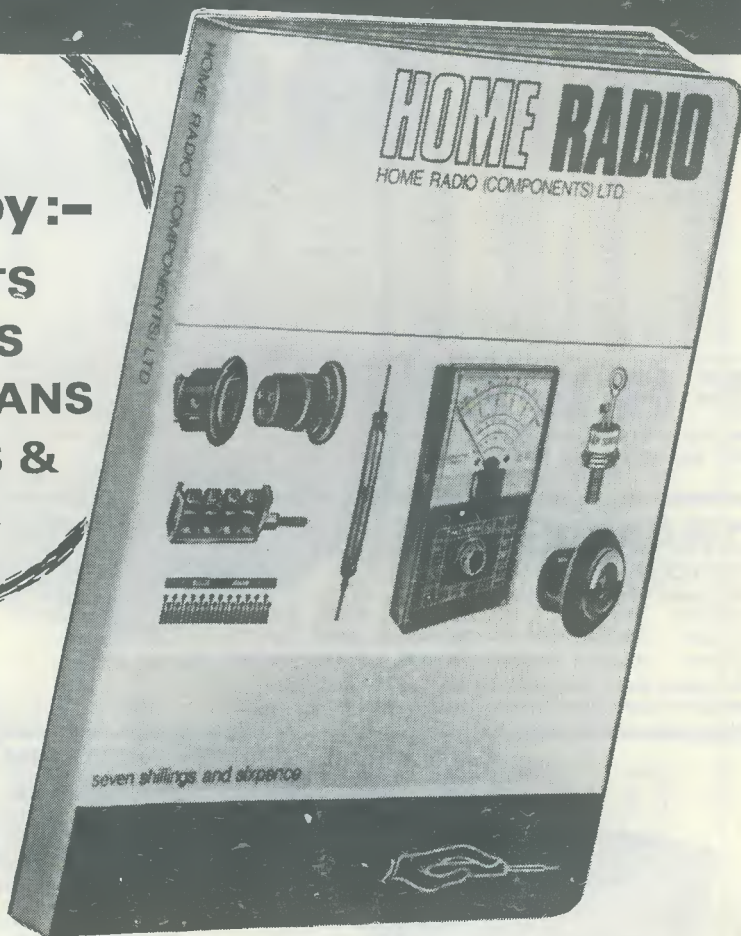
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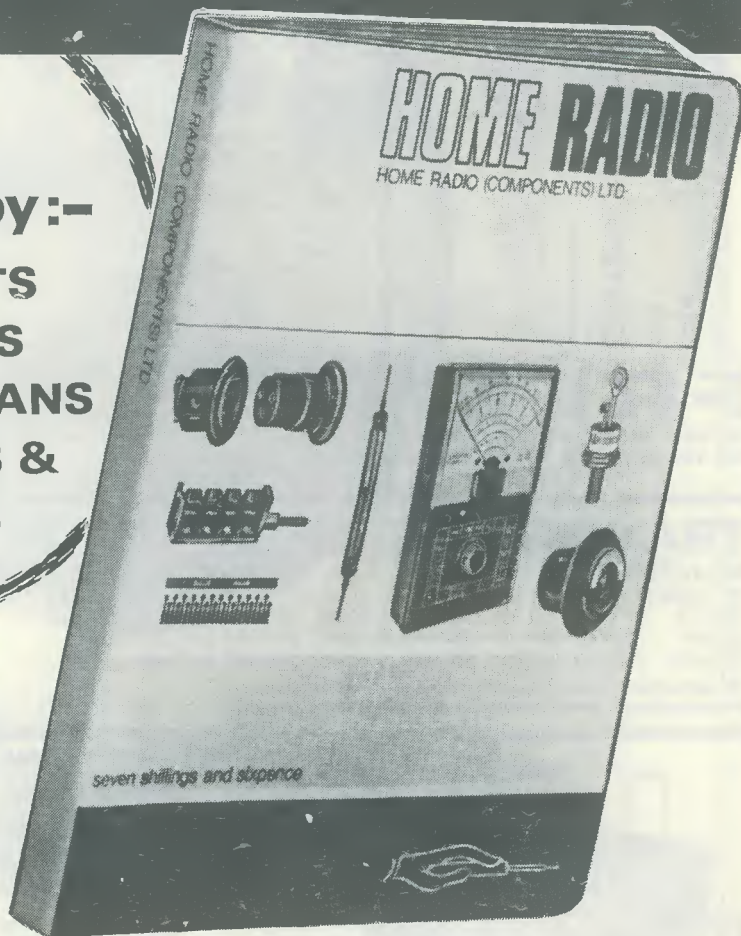
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ONE OF THE FIRST "TRICKS OF THE TRADE" THAT IS taught to an engineering apprentice is the use of an ordinary screwdriver as a "stethoscope" for detecting worn bearings, etc., in car engines and other pieces of machinery. When the engine is running, all kinds of noise and vibrations are developed within the engine by the action of the moving parts, and these noises are transmitted to the engine casing. If the blade of a screwdriver is placed against the casing and the ear is then pressed against its handle, these sounds are channelled through the screwdriver by the rigid structure of the metal blade and handle and reach the ear at a considerable high level.

Any sound is, of course, loudest at its point of origin so that, by merely moving the screwdriver blade over the engine casing until a particular sound is heard at maximum level it is possible to locate the exact position of the noise source, and thus identify the component that is causing it. In this way it is possible to positively diagnose such things as a worn crankshaft bearing or timing chain, without loosening a single nut on the engine. Clearly, this technique is of considerable value not only to the engineer, but to the car and motor-cycle enthusiast as well.

In spite of the delightful simplicity and effectiveness of this basic engineering "stethoscope", it suffers from one major short-coming. Many engines are surrounded by associated components that are either moving or very hot, and when the screwdriver "stethoscope" is used the operators head may have to be positioned very close to these items. A car engine, for example, is surrounded by a hot exhaust manifold, a fast moving fan, and by a whirling fan belt. The consequent risk of a dangerous accident may be readily imagined.

Fortunately, this difficulty can be overcome with the aid of electronics. A small transducer is held against the screwdriver handle, instead of pressing the handle to the ear, and the resulting electrical signal is fed to a transistor amplifier. The output of the amplifier can then be fed to a head-set worn by the operator, who can thus listen to the engine sounds in complete comfort and without the slightest danger. The unit that forms the basis of the present article employs this principle, and has the added advantage that, because of the increased sensitivity it provides, it is suitable for fault-finding in small electric motors or clockwork movements as well.

THE CIRCUIT

The full circuit diagram of the unit is shown in Fig. 1, and, as can be seen, only three transistors are used. An ordinary crystal earpiece is used as the pick-up

Resistors

(All fixed values ½ watt, 10%)

R ₁	220kΩ
R ₂	270kΩ
R ₃	82kΩ
R ₄	6.8kΩ
R ₅	1.2kΩ
R ₆	5.6kΩ
R ₇	1kΩ
R ₈	4.7kΩ
RV ₁	5kΩ potentiometer, log, with switch S ₁

Capacitors

(All sub-miniature electrolytic)

C ₁	1μF, 15V wkg.
C ₂	16μF, 15V wkg.
C ₃	30μF, 6V wkg.
C ₄	16μF, 15V wkg.
C ₅	16μF, 15V wkg.
C ₆	50μF, 15V wkg.

Transistors

TR ₁	2G374 or OC75
TR ₂	2G374 or OC75
TR ₃	2G374 or OC75

Switch

S ₁	s.p.s.t. (ganged with RV ₁)
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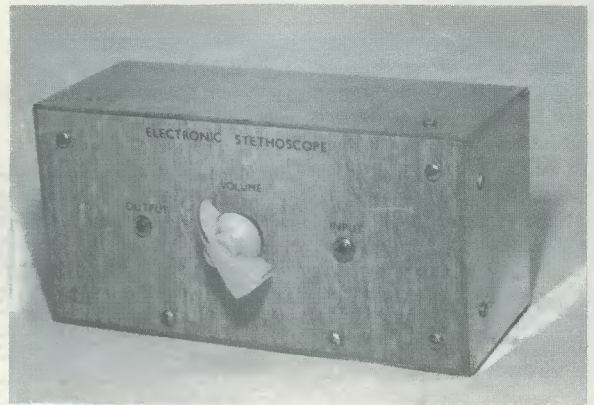
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transducer, and this is bonded to the handle of a small screwdriver. The crystal pick-up is used because it gives a far greater output signal, for a given input, than any other type, and thus requires less amplification.

The only snag of the crystal type of pick-up is that it has a high output impedance, which must be matched into an equally high impedance load if excessive loss of signal strength is not to take place, and the first stage of the amplifier is designed for this purpose.

The signal from the pick-up is fed, via C_1 , to the base of TR_1 , which is wired as an emitter follower, with RV_1 as emitter load. RV_1 is used as a volume control with RV_1 as emitter load. RV_1 is used as a volume control. The emitter follower offers unity voltage gain, but gives a high input impedance and low output impedance. To a first approximation, the input impedance is given as the emitter load, RV_1 , times the current gain of the transistor, and the resulting impedance is shunted by the base bias resistors R_1 and R_2 to give

an actual input impedance of approximately $100k\Omega$. This input impedance is a little lower than would be presented to a conventional crystal transducer and, whilst it allows good signal strength to be obtained, may result in some attenuation of the lower audio frequencies. For the present application such a response is, however, quite acceptable, particularly when it is compared with what is offered by simply placing a screwdriver handle against the ear.

The low impedance output of the TR_1 stage is taken from the slider of RV_1 and fed, via C_2 , to the base of TR_2 , which is wired as a rather sophisticated common emitter amplifier.

One of the snags of the conventional common emitter amplifier is that if the output from the collector is fed into a following impedance, such as the input of another amplifier stage or, say, a headphone, the following impedance is effectively in parallel with the collector load, and thus reduces its effective value and

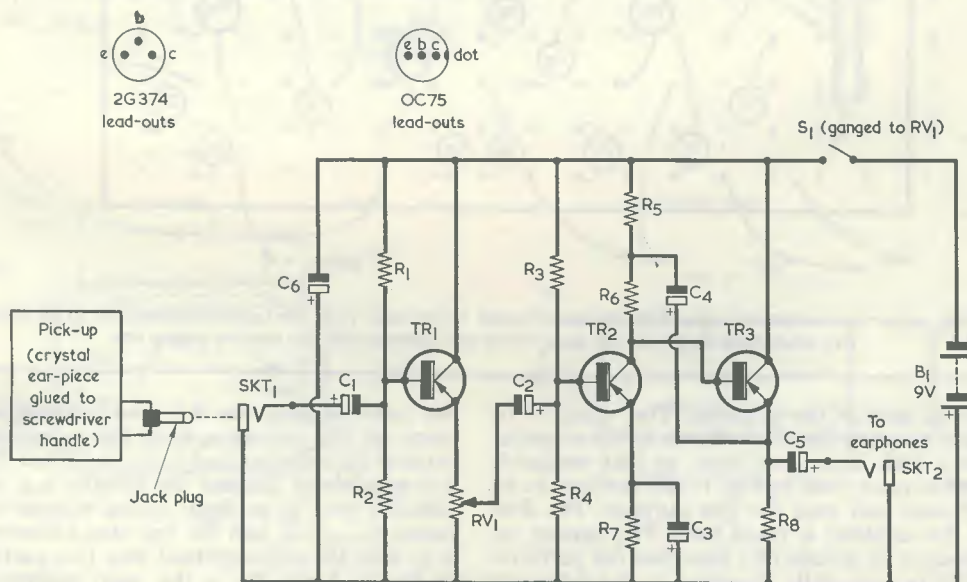
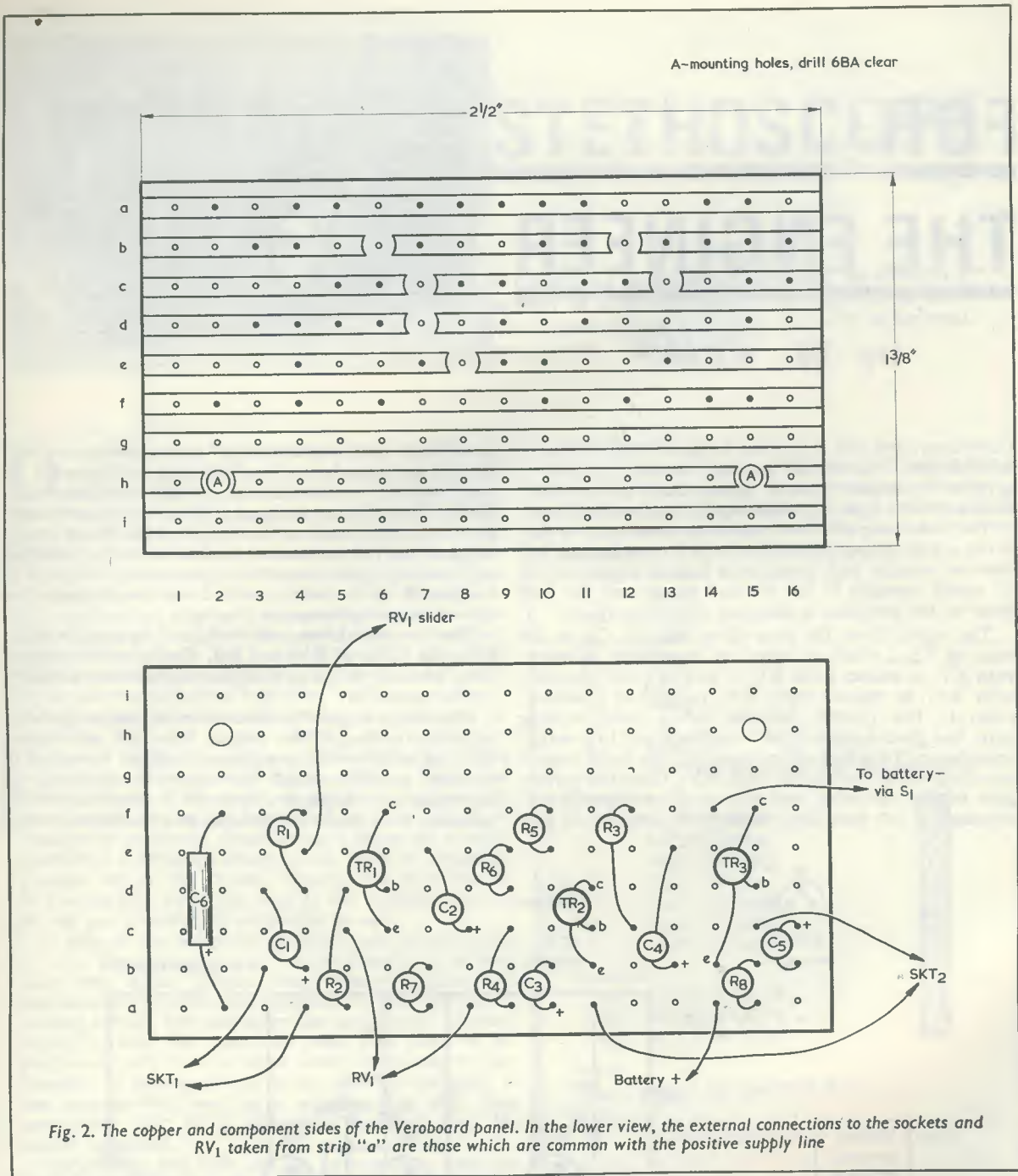


Fig. 1. The circuit diagram of the electronic stethoscope. In practice, the pick-up unit connects to the jack plug via a length of flexible wire



so reduces the gain of the amplifier. This snag can be overcome by ensuring that the collector of the amplifier is fed into a high impedance load, so that negligible shunting takes place, and in Fig. 1 TR₃ is wired as an emitter follower and used for this purpose. The final output of the amplifier is taken from TR₃ emitter via C₅. The manner in which TR₃ improves the performance of TR₂ is more fully described in the following paragraph.

It is well known that the larger the collector load of a transistor amplifier the greater will be the gain,

but unfortunately the d.c. and temperature requirements of the transistor limit the maximum practical value of the collector load to around 10kΩ. Fortunately, it is possible to increase the effective a.c. value of the collector load by artificial means without changing its actual d.c. value, and the first step towards doing this is to split the collector load into two parts, as shown in Fig. 1. Here, R₆ is the main collector load and R₅ is an "isolating" resistor. Now, the output at the emitter of TR₃ is of the same form and phase as the signal at TR₂ collector but is at a lower impedance,

and a part of this output signal is fed, via C_4 , to the junction of R_5 and R_6 . Consequently, when an output signal is available at TR_2 collector, similar a.c. signals appear at both ends of R_6 , the main collector load, and only a very small a.c. signal current flows in this resistor. The resistor therefore appears as a very high impedance, although its d.c. resistance actually is quite low. In practice, the effective collector load of TR_2 is of the order of $60k\Omega$, and the gain of the circuit is correspondingly high.

This technique of increasing the effective value of a resistor is known as "Bootstrapping."

The final output of the stethoscope amplifier may be taken to either an earpiece or a head-set, either of which should have an impedance of at least $1k\Omega$.

C_6 of Fig. 1 is wired across the supply lines to prevent instability when the internal resistance of the 9 volt supply battery rises with age. The unit is turned on and off by S_1 , in the negative supply line.

Two final points concerning the circuit need to be

mentioned. It may be noted that C_2 is operated with reverse polarity when RV_1 slider is at the lower end of its track. Although such a state of affairs is not normally desirable it is considered satisfactory in the present application since the reverse voltage is, at worst, only of the order of $700mV$ —a low figure when compared with the working voltage of 15 specified for C_2 . Also, the amplifier will normally be operated with RV_1 advanced from its zero setting position and the capacitor will then have correct polarity applied. No trouble was experienced with the prototype whatsoever due to the method of connection adopted for C_2 .

Finally, capacitor C_1 is shown as electrolytic although its positive plate has no obvious resistive circuit to the positive supply line. Despite the apparent lack of polarising voltage, this capacitor functions quite satisfactorily as shown.

CONSTRUCTION

As illustrated in the photographs, the circuit is wired up

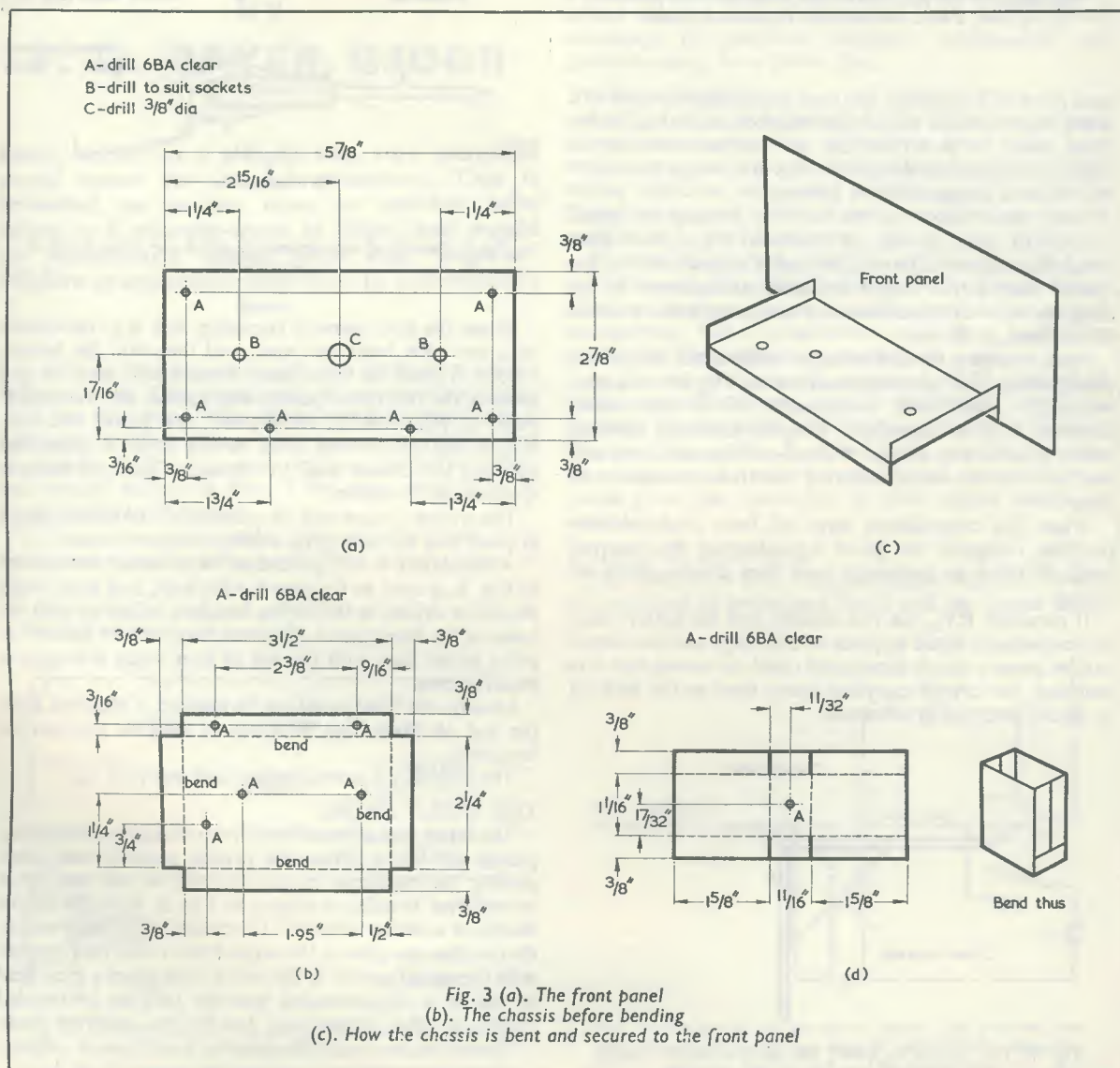
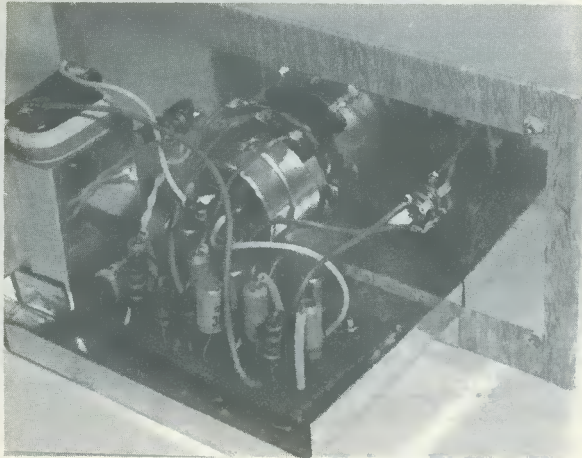


Fig. 3 (a). The front panel
 (b). The chassis before bending
 (c). How the chassis is bent and secured to the front panel



The layout of the parts inside the amplifier unit. As may be seen, a neat and compact layout is achieved

on a piece of Veroboard, the final unit being mounted in a small case with the control and sockets mounted on the front panel. If preferred, the unit can alternatively be miniaturised to fit in the pocket, but in this case the reader will have to design his own cabinet.

Start construction of the unit by cutting the small Veroboard panel to size, as shown in Fig. 2, and then break the copper strips with the aid of a small drill or the special cutting tool that is available, as indicated in the diagram. Now drill the two small mounting holes, to clear 6BA screws, as shown.

Next, assemble the components on the blank side of the panel, noting that all components except C_6 are mounted vertically. Mark each component off on the circuit diagram as it is assembled. Employ insulated sleeving where there is any danger of short-circuits occurring, and use heat shunts when soldering the three transistors in place.

When the components have all been soldered into position complete the panel by soldering the external leads in place as indicated, and then double-check all wiring.

If required, RV_1 , the two sockets and the battery may be temporarily wired in place at this stage and the circuit can be given a simple functional check to ensure that it is working, the crystal ear-piece being used as the pick-up to detect mechanical vibration.

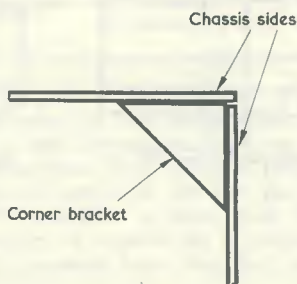


Fig. 4. The chassis in which the unit is housed should have corner strengthening brackets of the type shown here

The metalwork can now be made up and assembled. First, cut the front panel to size, as shown in Fig. 3 (a), and then drill it as indicated. A fairly heavy gauge of aluminium sheet is used here. Next, make up the small chassis, using light gauge aluminium, as shown in Fig. 3 (b), noting that the two holes near the centre of the chassis with 1.95in spacing must line up with the mounting holes in the Veroboard panel. The panel and chassis are assembled as shown in Fig. 3 (c).

Finally, complete the metal work by making up the battery holder as illustrated in Fig. 3 (d), again using a light gauge aluminium, and make sure that the battery is a good fit in it.

The front panel should now be covered with Fablon or a similar self-adhesive decorative plastic material, as shown in the illustrations. A light wood grained material was used on the prototype.

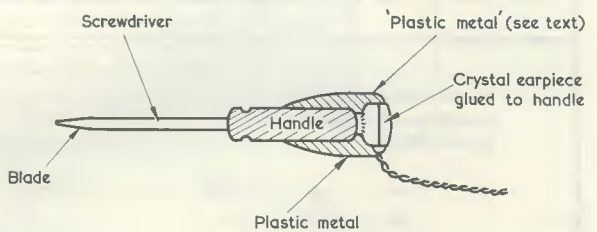


Fig. 5. Details of the manner in which the input probe is assembled

When the front panel is complete, bolt it to the chassis with two 6BA bolts and nuts, and then bolt the battery holder in place on the chassis. Mount RV_1 and the two sockets on the front panel, and secure the Veroboard panel in place on the chassis with the aid of two 6BA screws and nuts, fitting small rubber or p.v.c. grommets between the chassis and Veroboard. These act both as spacers and insulators.

The wiring up can now be completed, the battery fitted in place and the unit given another functional test.

A standard 6 x 3 x 2½in chassis, with corner brackets as in Fig. 4, is used as the case for the unit, and small holes should be drilled in the corner brackets to line up with the holes in the front panel. The unit may then be secured in place in the case with the aid of four small self-tapping metal screws.

Finally, the front panel can be marked, if required, with the aid of Panel-Sign lettering to indicate the various functions.

The amplifier is now complete and ready for use.

THE INPUT PROBE

The input probe is made up by removing the protruding plastic ear-fitting from the crystal earpiece and then gluing the resulting crystal pick-up to the end of a screwdriver handle, as shown in Fig. 5, with the aid of Bostik or a similar adhesive. Care must be taken to ensure that neither the glue or the screwdriver come into contact with the actual crystal. If the unit is to be given a great deal of use, it is recommended that the pick-up be bonded rigidly to the screwdriver handle by covering both components in so-called plastic metal or a similar hard-wearing material.

USING THE STETHOSCOPE

If the unit is to be used for fault finding on small electric motors, clockwork movements, gear boxes, or other devices that do not guarantee a great deal of noise, a single earpiece can be used for listening, but if the unit is to be employed for fault finding on car or motor-cycle engines, diesel engines, etc., it will almost certainly be

necessary to use a set of head phones that will exclude or minimise all background noise. In either case, the earpiece or phones should have an impedance of $1k\Omega$ or greater.

The current consumption of the completed amplifier is low, in the order of several milliamps, and the unit should give several hundred hours of use between battery changes.



AERIAL TUNER FOR 80 160 METRE TRANSMITTERS

by
F. G. RAYER, G3OGR

Some notes on a simple and very practical aerial tuner for 2-band operation. This is intended to couple into an end-fed wire which is a quarter-wave at 160m, and would be particularly useful with the "Jupiter" 160/80m transmitter described in last month's issue

WITH AN END-FED WIRE, THE FEED IMPEDANCE IS LOW on 160m if the aerial is about a quarter-wave long for this band. The same aerial is then near a half-wave on 80m, where it has an extremely high end impedance. As a result, series tuning is needed on 160m, and parallel tuning on 80m, if the same aerial is to be employed for both bands.

In Fig. 1 the aerial under discussion is shown as a quarter-wave for the 160m band. There is high current at

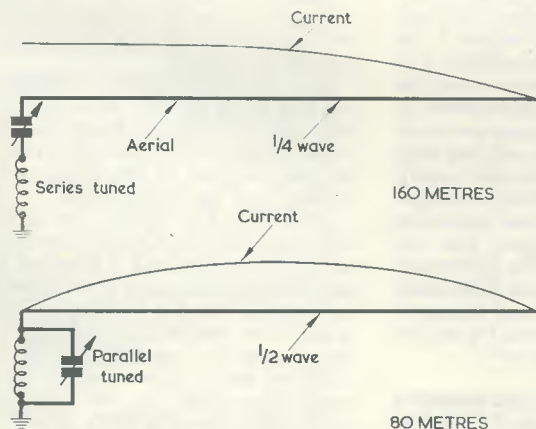


Fig. 1. An aerial which is a quarter-wave on 160 metres, and is best fed via a series tuned circuit, becomes a half-wave on 80 metres and requires a parallel tuned circuit

the feed point and the feed impedance is low. When the same aerial is used at twice this frequency, at 80m, it is a half-wave. The feed current is now very low, but the voltage high. That is, the aerial is fed at a high impedance point. Fig. 1 shows the tuning methods required in each case.

The impedances depend on the aerial (and earth) but may be under 50Ω for quarter-wave, and over $1,000\Omega$ for half-wave working. To bring these within the range of impedances which can be fed satisfactorily from the average 160/80m transmitter, the circuit illustrated in Fig. 2 has been used by the writer with every success. It allows ready tuning of the aerial (with the incidental advantage of additional harmonic suppression) and quick changing from 160 to 80m.

TUNER CIRCUIT

In Fig. 2, C_1 is in series with L_1 for 160m and can have close-spaced vanes. Also, it needs to be of quite large capacitance. An air-spaced broadcast receiver 500pF tuning capacitor was found satisfactory in practice. A 2-gang component would be ideal, one or both sections in parallel being used as required.

C_2 is in parallel with half the coil for 80m, and the voltage across this capacitor is high. A short wave tuning 250pF or similar capacitor is satisfactory for 10 to 15 watt transmitters, but the capacitor must have wide vane spacing for higher power or it will spark over.

In the author's tuner, L_1 consisted of 70 turns of 24 s.w.g. enamelled wire, wound side-by-side on a lin diameter Paxolin tube, and with a centre-tap at 35 turns for switching to 80m. L_2 was 6 turns of insulated wire, overwound on L_1 near the earthy end. A coaxial lead passes from the transmitter pi tank output circuit, as shown.

BUILDING AND USE

This circuit has been tried just clipped together, as well as assembled in permanent form, and the layout seems

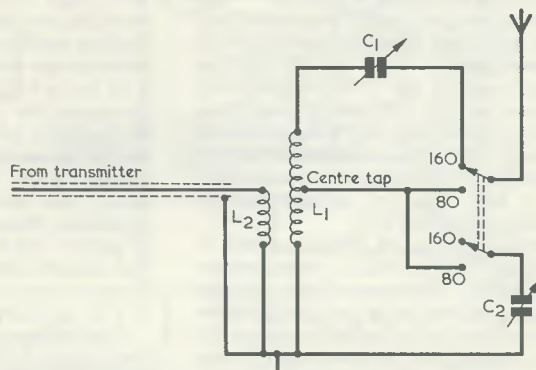


Fig. 2. The circuit of the aerial tuner. This provides the correct type of tuning, as well as independent capacitor settings, for the 160 and 80 metre bands

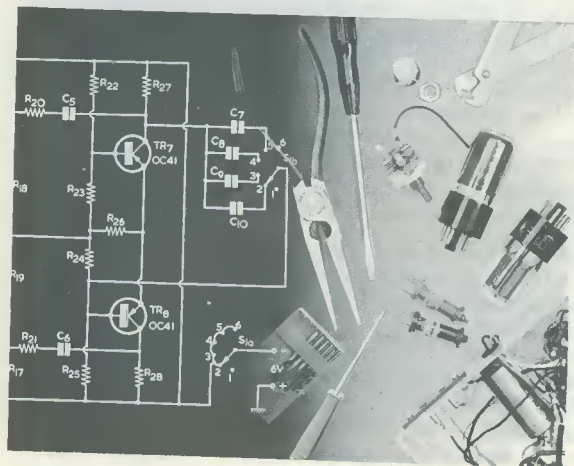
unimportant. Using a simple insulated front panel allows C_1 to be mounted clear of earth circuits. An insulated extension spindle for C_1 was not found necessary.

The aerial generally employed by the writer is 137ft in all, this including the portion forming the down-lead and coming to the tuner. It is not essential for the aerial to have this exact length, however.

If a standing wave ratio meter is available, it can be put in the coaxial lead, and the tuner adjusted for a low s.w.r. figure on each band. Having separate capacitors for 160 and 80m avoids complete retuning each time the band is changed.

If no s.w.r. meter is available, simply adjust C_1 on 160m, and C_2 on 80m, until the transmitter loads satisfactorily. This may leave standing waves on the coaxial line but, as this is only a few feet long any losses cannot normally be detected with a field-strength meter or similar means.

With some transmitter circuits it may be worth adjusting the position of L_2 , or changing the number of turns here. Should parallel tuning of large power be wanted on 80m, L_1 should be scaled up in diameter and gauge to match the transmitter p.a. coil.



SUGGESTED CIRCUIT No. 212

SIMPLE F.E.T. VOLTMETER

by G. A. FRENCH

VOLTMETERS OFFERING A HIGH resistance at their test terminals are always useful instruments to have available, both for servicing and experimental work. When extremely high terminal resistance values are required it is usual practice to rely on valve voltmeters or on voltmeters having transistor amplifiers.

However, valve voltmeters normally require a mains supply voltage, with the consequent disadvantage that they cannot be employed at locations where the mains is not available and that their test terminals have a relatively high capacitance to earth. These disadvantages are overcome in voltmeters having transistor amplifiers because these may run from an internal battery. On the other hand, transistor amplifier circuits are rather complex and, if a high level of amplification is provided, tend to drift.

A solution to all these problems is provided by voltmeters incorporating field-effect transistors. The internal resistance between the gate and the other electrodes of a field-effect transistor (of the type discussed in the present article) is comparable to that given at the signal grid of a valve, and the device lends itself very readily, therefore, to use in a high resistance voltmeter. Such a voltmeter

can employ an extremely simple and straightforward circuit, and it can be powered by a small internal battery. Also, the problem of drift, working from the writer's experience, is considerably reduced.

This month's Suggested Circuit is devoted to an f.e.t. voltmeter which should be quite easy to assemble and bring into working order. The instrument offers a resistance, across the test terminals, of $10\text{M}\Omega$ on all ranges. If the constructor wishes to experiment, it is probable that this resistance could be doubled without any degradation in performance. Seven voltage ranges, from 0-1V up to 0-1,000V are provided and, here again, the constructor may modify the circuit to provide alternative ranges should he so desire. One important practical point is concerned with the wiring into circuit of the field-effect transistors. Precautions have to be taken to prevent the devices being damaged, and these are detailed later in the article.

F.E.T. OPERATION

The voltmeter employs two field-effect transistors, these being the R.C.A. type 40468 (available from Amatronics Ltd., 396 Selsdon Road, Croydon, Surrey).

The 40468 is a silicon insulated-gate f.e.t. with an n-type channel. Readers

who are unfamiliar with f.e.t. operation may find it helpful to look upon the channel as a length of either n-type or p-type silicon with one terminal (the source) at one end and another terminal (the drain) at the other end. With an n-type channel electrons can flow from one terminal to the other, normally from the source to the drain. Thus, when a supply is applied (via a limiting resistor) such that the source is negative and the drain is positive a current flows through the channel.

The gate electrode is positioned mid-way along the channel and if (with an n-type channel) it is biased negative of the source, the resultant field causes the effective width of the channel to be reduced, and less current flows. To be more precise, the negative bias causes the channel depletion region (which has no current carriers and is therefore an insulator) to be increased in size, thereby reducing the region in the channel which is capable of passing current. By varying the negative bias on the gate, say by superimposing a signal voltage on a steady bias voltage, the current flowing in the channel may be made to vary in sympathy. An amplified version of the signal can then be developed across a resistor or other load in series with the drain.

It will be seen that the functioning of the n-channel f.e.t. is very roughly analogous to that of the triode valve, with the source being similar to the cathode, the gate to the grid and the drain to the anode. If an f.e.t. has a p-type channel all external polarities are reversed.

There are other types of f.e.t. operation but the one just described is that for which the R.C.A.40468 is designed. It is, in consequence, described as a "depletion type." In some field-effect transistors the gate is silicon of opposite polarity to the channel (e.g. p-type if the channel is n-type) whereupon the bias voltage reverse-biases the diode thus formed. With the 40468, however, the gate is a metal film insulated by a very thin layer of dielectric from the channel, whereupon an exceptionally high resistance exists between the two. Field-effect transistors of this type are often referred to as MOSFET's, the letters standing for Metal Oxide Silicon Field-Effect Transistor.

As a final point, a field-effect transistor has a *substrate*, on which the channel and gate are formed, the substrate being silicon of opposite polarity to the channel. In the R.C.A. 40468 one of the lead-outs connects to this substrate and to the metal transistor case.

THE VOLTMETER CIRCUIT

The circuit of the voltmeter appears in the accompanying diagram, and two 40468 field-effect transistors being shown as TR₁ and TR₂. These are connected in a balanced circuit reminiscent of that encountered in twin-triode valve voltmeters and d.c. transistor voltmeter amplifiers. As a result of this method of connection, changes in f.e.t. performance due to ambient temperature variations tend to cancel out.

The positive supply is applied to both drains, and the two sources couple to the negative line via R₁₁, R₁₂ and the zero-adjust potentiometer R₁₃. The gate of TR₂ is held at a fixed potential by R₁₄ and R₁₅, the junction of these two resistors connecting also to the metal case of the voltmeter and to the negative test terminal. It is intended that the voltmeter should indicate zero when the gate of TR₁ is at the same potential as the gate of TR₂. If the circuit is examined, it will be seen that this requirement is met by reason of the fact that TR₁ gate couples to the negative test terminal via whatever resistors are selected by range switch S₁. With no voltage applied to the voltmeter test terminals, R₁₃ is then adjusted so that both sources are at the same potential and meter M₁ offers zero indication.

In practice, both TR₁ and TR₂ draw about 0.8mA channel current whereupon, assuming that the zero setting is given with R₁₃ at the centre of its travel, both sources are approximately 6 volts positive of the negative supply line from the battery.

Since the gates are about 3 volts positive of the negative supply line (this being the potential at the junction of R₁₄ and R₁₅) it follows that each gate is biased negative of its source by some 3 volts. The biasing arrangement is very similar to cathode bias with a valve. It will be seen that the component values employed enable TR₁ and TR₂ to work at potentials which are comfortably "centralised" within the 9 volts available from the battery. This fact is borne out by the fact that the voltmeter still continues to function when the supply is reduced to as low a figure as 7 volts.

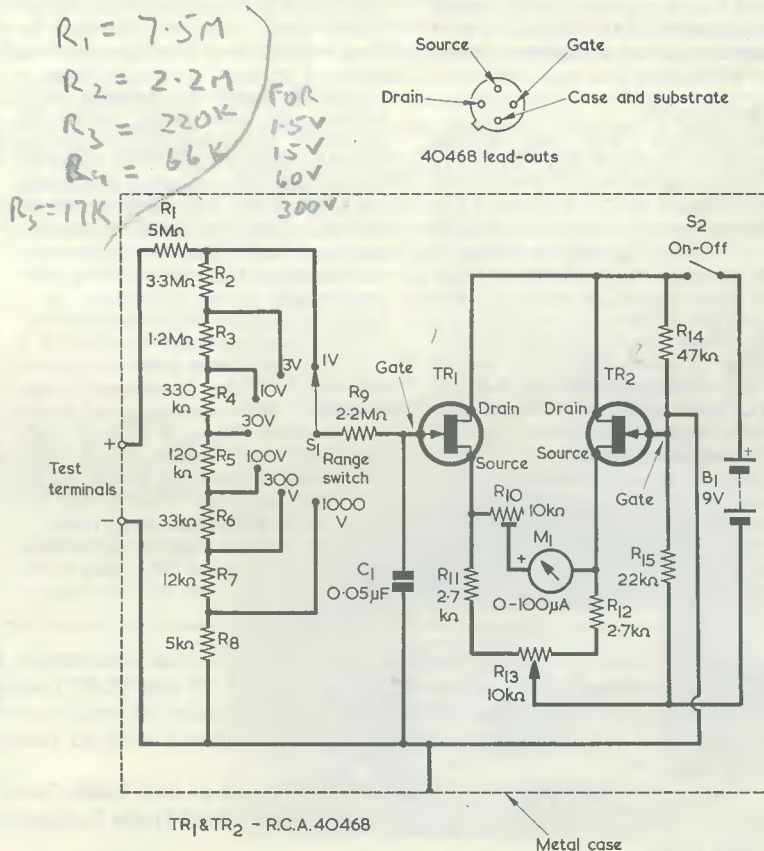
Pre-set potentiometer R₁₀ is adjusted so that meter M₁ gives full-scale deflection when the gate of TR₁ is 0.5 volts positive of the gate of TR₂ (and, thus, of the negative test terminal). Working from what has previously been explained, when the gate of TR₁ goes positive channel conductivity increases, and the source of TR₁ goes positive also. As will be noted, it is the positive terminal of M₁ which couples to TR₁ source.

The range selector circuit is arranged on the assumption that TR₁ gate possesses infinite resistance to the channel. The resistors R₁ to R₈ form a potentiometer which always presents 10Ω to the test terminals and which

causes 0.5 volts to be applied to TR₁ gate when the full range voltage selected by S₁ is applied to the terminals. If, for instance, the values of R₂ to R₈ inclusive are added up it will be found that their sum is 5MΩ. Thus, when S₁ is set to the "1V" position and I volt is applied to the voltmeter, this test voltage is passed to a potentiometer consisting effectively of two 5MΩ resistors in series, and 0.5 volts is then applied to the gate of TR₁. Again, with S₁ in the "1,000V" position and 1,000 volts applied, the voltage across

R₈ is $\frac{5k\Omega}{10M\Omega} \times 1,000$, i.e. 0.5 volts. This

0.5 volts is applied, as before, to the gate of TR₁. The resistances of R₈ to R₂ are calculated to provide the correct ratio for all settings of S₁. It may be added that the values of R₇, R₅ and R₃ are connected to two significant figures and should really be 11.7kΩ, 117kΩ and 1.17MΩ respectively. Constructors requiring exceptionally high accuracies may prefer to fit pre-set resistors in each of the R₂ and R₈ positions, these being set up, starting with R₈, to give the desired range readings required. Such a procedure is, however, rather a time-consuming approach for a simple instrument of this nature.



The complete circuit of the simple f.e.t. voltmeter. Terminal resistance is 10M.Ω on all ranges

Whilst on the subject of the range selector section of the circuit, it is possible for this to be modified to meet constructors' requirements. If, for example, the "1,000V" range is not needed, R_7 and R_8 may be combined in a single $17k\Omega$ resistor, and so on.

The writer felt that a test terminal resistance of $10M\Omega$ was more than adequate for most applications. He has not checked the circuit with a higher terminal resistance, but tests with the prototype indicated that this would be quite a feasible proposition. Thus, if all the resistors R_1 to R_8 inclusive were increased in value by 50% the meter would have a test terminal resistance of $15M\Omega$. Doubling the values of these resistors would give a test terminal resistance of $20M\Omega$. Higher resistances are not recommended for general work.

A potentiometer range selector circuit is used instead of the familiar "series voltage multiplier" circuit because it simplifies switching, and because a "series multiplier" circuit would require fantastically large values for the higher voltage multipliers! However, a series multiplying approach can be used with the instrument in its present form by inserting an external resistance in series with the positive test terminal. A $30M\Omega$ resistor so inserted would enable a load of $40M\Omega$ to be presented to the voltage to be measured and the voltmeter would indicate one-quarter of the actual voltage on all ranges.

COMPONENTS

Dealing first with the simpler components, resistors R_{11} , R_{12} , R_{14} and R_{15} may all be $\frac{1}{4}$ watt or $\frac{1}{2}$ watt types with a tolerance of 5%. Resistors R_1 to R_8 should have a tolerance of at least 2% or, better, 1%, with a rating of $\frac{1}{2}$ watt or more. Many constructors may select these resistors, or make each one up from several resistors, working from stock already on hand. High-stability resistors are preferable, and it should also be remembered that the ordinary carbon composition types can suffer relatively large shifts in value if they are overheated during soldering.

Meter M_1 is any standard 0–100 μ A moving-coil movement with, if required, 0–3 range markings added to its scale. The pre-set resistor R_{10} is mounted inside the case of the instrument, as it should need only one initial adjustment.

The zero-control potentiometer, R_{13} , should be mounted on the front panel of the voltmeter case.

The function of R_9 and C_1 is to prevent any pulses or "spikes" from the test terminals reaching the gate of TR_1 , where they could cause breakdown of the f.e.t. Capacitor C_1 should be a good quality paper or plastic foil component having very high insulation resistance. Resistor R_9 may be a $\frac{1}{4}$ watt or $\frac{1}{2}$ watt component with a tolerance of 10%. Incidentally, there was no change in voltmeter reading with the prototype when this resistor was experimentally short-circuited.

The field-effect transistors need to be treated with care during wiring-up, because of the very high resistance between the gate and the channel. The absolute maximum gate-to-source continuous voltage ratings for the 40468 are zero to –8, and these ratings could be easily exceeded if a soldering iron whose tip is not at earth potential were used to solder the gate lead-out, with the result that the transistor would be ruined. R.C.A. recommend earthed soldering iron tips and that appropriate precautions be taken to protect the devices against high electric fields. The care which has to be taken in this respect is reflected in the fact that these transistors are supplied with metal eyelets fitted over the lead-outs to short-circuit them together during transit.

Since the writer was carrying out a number of experiments with the field-effect transistors in the present circuit he employed two 4-way transistor holders (also available from Amatronix Ltd.), fitting the field-effect transistors into these only after initial wiring had been carried out. They were temporarily removed from the holders during later experimental wiring alterations. As a further precaution, he also ensured that C_1 was discharged before inserting TR_1 .

Arising from these points is the fact that TR_1 will also be damaged if an excessively high voltage is applied to the test terminals. There is a fairly high safety factor here, however, but it is still good practice, as with all voltmeters, to first check unknown voltages with the meter switched to a high voltage range.

No connection is made to the substrate lead-outs of TR_1 and TR_2 , these being left out of circuit. Care must be taken to

ensure that the transistor cases do not touch any other wiring or metal-work as damage or incorrect functioning could result. The cases are sensitive to electric fields from mains wiring and the like and, partly because of this, it is recommended that the whole voltmeter circuit be enclosed in a metal case which is earthed to the negative test terminal. Such a precaution is, in any case, desirable because of the high impedances in the range selector circuit. If required, the metal case can be provided with an outside insulating cover. S_1 , S_2 , R_{13} and meter M_1 are fitted to the front panel of the case. Note that neither of the battery connections is at the same potential as the metal case.

SETTING UP

Once the unit has been completed it may be set up. Adjust R_{10} to insert maximum resistance, switch on S_2 , and set up R_{13} for zero deflection in the meter. Reduce the resistance inserted by R_{10} (thereby making M_1 more sensitive), and re-adjust R_{13} as required, until R_{10} inserts zero resistance.

Re-set R_{10} to insert maximum resistance and apply any known voltage to the test terminals which, after passing through the range selector circuit, will cause 0.5 volts positive of the negative test terminal to appear at the gate of TR_1 . Set up R_{10} so that meter M_1 gives full-scale deflection. No further adjustments in R_{10} are required. When needed, the zero can be readjusted by means of the panel control R_{13} .

RESULTS WITH THE PROTOTYPE

The prototype circuit gave good results, readings in M_1 being linear over all its scale. Depletion type field-effect transistors have a constant-current characteristic and it was found that these was negligible change in readings when the supply voltage was reduced to 7 volts only. In consequence, no supply voltage regulation is required.

There was no undue tendency towards drift and it was found that the same zero setting held for the test terminals both open-circuit or short-circuited. During an hour's use, it was found necessary to slightly readjust the zero control once.

The current drawn from its 9-volt battery by the prototype voltmeter was 1.6mA.



BBC-2 Trade Test Transmissions now include Service Information bulletins for the Television Industry and Trade, Mondays to Saturdays at 10.00, 11.30, 14.30 and 19.00 (except Saturdays). The bulletins include items on new BBC-2 stations, interruption or cancellation of trade test transmissions for urgent engineering work, details of exhibitions including "Colour Television Comes to Town" and other items of importance to Industry and Trade.

There is an additional colour film transmission in the Trade Tests following the Service Information bulletin at 19.00, Mondays to Fridays. The full schedule of Trade Test colour films, with titles, is now published in Radio Times.

As previously, trade test transmissions are made subject to programme commitments and urgent engineering work.

Simple Substitution Boxes

by
E. SOHAM

Puzzled about the best component value for that circuit you're designing? Clip in a substitution box to replace the component whilst the equipment is operating, and you can't fail to find the exact value it requires! The substitution box technique is ideal for development work at a.f. and the lower radio frequencies, and this article describes two examples which fully demonstrate the principles involved

LIKE MANY OTHER CONSTRUCTORS, THE WRITER SPENDS many hours at the workbench modifying existing equipments—some of them commercial designs—and designing and building typical homebrew units such as receivers and amplifiers, etc. An additional favourite pastime is the marrying together of parts of differing published circuits into a complete design, taking one part of a circuit from here and another bit of a circuit from there, until the final design is complete. During these workbench periods, it has been found by experience that much time may be saved by the use of simple substitution boxes. Many beginners, for whom this article is especially written, may like to make up such boxes and gain the advantages that their use entails.

Each unit is built into a 2-oz tobacco tin and consists of a few components—most of which will already be found available in the average spares-box.

UNIT A

Fig. 1 shows the simple circuit of the first unit to be described. In this diagram are a 500k Ω linear potentiometer, an on-off switch, an 0.1 μ F capacitor, and a chassis solder tag. As may be seen from the photographs, these components are assembled in a 2-oz tobacco tin, this being fitted with a Paxolin socket strip having two sockets to provide terminals 1 and 2. Also required are two short lengths of p.v.c. covered flexible wire, each being

terminated at one end with a crocodile clip and at the other end with a wander plug. One wander plug is black and the other red. The lead connected to the black wander plug should be about 5in long and that connected to the red wander plug about 18in long. A small pointer knob together with a simple calibrated scale affixed to the bottom of the tin complete the unit.

From the illustration of the inside of the tin it will be noted that the Paxolin socket strip is secured to the side of the tin by means of two 6BA nuts and bolts. The switch used in the unit illustrated is of the "pressel" type, whose contacts close and open for alternate presses of the button. A small slide or toggle switch could be used instead, and would function equally well. One terminal of the switch is wired to a chassis solder tag mounted inside the tin. On the same 6BA bolt is fitted a further solder tag, this being secured into position outside the tin.

Terminal 1 of the Paxolin socket strip is wired direct to the slider of the 500k Ω potentiometer. Terminal 2 of the Paxolin socket strip is wired to one of the remaining potentiometer tags, such that resistance increases with a clockwise rotation of the potentiometer spindle. To this latter potentiometer tag is also connected one side of the

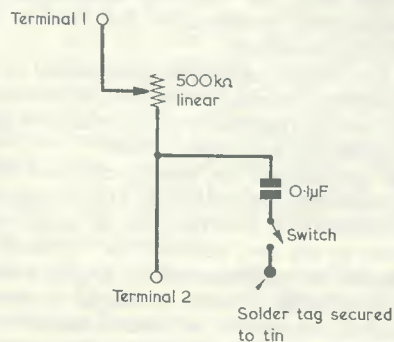
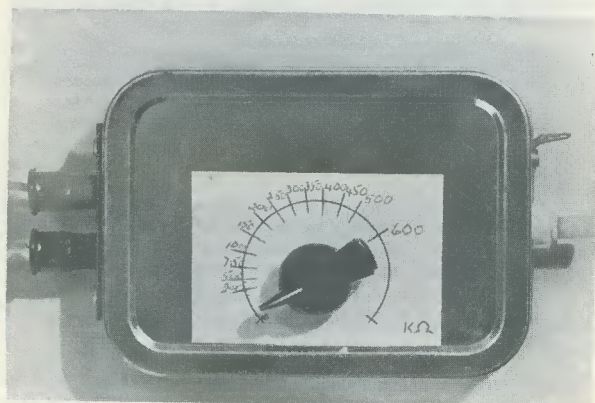
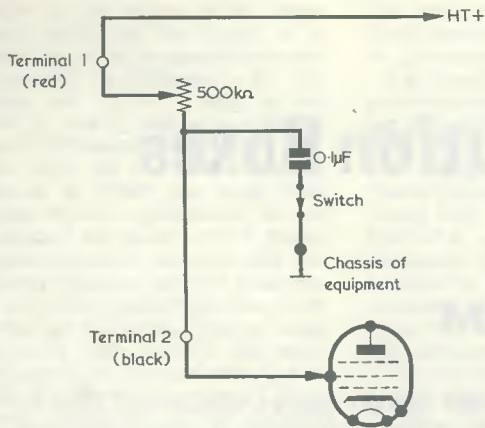


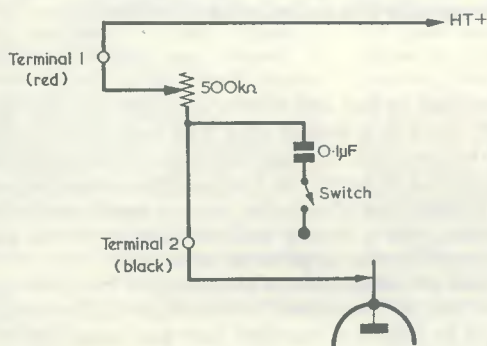
Fig. 1. The internal circuit employed in Unit A



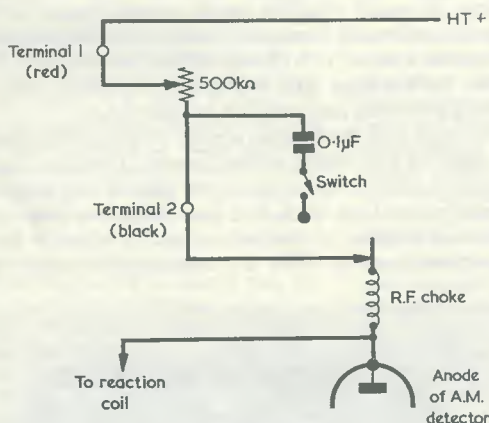
Front view of Unit A with self-calibrated scale



(a)



(b)

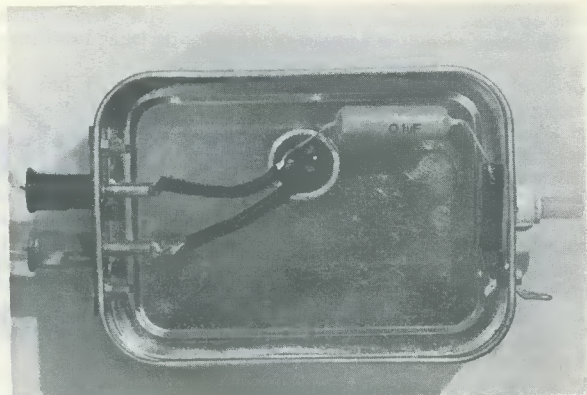


(c)

Fig. 2 (a). Using Unit A to find the optimum value of screen-grid resistor for an r.f. pentode or a.f. voltage amplifier pentode

(b) Determining the best value of anode load resistor When the valve is an a.m. detector with reaction, Unit A is inserted after the r.f. choke

0.1μF capacitor, the other end of which is connected to the remaining terminal of the switch. The 0.1μF capacitor requires a working voltage of 400, and should be a paper or plastic foil type.



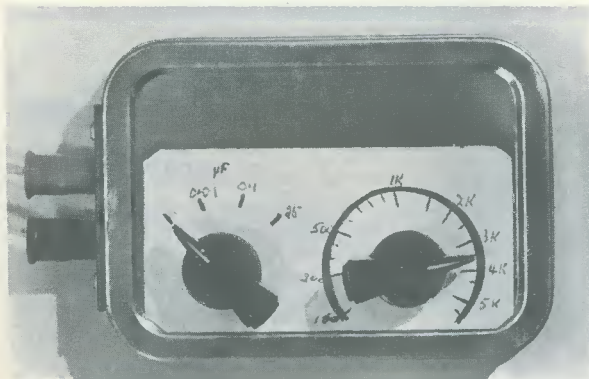
Showing the method of construction and the components inside the 2-oz tobacco tin

Once the unit has been built, it should be calibrated using an ohmmeter set to the appropriate ranges connected across terminals 1 and 2. A calibrated dial is then made up and secured to the tin by means of Bostik or some similar adhesive. It will be noted from the illustration of the front of the unit that the writer is no great hand at being a draughtsman! In the present instance, an ordinary Biro pen was used but readers may like to use indian ink and suitably sized stencils for the dial-marking task.

A typical application for the unit is given in Fig. 2 (a), in which it is employed for finding the optimum value of screen-grid resistor for a pentode valve. The crocodile clip at the end of the short lead connected to the black wander plug is clipped to the screen-grid tag of the pentode valveholder, the plug being inserted into terminal 2 of the unit. The lead with the red plug couples terminal 1 to the h.t. positive line. The solder tag on the tin is then connected, by a short wire, to the chassis of the equipment on which work is being carried out. The switch is closed. Starting at the high resistance end of its range, the potentiometer in the unit is next adjusted until optimum screen-grid volts are given, as indicated by the performance of the equipment. Alternatively, the potentiometer may be adjusted to give the screen-grid voltage recommended by the valve manufacturer, this being measured with a high resistance voltmeter connected between the screen-grid and chassis. After the potentiometer has been correctly set up, the resistance it inserts may be read from its scale. The unit is then removed, and a fixed resistor of the same value together with the required screen-grid bypass capacitor connected permanently into circuit in the equipment being developed.

With the lead lengths employed, this method of finding screen-grid resistance should not introduce instability into a.f. pentode voltage amplifier circuits, or into r.f. pentode circuits at frequencies up to 1Mc/s or so.

A similar application, for finding optimum value of anode load resistance, is given in Fig. 2 (b). In this instance the 0.1μF capacitor is switched out of circuit and the potentiometer in the unit adjusted for optimum value, either in terms of performance or anode voltage. If voltage is the criterion it may be helpful to switch the bypass capacitor into circuit and couple the solder tag of the unit to the chassis of the equipment. This will prevent misleading readings due to a.f. or r.f. signals at the anode.



Front view of Unit B

The approach in Fig. 2 (b) is especially useful for determining the best anode load resistance for an a.m. detector with reaction. The unit may be connected into circuit in the typical manner illustrated in Fig. 2 (c), where an r.f. choke appears between the detector anode and terminal 2 of the unit. The potentiometer is adjusted for "smoothest" reaction.

In the examples given in Figs. 2 (a), (b) and (c), terminal 1 is shown as being returned to the h.t. positive line. In many instances the actual h.t. positive point will be after a decoupling resistor and bypass capacitor. If, later, it is desired to determine the best value of decoupling resistor, the substitution box may be used for this purpose, too!

As will be appreciated, the substitution unit of Fig. 1 offers a wide range of applications in addition to those already discussed. It can be particularly helpful in servicing applications, where it can be employed to bridge resistors which are suspected of open-circuits or shifted values. The main point to remember is that the potentiometer in the unit should always be initially set to insert maximum resistance before being coupled into a working circuit.

UNIT B

The accompanying illustrations and Fig. 3 show the other simple substitution box—Unit B—in both physical and circuit form. This unit is used for determining the value of resistor required in the cathode circuit of a valve, the results being either determined aurally where possible or by means of a voltmeter connected at the same time from cathode to chassis, whereupon the potentiometer is adjusted to provide the cathode voltage specified by the manufacturer of the valve.

In Fig. 3 it will be noted that a 100Ω resistor is in circuit at all times and this value has been chosen as that most desirable to have permanently in circuit to prevent any possible damage to the valve. Few designs include a lower value than 100Ω in the cathode circuit. Variation of the 5kΩ potentiometer will quickly determine the optimum resistance value required, this being read from its calibrated scale. This scale is, of course, calibrated in terms of the total resistance (including the 100Ω resistor) between the two terminals.

The single-pole 4-way switch enables any of three bypass capacitors to be coupled into circuit between the two terminals. For valves working at a.f. the electrolytic capacitor may be switched in and, for r.f. valves, either the 0.1μF or 0.01μF capacitor. The last two capacitors are included as it is sometimes helpful to judge whether an

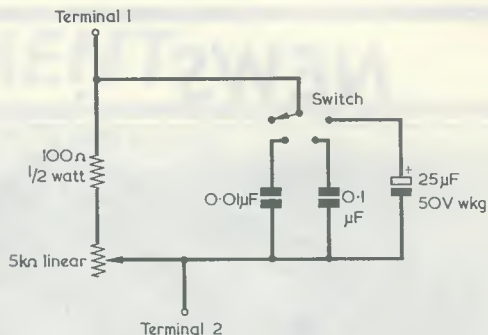


Fig. 3. The internal circuitry in Unit B

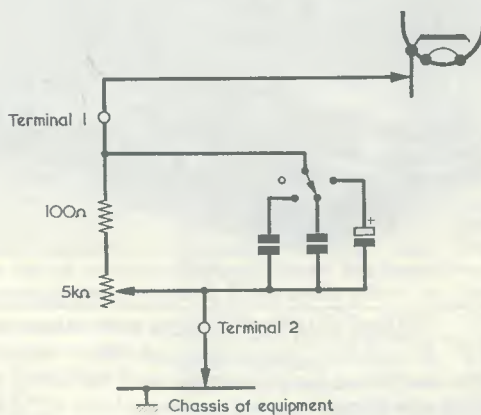
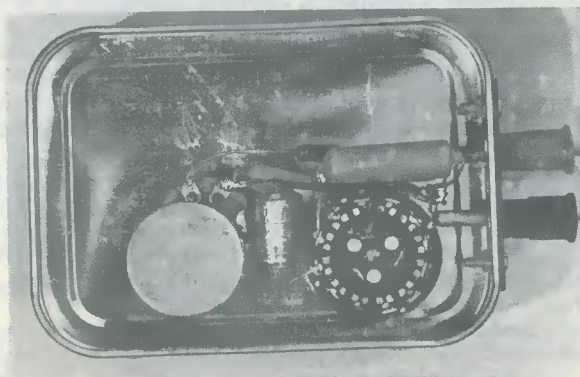


Fig. 4. Unit B is employed to find the optimum value of cathode bias resistor

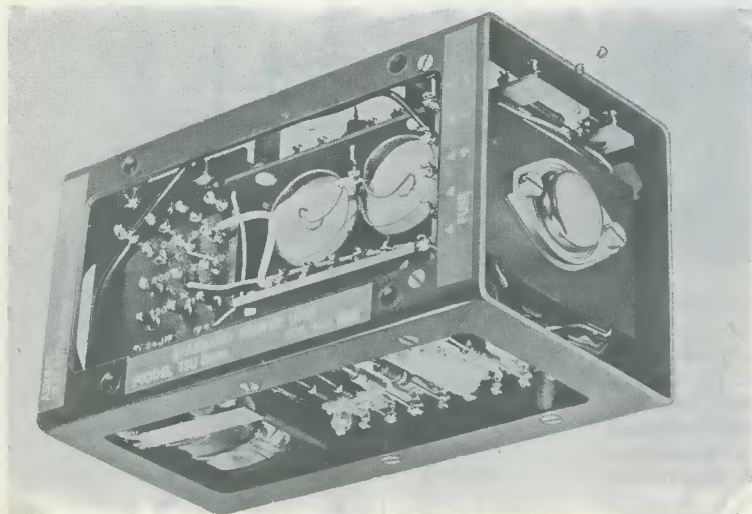


The components of Unit B mounted inside the 2-oz tobacco tin

r.f. cathode circuit may be adequately bypassed by a 0.01μF capacitor rather than the larger 0.1μF component. The fourth switch position is blank, this being selected if a cathode bypass capacitor is already in circuit.

In use, the unit is inserted between chassis and cathode in the manner shown in Fig. 4, the potentiometer being initially set to insert maximum resistance and the appropriate capacitor selected by the switch. The potentiometer is then adjusted for the desired results, after

(continued on page 750)



One of the new TSU-0500 range of silicon power supplies from A.P.T. Electronic Industries Ltd.

SILICON TRANSISTORS WIDEN HEAT RANGE OF TSU-0500

A.P.T. Electronic Industries Ltd. has modified the TSU-0500 transistor stabilised power supply unit by using all silicon devices to extend its operating temperature range from 45°C to 60°C.

Now the Series TSU-0500, provides a stabilised d.c. output of up to 0.5mA at voltages which may be preset to any value from 6 to 30V and its small size (only 5 $\frac{5}{8}$ in. x 3 $\frac{1}{16}$ in. x 2 $\frac{3}{4}$ in. high) enables it to be used for incorporation in customers' own equipment as well as normal laboratory work.

The use of all silicon transistors makes it possible for the unit to operate in ambient temperatures from -10°C up to 60°C and electronic overload protection, operative over the full ambient temperature range, clamps output voltage to zero if it begins to fall and limits output current to a safe value in the event of a short circuit. Further overload protection can be provided if required, by replacing a link with a 1A fuse between the transformer secondary windings and the rectifiers.

All models in this size have universal mains input tappings from 100-250V 45/65c/s. Output impedance on all models is less than 0.5 ohm at all frequencies up to 500kc/s and ripple and noise is less than 1 mV peak to peak.

A useful feature of the unit is that output terminals are isolated from earth and also from the frame, so that the output may be connected in series with any other voltage source up to a maximum of $\pm 500V$. Unit weight is only 2 lb, fixings are made by 4BA bushes in frame top and base and terminations are made by solder lugs.

Operation

Conventional series stabiliser techniques are used. Unstabilised d.c. obtained from a bridge rectifier and capacitor-input filter is fed, via a series transistor, to the output terminals. A proportion of the output is compared with a reference voltage derived from a zener diode and, after amplification, the difference voltage is fed via emitter follower stages back to the series transistor. Thus voltage is controlled across this transistor in such a way that any tendency for the output voltage to change is neutralised. Stabilisation is effective against mains voltage variations of up to $\pm 10\%$ of nominal.

Further details of the TSU-0500 transistor stabilised power unit may be obtained from the manufacturer. A.P.T. Electronic Industries Ltd., Chertsey Road, Byfleet, Surrey.

21 TODAY

With this issue *The Radio Constructor* completes 21 years of publication.

Looking at our very first issue brings home to us at Data Publications the enormous strides we have taken during this time. The "*Constructor*" then contained only 28 small size pages and was launched in hope rather than expectation.

Perusing our file copies from those early days until now, we can see the magazine's gradual growth, and we feel rather like a fond parent who suddenly realises that his young infant has become a vigorous adult.

From the very first our policy has been only to publish sound, essentially practical, reliable articles. It is the maintenance of this policy which has undoubtedly led to our success. The "*Constructor*", or "*R.C.*" as it is often affectionately called, is respected throughout the world as a sound, reliable hobby cum technical journal.

Publishing articles of a good standard, whether they be for beginners or advanced amateur, attracts the best type of author in the various fields that we cover. Many have achieved distinction in their careers or in some activity or other. One such is referred to in our notes below.

Enough of nostalgia. Regular readers will see the steady consolidated progress of the past continued as our plans for the future gradually unfold.

CONSTRUCTOR CONTRIBUTOR IN 'TOMORROWS WORLD'

Readers who follow the B.B.C.'s science progress programme "*Tomorrow's World*" will have been particularly interested to see our old friend John Tuke GM3BST featured recently. John will be remembered for his contribution to this magazine some years ago on "*Amateur Radio Teletyping*". From RTTY he progressed to FAX—facsimile transmitting—particularly of weather charts, by radio. He designed and built his own receiving equipment, for the radio reception of weather maps broadcast on short waves from various meteorological stations. This was followed by the addition to his equipment of UHF receiving facilities, for the reception of weather maps from various satellites, and it was this aspect of his activities which was featured in "*Tomorrow's World*".

We extend our congratulations to John for his unique ability in this sphere, and for pushing the frontiers of amateur radio into still another aspect of scientific activity.

COMMENT

NEW DELUXE SOLID-STATE VOLT-OHM-METER FROM HEATHKIT

Brief Specification of the Deluxe Solid-State Volt-Ohm-Meter, Model IM-16.

(1) All solid-state circuitry. (2) Operates either from internal batteries or from 120/240V, 50/60c/sAC mains voltage. (3) Seven ohmmeter ranges x1 (with 10 ohms at centre scale), x10, x100, x1K, x10K, x100K and x1 megohm. (4) Eight AC and eight DC ranges, from 0.5 volts to 1500 volts full scale. (Accuracy: AC, $\pm 5\%$ of full scale; DC, $\pm 3\%$ of full scale). (5) Eleven megohm input on DC ranges, 1 megohm on AC ranges. (6) Separate switches for individual functions reduce constant knob twisting.



Price: Kit K/IM-16. £28 8s. 0d. P.P. 6s. extra. Assembled price on request.

"GB2LO" IN "DAILY MIRROR" BUILDING

The amateur radio station to be operated by the Radio Society of Great Britain for the 1968 CITY OF LONDON FESTIVAL, July 8-20, will be located in the "DAILY MIRROR" Building, Holborn, London, E.C.1.

This location, within the 1.03 square miles of the City of London, is about 200 yards from the premises at 107 Hatton Garden, where some of the earliest meetings of the Radio Society of Great Britain, when it was still called the London Wireless Club, were held in the late Summer of 1913.

It is expected that world-wide, 2-way, radio contact will be made during the Festival. Great interest has already been aroused by the project in communications circles all over the world. Contacts have been arranged with London, Ontario, Canada, where an Exhibition Station, callsign VE3LON, is being operated during the London (Ontario) "Fortnight Festival", whose theme is "THE BRITISH ARE COMING!"

"GB2LO" will be on view to the public and it is anticipated that several distinguished guests will visit the installation during the period of the City of London Festival.

RECORDS BROKEN AT 1968 INTERNATIONAL INSTRUMENTS, & AUTOMATION EXHIBITION

"This show has put the future in perspective," said Mr. David D. Walker, Chairman of the International Instruments, Electronics and Automation Exhibition.

"The IEA has again been an enormous success," he said, "and it has attracted wide overseas interest.

"Though you don't expect sales to be made 'over the counter' at a highly technical exhibition, there is every indication that trading initiated at the IEA will increase the big turnover of the industry and have a substantial impact on our export effort.

"To attract 112,363 people to a show of this technical level, including 9,431 from 80 foreign countries is an achievement in itself. Important is that, as the exhibitors tell me, the quality of the visitors has been so high: they have been either buyers or potential buyers.

"No assessment can be made of the total trade initiated at the IEA. Several million poundsworth of orders have been placed directly, but considerably more contracts are in the course of negotiation."

Mr. Ted Rees, Chairman of Industrial Exhibitions Limited, congratulated the exhibitors on the effort they had put into the IEA.

"We present the show," he said, "but close co-operation of the whole industry was needed to make it such a success as this. We know what sells to the world and it is encouraging to have the energetic support of all the firms who were associated with us."

COMBINED ANNOUNCEMENT

A combined announcement has been made by Radiatron of 7 Sheen Park, Richmond, Surrey and Electronic Services-STC of Edinburgh Way, Harlow, Essex to the effect that Electronic Services are now official stockists/distributors for the Radiatron range of Elma Switches Types 01 and 03. Electronic Services-STC now offer an ex stock service—normal despatch within 24 hours—of any standard types of ELMA 01 and 03 switches, which comprise the major part of the Elma range. Production quantities are available from Radiatron.

The seven-day prototype service already established by Radiatron has also been extended, and small quantities of prototype switches with special features, such as concentric spindles, dummy wafers, etc., can normally be supplied within seven days.

This combined effort to achieve rapid switch deliveries by Radiatron and Electronic Services fulfils a long-felt need in the electronics industry for immediate supply of either standard or special switches.

Further details may be obtained from: Radiatron, 7 Sheen Park, Richmond, Surrey. Tel.: 01-940 3285/9352

or

Electronic Services-STC,
Edinburgh Way, Harlow, Essex.
Tel.: 02-796 26777



Specimen Radiatron Switches

LOW VOLTAGE POWER SUPPLY FOR TRANSISTORS

by
B. HUNTER and A. FRASER

It is often desirable to have at hand, for transistor equipment, a simple mains power supply unit capable of offering a wide range of output voltages without the complication of a stabilising circuit. The power supply described in this article meets this requirement and it provides outputs from some 3 to 30 volts on load with the regulation associated with a bridge rectifier circuit

SOME TIME AGO, IT WAS FOUND NECESSARY TO PROVIDE a power supply for testing a transistorised amplifier which required 30 volts and, from time to time, various other pieces of transistorised equipment which required voltages from about 6 upwards. With this in mind, a power supply unit was designed which would cater for these requirements and also be inexpensive. The unit was designed around a multitapped transformer which obviates the need for circuitry to give continuously variable output; the necessary d.c. voltage being obtained by selecting tapings on the transformer, the a.c. voltage thus obtained then being rectified and smoothed. While this does not give continuously variable voltage, sufficient convenient voltages are available for most experimental applications.

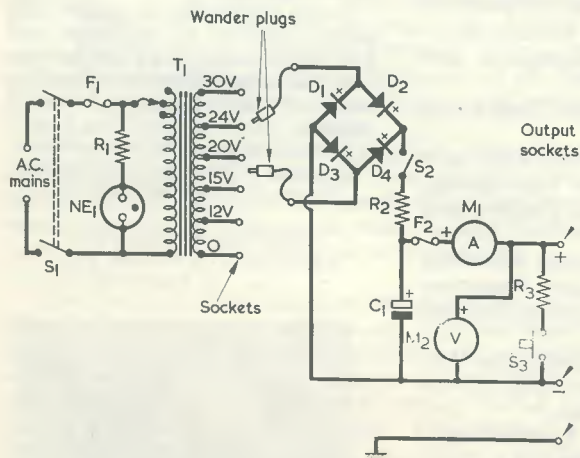


Fig. 1. The complete circuit of the low voltage power supply. A wide range of alternating voltages is available from the mains transformer secondary

COMPONENTS

Resistors

- R₁ Part of neon lamp assembly
- R₂ 4.7Ω 3 watt 10%
- R₃ 1kΩ 2 watt 20%

Capacitor

- C₁ 4,000μF 50V wkg. (May be two 2,000μF in parallel)

Transformer

- T₁ Douglas type MT3, secondaries 0, 12, 15, 20, 24, 30V at 2A. (Home Radio Cat No. TMM1)

Fuses

- F₁, F₂ 1A fuse, 20mm, with miniature panel mounting fuse-holder (Henry's Radio)

Rectifiers

- D₁-D₄ Silicon power rectifiers (see text)

Switches

- S₁ d.p.s.t. toggle
- S₂ s.p.s.t. toggle
- S₃ s.p.s.t. push-button

Meters

- M₁ 0-1A moving-coil
- M₂ 0-50V moving-coil

Neon

- NE₁ Neon lamp and holder with series resistor (R₁) for mains operation. (Home Radio Cat. No. D841/250V or similar)

Plugs, Sockets

- 5 Banana wander plugs (inc. 3 for output and chassis sockets)
- 9 Sockets, to suit plugs

Voltage selection is done by plugging two wander plugs into six sockets which are connected to the tappings on the transformer secondary.

Because the supply was required to give a smooth d.c. output, half-wave rectification was not considered suitable, and because full-wave bi-phase rectification requires a centre-tapped supply, this was also ruled out. Thus the most suitable rectifier is the bridge. Continuous monitoring of the supply voltage and current is provided using two meters. Although this monitoring could have been done with one meter which could be switched from voltage to current, the circuit under test could draw an excessive current whilst the meter was switched to volts and this might not be readily evident.

THE CIRCUIT

The circuit of the power supply unit appears in Fig. 1. The mains input supply is applied via fuse F_1 and switch S_1 to the indicator neon bulb NE_1 and the primary of mains transformer T_1 . The transformer is a Douglas type MT3, and it offers secondary voltages at 0, 12, 15, 20, 24 and 30, all at 2 amps. All the secondary connections are brought out to sockets on the front panel of the power supply, and two wander plugs from the rectifier section may be plugged into any of these. As may be seen, if then becomes possible for the wander plugs to select any of the following a.c. voltages: 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24 and 30 volts. If low alternating voltages are required for experimental work these may be selected direct from the sockets on the front panel, the plugs from the rectifier section then being left out of the sockets.

When the unit is required to give a d.c. output, the two wander plugs from the rectifier section are fitted to the sockets appropriate to the alternating voltage required, whereupon this voltage is applied to the bridge rectifier given by D_1 to D_4 . The rectified output from this bridge is next passed via S_2 and limiter resistor R_2 to reservoir electrolytic capacitor C_1 , and thence, by way of fuse F_2 and a series ammeter, to the d.c. output terminals. A voltmeter across the terminals continually monitors output voltage whilst the series ammeter indicates output current. Since the output voltage off load can rise to 1.4 times 30, i.e. 42 volts (assuming the 30 volt secondary tappings are selected), a convenient figure for voltmeter f.s.d. is 50 volts. The rectifiers used by the authors were Radiospares type REC 50A, which are rated at 125 volts r.m.s. and 750mA, and it was decided to use an ammeter with an f.s.d. of 1 amp. Any other silicon rectifiers capable of working at 30 volts r.m.s. (with a p.i.v. of at least 42 volts) and the required current capability may be employed instead of the Radiospares types, if desired. The d.c. output drawn from the supply unit should not exceed the current rating of the rectifiers used. (As alternatives, the 100/1.25 silicon rectifiers available from Henry's Radio with a maximum current of 1.25 amps and a p.i.v. of 100 would, for instance, be suitable. It should be noted, incidentally, that Radiospares components may only be obtained through retailers.

—EDITOR)

Due to its high value, capacitor C_1 will remain charged for quite some time after the unit has been switched off. This can be particularly annoying if the unit has been used to supply a high voltage and is then required to supply a low voltage. Because the voltmeter is the only load on the supply when it is not in use, the charge in C_1 falls very slowly. To speed

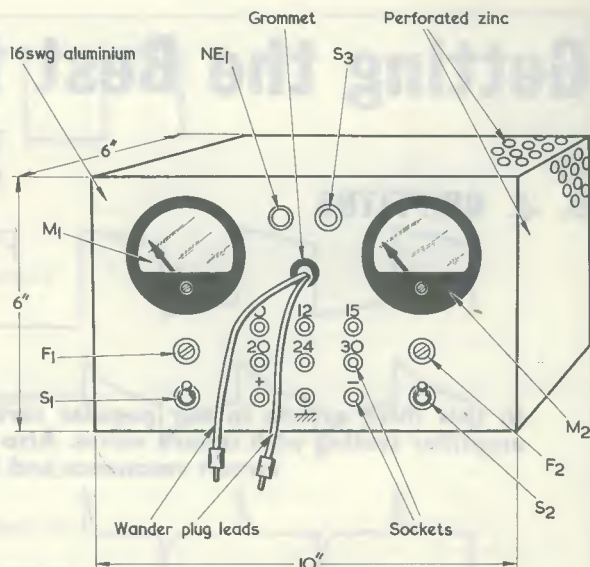


Fig. 2. Details of the case and panel layout used for the prototype

up this discharge, push-button S_3 is fitted, this connecting resistor R_3 across the output and thus causing a current to flow and discharge the capacitor.

With a resistor of $1k\Omega$, the discharge takes about 10 seconds from a fully charged capacitor. If a faster discharge time is required the resistor may have a lower value, but on no account should the resistance be so low that the ammeter is overloaded. Care should also be taken that the output is not short-circuited. Despite the protection provided by fuse F_2 , short-circuits can still cause damage to the series ammeter.

CONSTRUCTION

Construction is quite simple and, since layout is not critical, should raise few problems. The prototype was built into a metal case measuring $10 \times 6 \times 6$ in with a front panel as in Fig. 2. It will be seen that the transformer secondary sockets appear at the centre with the d.c. output sockets below. There is also a socket connecting to the chassis of the supply unit. None of the outputs, a.c. or d.c., are connected to chassis inside the case, and whichever output is used can be left "floating" or have one side earthed to chassis as required. The two flying leads with wander plugs from the rectifier section pass through the grommet above the sockets.

The front panel, back and base plate of the case illustrated in Fig. 2 are made of 16 s.w.g. aluminium. The top and two sides consist of a single piece of perforated zinc, bent to shape, which also provides ventilation.

This power unit has been in use now for a number of months and has given very satisfactory results. Although its output voltage is not continuously variable, the voltages available have been found quite satisfactory for most uses.

EDITOR'S NOTE

If any doubt exists as to rectifier polarity—as could occur if unbranded rectifiers were employed for D_1 to D_4 —it would be a good plan to complete the wiring with C_1 out of circuit. If the voltmeter indicates correct polarity when the mains supply is applied, then C_1 may be connected up. This approach prevents damage should the rectifiers be accidentally connected the wrong way round.

Getting the Best from your Oscilloscope

by
D. J. GRIFFITHS

PART 3

In this third article in our popular series, waveforms are given to illustrate a.f. amplifier testing with square waves. Also discussed are oscilloscope traces for tuned circuit resonance and f.m. detector alignment

SQUARE WAVE TESTING

Sine waves can be used, as has been shown in the preceding article in this series, to check for distortion in a.f. amplifiers, but a more definite test is afforded by square waves. Figs. 1 (b) and (c) show the effects of typical capacitor-resistor circuits of various time constants on a square wave.

Typical amplifier output responses are given in Figs. 1 (d) to (g). Fig. 1 (d) indicates that the amplifier frequency response is reasonably flat, there being only slight sloping of the square wave. In Fig. 1 (e) the sloping is considerably more pronounced, this indicating a good h.f. response and a poor l.f. response. Fig. 1 (f) illustrates a reverse effect, in which the rise and fall sections of the square wave are rounded. This corresponds to a poor h.f. response and a good l.f. response.

Fig. 1 (g) shows a damped train of oscillations after each rise and fall section of the square wave. This effect is the result of peaking at a high frequency or of a tendency towards parasitic oscillation at that frequency. A useful measure of the frequency at which the damped train of oscillations occurs is given by counting the number of cycles in the damped train and comparing these with square wave frequency.

For general amplifier testing a square wave of the order of 400c/s is useful for practical work. High and low square wave frequencies may be used for more specialised testing.

Square wave checks are capable of showing amplifier response shortcomings because a square wave may be analysed into a set of harmonically related sine waves. If any of these harmonics are amplified or attenuated excessively then the wave becomes distorted. Since the oscilloscope amplifier may not be capable of reproducing the square wave exactly, it is desirable to initially couple the square wave generator directly to the oscilloscope and note the result.

It is of particular interest to pass square waves through the differentiating and integrating networks shown in

Figs. 1 (b) and (c). Depending on the values of R and C the square wave may be deformed in various ways, from a series of pulses of almost no duration to a wave similar to that shown for a long CR in Fig. 1 (c). Many of the simpler tone circuits in a.f. amplifiers are, in fact, integrator or differentiator circuits, hence square waves are most useful in obtaining an idea of their overall effect.

RESONANCE CURVES

With the proper equipment it is possible to align tuned circuits visually. Apart from the oscilloscope an instrument known as a frequency modulated signal generator, or wobulator, is necessary. A wobulator is simply a frequency modulated oscillator designed to produce a sweep over a band of frequencies, and it may be adjusted so that the centre of the band of frequencies is at the resonant frequency of the tuned circuit or circuits being checked. According to the design of the wobulator and the method of coupling to the oscilloscope it is possible to obtain one or two response curves. Figs. 2 (a) and (b) show two basic response curves presented on the oscilloscope screen; as is evident from Fig. 2 (b) one is obtained with the wobulator sweep in one direction and the other with the wobulator sweep in the reverse direction. Here, wobulator sweep frequency is equal to timebase frequency. Single responses can be obtained if the oscilloscope amplifier or wobulator output is blanked out for one direction of sweep, but should this prove impossible the return sweep may be ignored. Alternatively, by running the oscilloscope speed at twice the wobulator sweep speed the two curves, if they are symmetric, may be superimposed. These remarks assume that the wobulator is sine wave modulated.

As just mentioned, two basic response curves are shown in Figs. 2 (a) and (b). That illustrated in Fig. 2 (a) corresponds actually to a single symmetric response and that in Fig. 2 (b) to a single asymmetric response.

Figs. 3 (a) and (b) illustrate single responses obtained from a.m. sound radio receivers, the figures at the base lines indicating frequency in kc/s. (Normally, frequency

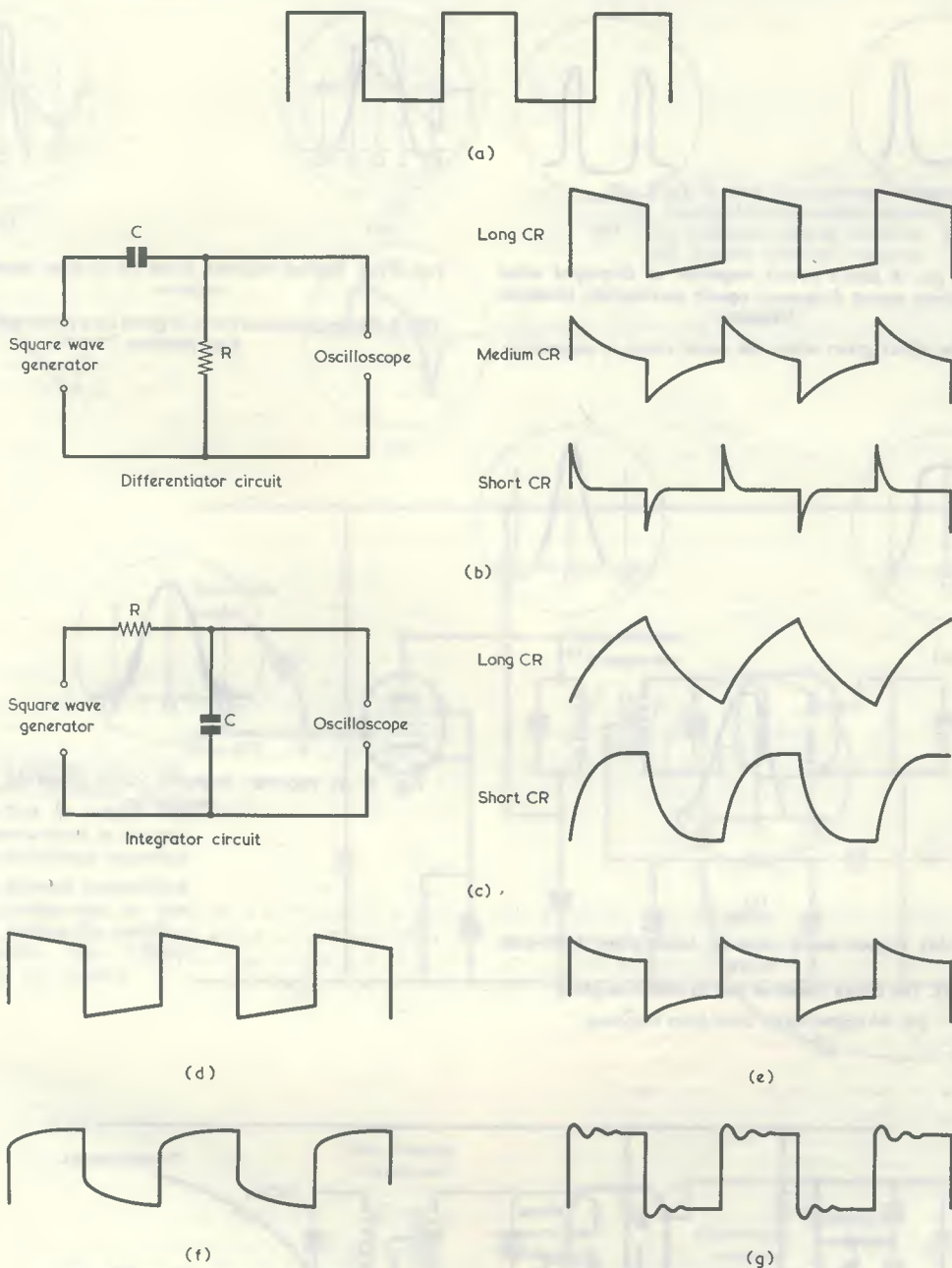


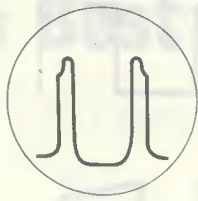
Fig. 1 (a). The square wave fed to the amplifier input
 (b). Waveform distortion of the type given by a differentiator circuit
 (c). The type of distortion given by an integrator circuit
 (d). The output given by an a.f. amplifier with a reasonably flat response
 (e). Increased sloping indicates poor l.f. response
 (f). Good l.f. response but poor h.f. response
 (g). The output resulting from h.f. peaking or a tendency towards parasitic oscillation

markers should be provided in the wobulator or by an external signal generator to enable frequency indications to be provided). The wobulator output is applied to the aerial terminal of the receiver and the oscilloscope input

is taken off after the detector. The response of Fig. 3 (a) is that for an average broadcast receiver, and it exhibits good symmetry. The narrower curve in Fig. 3 (b) is typical of the response given by a communications receiver



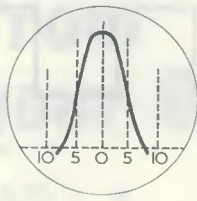
(a)



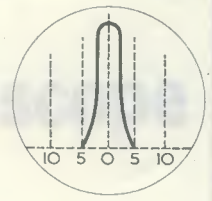
(b)

Fig. 2 (a). A tuned circuit response, as displayed when wobulator sweep frequency equals oscilloscope timebase frequency

(b). The effect given when the basic curve is asymmetric



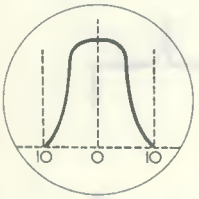
(a)



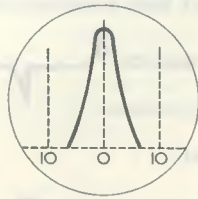
(b)

Fig. 3 (a). Typical response curve for an a.m. sound radio receiver

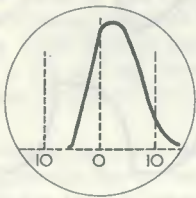
(b). A sharper response curve is given by a communications-type receiver



(a)



(b)



(c)

Fig. 4 (a). A good sound radio i.f. transformer band-pass curve

(b). The peaky response due to under-coupling

(c). An asymmetric band-pass response

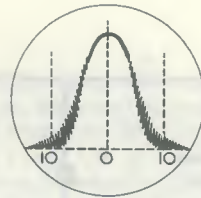


Fig. 5. A receiver response curve, showing parasitic oscillation

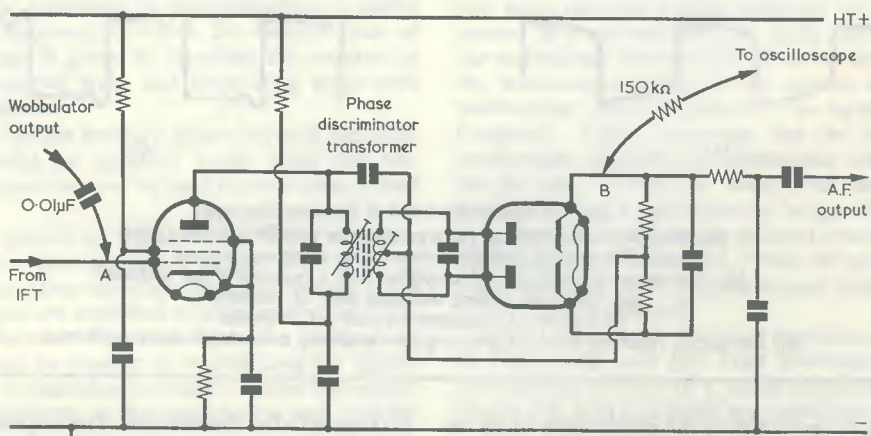


Fig. 6. Coupling a wobulator and oscilloscope to an f.m. phase discriminator

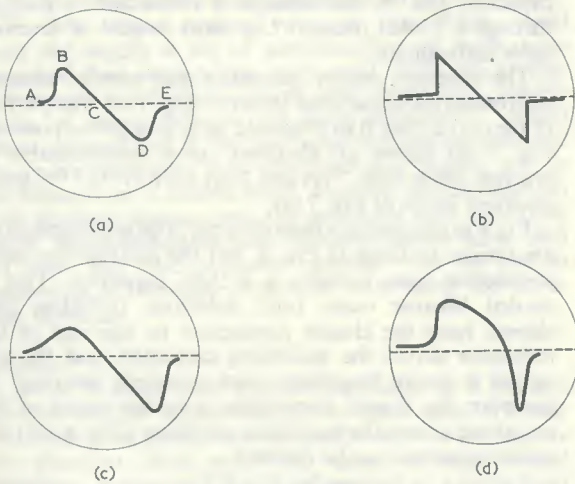
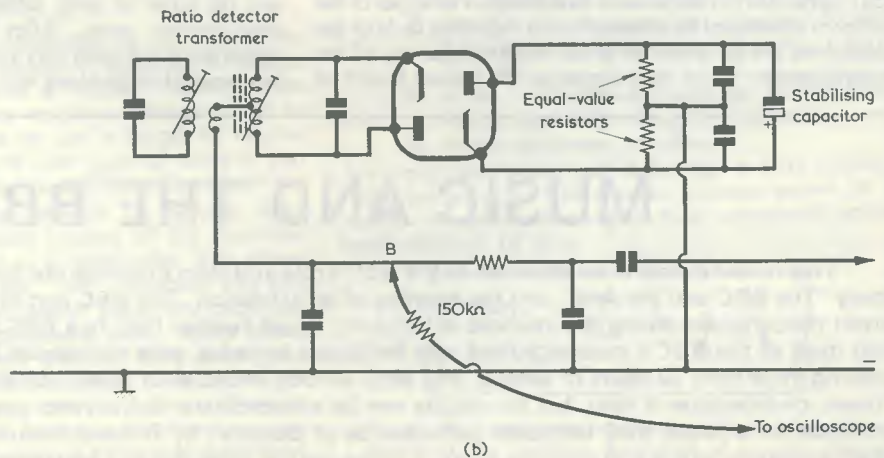
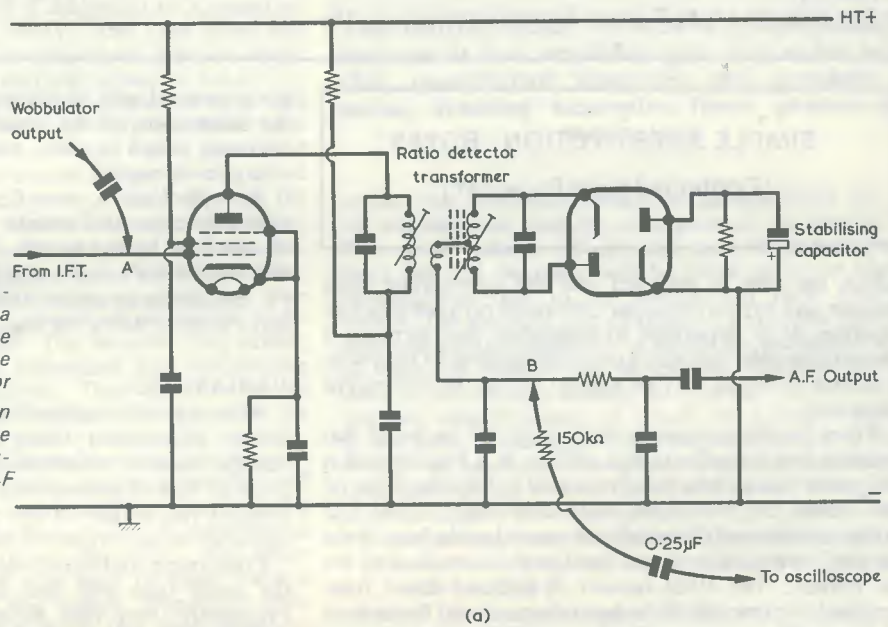


Fig. 7 (a). A good discriminator response
 (b). Idealised discriminator response
 (c). Distorted form of response
 (d). Another distorted response

Fig. 8(a). Coupling the wobblulator and oscillator to a ratio detector in which the chassis connection is to one side of the stabilising capacitor
 (b). If the chassis connection is to a centre-tap in the resistance across the stabilising capacitor, the 0.25 μ F capacitor is not needed.



without i.f. filters.

A good band-pass response, as would be required in a sound radio i.f. amplifier, appears in Fig. 4 (a). This has a flat top with a width of some 3 kc/s on either side of the central frequency. If the coupling is too loose the narrow peaky response in Fig. 4 (b) may result. A misaligned band-pass circuit can give the appearance shown in Fig. 4 (c). Regeneration in the associated amplifier may also result in a distorted response of this type.

Fig. 5 indicates a correctly aligned receiver or i.f. strip, but the fagged sides and the thickness at the bottom of the curve show that parasitic oscillation is occurring at lower input signal levels.

F.M. RECEIVER ALIGNMENT

A.M. and f.m. sound receivers are very similar except for the detector, hence this section deals exclusively with the alignment of the f.m. detector.

There are two common types of detector in use, the phase detector and the ratio discriminator. These require somewhat different treatment and are dealt with separately.

Fig. 6 shows a typical phase discriminator circuit. The

wobbulator is connected to point A through a $0.01\mu\text{F}$ capacitor and the oscilloscope is connected to point B through a $150\text{k}\Omega$ resistor. Use short lengths of screened cable throughout.

The trimmers and/or dust cores may now be adjusted to produce the single trace shown in Fig. 7 (a). The portion of the curve from B to D should be as straight as possible. Fig. 7 (b) shows an idealised curve, unobtainable in practice, while Figs. 7 (c) and 7 (d) show two of the many incorrect forms of Fig. 7 (a).

Fig. 8 (a) illustrates a ratio detector. The test connections are similar to those in Fig. 6, but the oscilloscope input connection now includes a $0.25\mu\text{F}$ capacitor. This is needed because many ratio detectors, including that shown, have the chassis connection to one end of the resistance across the stabilising capacitor, and the a.f. output at centre frequency is not at chassis potential. If, however, the chassis connection is to the centre of the resistance across the stabilising capacitor (Fig. 8 (b)) the series capacitor may be omitted.

(To be concluded)

SIMPLE SUBSTITUTION BOXES

(Continued from Page 741)

which the unit is removed and the appropriate fixed resistor and bypass capacitor connected permanently into position. It is important to remember that terminal 2 should always be that which connects to chassis. Otherwise, a reverse potential may be applied across the electrolytic capacitor.

From the illustrations of this unit, it will be noted that construction is similar to that of Unit A, a Paxolin socket strip with two sockets being mounted to the side of the tin by means of two 6BA nuts and bolts. The $5\text{k}\Omega$ potentiometer and the switch are secured to the base of the tin and have suitable scales fitted to the outer face of the tin bottom. The 100Ω resistor is soldered direct from terminal 1 to one side of the potentiometer and the various capacitors are connected at one end (positive for the $25\mu\text{F}$ capacitor) to the various switch tags. The wiper of the switch is connected to terminal 1 and the other ends of the capacitors are all soldered to the centre slider tag of the potentiometer, which then connects, via a short length of

p.v.c. covered wire, to the terminal 2 socket. As shown in the illustration of the inside of the unit, a three-pole, four-way switch has been used, this being to hand at the time of construction.

As with Unit A, two flexible leads terminated with crocodile clips and wander plugs are required. These should each have a length of about 6in, whereupon the unit should not cause undue alteration in performance in r.f. circuits up to about 500kc/s . For higher frequencies, up to some 1.5Mc/s , the leads should be shorter.

VARIATIONS

Although this article has centred around the two simple substitution boxes discussed, the reader may readily visualise variations on the basic idea. From the point of view of convenience in construction and use, the tobacco tins employed are exceptionally useful for the assembly of test circuits of this nature.

Component and circuit substitution boxes amply repay the small time and cost incurred in their assembly. Frequently, they may be made up from components which are already on hand. It only takes a little time to fall into the habit of using substitution boxes for design and development work. After acquiring that habit, the constructor will then very probably wonder how on earth he managed to get along without them in the past! *

MUSIC AND THE BBC

Two recent events draw attention to the BBC's role in Britain's musical life: the publication of a pamphlet study "The BBC and the Arts", and the opening of an exhibition "The BBC and Music", specially designed to divert concertgoers during the intervals at London's Royal Festival Hall. In a BBC broadcast, Ian Gillham said that most of the BBC's musical output was broadcast by radio, with the special Music Programme network offering more than 70 hours of serious, and semi-serious, music each week. "Understandably," he continued, "music on television is rarer, but the results can be extraordinary. Some years ago it was calculated that the audience for a single BBC television performance of 'Salome', by Richard Strauss, was larger than the total of all audiences which had seen the opera in opera-houses since the first performance in Dresden in 1905."

COMMUNICATION SYSTEMS HAVE LONG SINCE PASSED the stage where mere amplification denoted merit. The bright emitter valve of the 1920's could and did supply a lot of amplification—if more were required then more valves were used. With the greater efficiencies of modern valves and transistors voltage gains of many millions are easily attainable; indeed these are essential if the very weak signals encountered by radio telescopes and interplanetary probes are to be brought up to usable levels. Further, heat dissipation and physical size are not the problems that they once were. Semiconductors and miniaturisation have seen to that. But one problem remains with us and is becoming increasingly important, this being the problem of noise.

NOISE

Noise is quite often the limiting factor in a modern communication system for if the signal level is below the noise level no amount of amplification will improve the situation. Both signal and noise will be increased together. A signal of $0.5\mu\text{V}$ submerged in a noise level of $1\mu\text{V}$ is no more readable if magnified to a signal of $50\mu\text{V}$ in a noise level of $100\mu\text{V}$. And even when the signal and noise are at the same level we can never be sure whether we are receiving signal or noise.

But what is noise? We are not concerned here with noise that arises from faulty components, loose connections or dirty contacts. Noise from these and similar sources can be eliminated by good design and careful construction. Nor are we concerned with the noises that arise from atmospherics, car ignition, power lines etc. for, real and annoying as these are, they too may be eliminated or their effects minimised. The noise that circuit and systems designers are concerned with is the noise arising from within the components of the system itself. The resistors, the valves, the transistors, even the capacitors and conducting wires—these are the culprits. They generate noise and hence may cause the desired information to be masked or obscured.

One source of noise is the ordinary carbon resistor. Due to its granular structure a carbon resistor will develop a noise voltage across its terminals when a direct current is passed through it. A wire-wound resistor however is free from this effect. The lower frequency components of this type of noise have a greater amplitude than the higher frequency components, and at around 1 Mc/s this type generally becomes negligible compared with the thermal noise generated by the resistor.

Thermal noise is not restricted to any particular type of resistor and arises wherever resistance is present, whether it is in the form of a resistor—carbon, wire-wound, thin film, etc.—the resistive component of an inductor, an aerial system or just a length of copper wire. If resistance is present then thermal noise is also present, even when no voltage is applied to the terminals.

To understand the phenomenon of thermal noise let us consider the classical picture of the electrons and atoms (or molecules) in a conductor. The atoms are fixed in position but the “free” electrons can and do move easily between the atoms. These free electrons, not associated with any particular atom, move about constantly and change their position in a haphazard manner, as in Fig. 1. This movement of electrons, in any direction, constitutes an electric current. Since at any one instant there will be more electrons moving in one direction than the other, a voltage is developed

Communication Systems and Noise

by P. B. Brodribb,
B.A.Sc., C. Eng

The limiting factor in modern communication systems is not amplifier gain but noise level. Our contributor discusses the problem of noise, drawing examples from present-day technology

across the conductor which is proportional to the net current flow and the resistance of the conductor. This noise voltage will depend also on temperature, since the free electrons will be more active at higher temperatures due to an increase in their thermal energy. The polarity also changes in a random fashion, depending on the direction in which the greater number of electrons happens to be moving. Because of this there is no definite pattern to thermal noise voltage nor any one frequency at which the voltage appears. It has been found in fact that the distribution of noise energy is uniform throughout the entire frequency spectrum, giving rise to the term “white” noise. This is an analogy with white light, which is a combination of light energy from the whole of the visible spectrum.

An equation bringing together all these factors is

$$E^2 = 4kTB R$$

- where E is the r.m.s. value of the noise voltage,
k is Boltzmann's Constant, 1.38×10^{-23} Joules/°K,
T is the temperature in degrees Kelvin ($273 + \text{temperature in degrees Centigrade}$),
B is the bandwidth in cycles per second over which the noise voltage is measured.
R is the resistance in ohms.

A simple calculation will show that a $1\text{k}\Omega$ resistor at room temperature has a noise voltage across its terminals of approximately $0.4\mu\text{V}$, measured over a bandwidth of 10 kc/s.

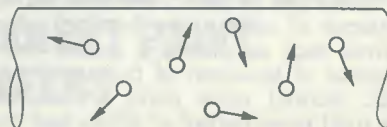


Fig. 1. In a conductor, random movement of electrons results in the continual generation of a noise voltage

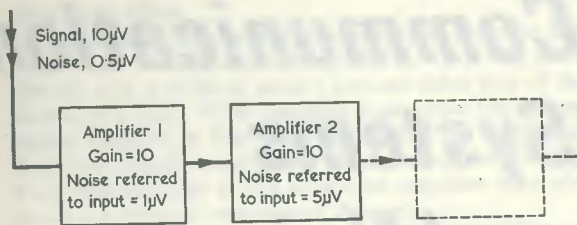


Fig. 2. A typical amplifying sequence. As is explained in the text, the signal-to-noise ratio at the output of Amplifier 2 is only slightly different to that at the output of Amplifier 1

NOISE IN RECEIVING EQUIPMENT

Now, we can see the importance of noise in receiving equipment that is to detect signals from a satellite or an interplanetary probe. The power of the transmitters carried by these space vehicles is often only a few watts and frequently only milliwatts. The level of the signal received from Mariner IV when it transmitted its historic pictures of Mars was of the order of 10^{-19} watts. If this signal power were to be developed in a resistance of $1k\Omega$ it would yield a signal voltage of $0.01\mu V$, far below the noise voltage. For signal levels as low as this it is obvious that special steps must be taken to reduce the noise inherent in the receiving equipment, otherwise the signals would be swamped by the noise generated within the receiver itself. Some of the techniques employed include the use of very narrow bandwidths with consequent low information rate and long transmission times, together with low noise devices such as masers and parametric amplifiers.

The picture so far may seem rather discouraging; that of a receiver in which every resistor, indeed every device, is busily churning out noise while the signal struggles bravely to be heard above the tumult. In fact, the situation is not as unfavourable as this.

One helpful factor is that not all parts of the receiving system have the same importance where noise is concerned. As we shall see, the major role is played by the first stage or stages. Also the effect of temperature change is not very serious in practice; since most resistors operate only over a limited range near room temperature. It is interesting to observe that not until the temperature approaches Absolute Zero, 273 degrees below zero degrees Centigrade, will the random motion of the electrons cease and the resistor become "quiet".

Since noise is closely associated with resistance it is sometimes useful to express the "noisiness" of a device in terms of an equivalent resistance across the input and to regard the device itself as noise-free. Thus, if a valve has an equivalent noise resistance of 500Ω , it means that the valve may be regarded as noise-free with a noise source equivalent to a 500Ω resistor across its input. Some low noise valves have an equivalent noise resistance of only a few hundred ohms, while noisier valves such as multigrad mixers may have a noise resistance of hundreds of thousands of ohms.

However, thermal noise plays a relatively minor part in the total noise output of valves and transistors. It is present of course wherever resistance is present but most of the noise in these devices is shot noise, so called because the effect is much the same as lead

shot falling on a tin plate. Shot noise arises wherever emission takes place, whether from a cathode surface or a base-emitter junction, and again, as with thermal noise in resistors, it is the random nature of the electron motion that is chiefly responsible. Transistors have the added complication of hole flow as well as electron flow and for a long time they had to give precedence to the valve in applications where low noise was the paramount factor. It is only recently that the transistor has come into its own in this respect and it may be that the field effect transistor, a unipolar device like the valve, will lead the way to really low-noise semi-conductors.

EQUIVALENT NOISE TEMPERATURE

Yet another way of expressing the noise present in a system is by its equivalent noise temperature. For example, an aerial may deliver far more noise to a receiver than can be accounted for merely by the thermal noise of the radiation resistance. This extra noise, called Galactic or Cosmic noise, arises in the Milky Way and other galaxies and in character is very like thermal noise. The aerial is said in these circumstances to have a noise temperature equal to that which would be required to generate the same level of thermal noise.

The usual method of describing the extent to which noise is associated with a signal is by means of the signal-to-noise ratio, abbreviated to S.N.R. It is generally expressed in decibels as a power ratio. Thus, if a signal of $5\mu V$ is associated with a noise of $1\mu V$, the S.N.R. is

$$10 \log \frac{(5\mu V)^2}{(1\mu V)^2} = 14dB.$$

The idea of signal-to-noise ratio is helpful in understanding why it is that the early stages of a system are so important.

Suppose a chain of amplifiers, as in Fig. 2, is needed to process a signal. The first amplifier in the series has a gain of 10 and generates noise equivalent to $1\mu V$ referred to its input. The second amplifier also has a gain of 10 but generates noise equivalent to $5\mu V$ referred to its input. The signal entering the system is $10\mu V$ associated with a noise voltage of $0.5\mu V$. A much clearer picture of the true situation is obtained by examining the S.N.R. at various points in the circuit.

The signal at the output of the first amplifier is,

$$10\mu V \times 10 = 100\mu V$$

The noise at the output of the first amplifier is,

$$0.5\mu V \times 10 = 5\mu V \text{ (associated with the signal)}$$

plus $1\mu V \times 10 = 10\mu V$. (generated by the amplifier).

Therefore the total noise at the output is $\sqrt{5^2 + 10^2}$

$$= 11.2\mu V, \text{ and the S.N.R. is } 10 \log \frac{(100\mu V)^2}{(11.2\mu V)^2} = 19dB.*$$

A similar calculation applied to the output of the second amplifier will show that here the S.N.R. is 18.2dB. Even though the second amplifier generates five times more noise than the first, it has relatively little effect on the S.N.R. This will always be so provided the first stage is a low noise amplifier of reasonable gain.

Since noise introduced early in the system will be amplified more than noise introduced later, such low-noise devices as triodes find widespread use as radio frequency amplifiers and mixers in systems where the signal-to-noise ratio at the input may be low, as in television reception. Triodes may well have less gain

*Total noise is the square root of the sum of the squares of the individual noise voltages.—Editor.

than some of their multigrid colleagues, but gain is relatively easy to achieve whereas low noise is not

Small wonder then that *noise* is the important design factor of many systems.



LOOK OUT FOR

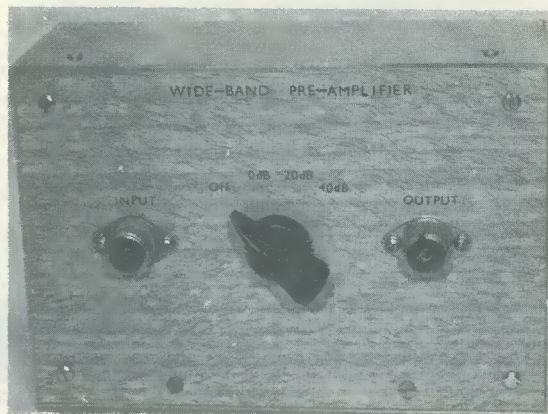
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Cover Feature

High Performance, Communications

by R. MURRAY-

AMONG THE FEATURES OF THE RECEIVER TO BE DESCRIBED in this and next month's articles are some which render the unit more versatile, and thus more useful, than similar receivers, whether these be commercial or otherwise. It is thought that the constructor who already owns a high performance receiver might find some portions of the present circuit adaptable to his own, thus increasing its usefulness.

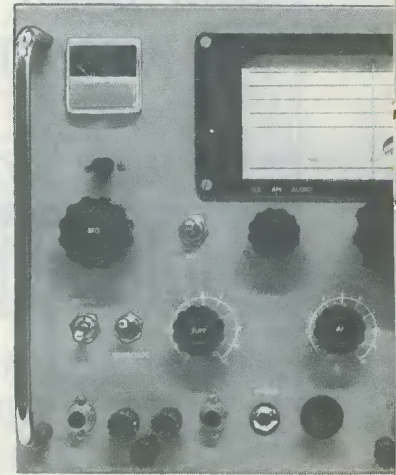
Inevitably, a receiver having the specification of the equipment to be described is rather complex. In this case, however, the construction has been kept as simple and straightforward as possible by the use, firstly, of a commercially made "front end" unit and, secondly, by the use of the "Lektrokit" chassis and cabinet building system which minimises mechanical metalworking. The "front end" unit referred to comprises the r.f. amplifier stage and first frequency changer, together with all coils and coil switching.

THE CIRCUIT

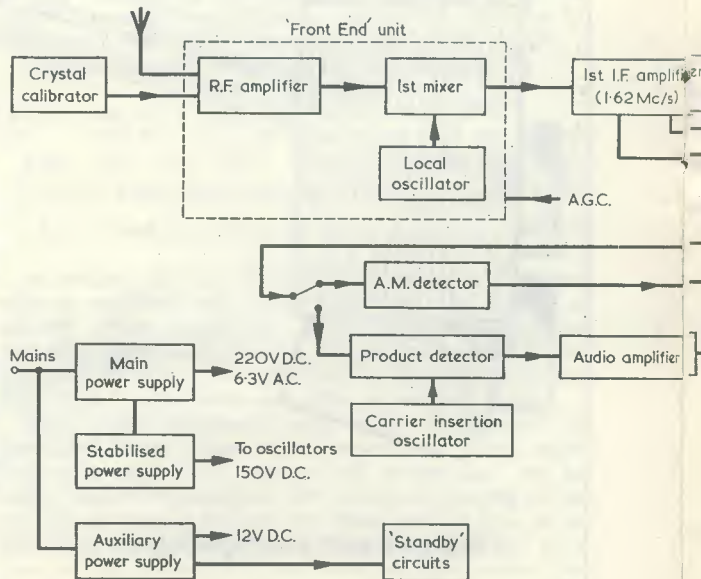
The complete circuit is shown in block diagram form in Fig. 1. The receiver is based on a "front end" unit, or "Qoilpax," manufactured by Electroniques of Harlow. Two versions of this unit are available. One, that used in the prototype, is restricted in coverage to the amateur bands only. The second is of the general coverage type, incorporating most of the medium waveband and 1.7 to 30 Mc/s, in a total of six bands. The full frequency specifications of the two units are given in the components list.

These two units are interchangeable so far as the receiver's circuitry is concerned. They are also virtually identical in physical size and appearance. It follows, therefore, that either may be incorporated in the receiver, the choice depending on the type of coverage required. If the constructor is primarily interested in the amateur bands, then the limited coverage model should be chosen. Thus, a very slow tuning rate—so essential to ease of operation on the crowded amateur bands—may be obtained when this limited coverage model is used in conjunction with a good quality tuning drive assembly.

The basic circuit of the front end unit is given in Fig. 2. An r.f. amplifier incorporating a frame grid valve type EF183 connected in a Miller compensating circuit is used. This ensures a low noise level at this most critical stage of any high performance receiver. Provision is made for connecting unbalanced or balanced feeder systems at will. This r.f. stage is followed by a triode heptode frequency changer using an ECH81. The oscillator section is fed from a stabilised high tension supply, and this, together with the negative temperature coefficient compensating components incorporated in the "front end" unit makes for a very high order of stability. The first intermediate



Aimed specifically at the more experienced constructor, this article, together with the concluding instalment next month, gives full details of a highly specialised communications receiver offering reception over either the amateur



Double Conversion Receiver—Part—1

SHELLEY, B.Sc.



bands or broadcast bands as desired. Full construction details are not given, but readers will find it of advantage to build up the receiver on Lektrokit Chassis System parts, as has been done by the author.

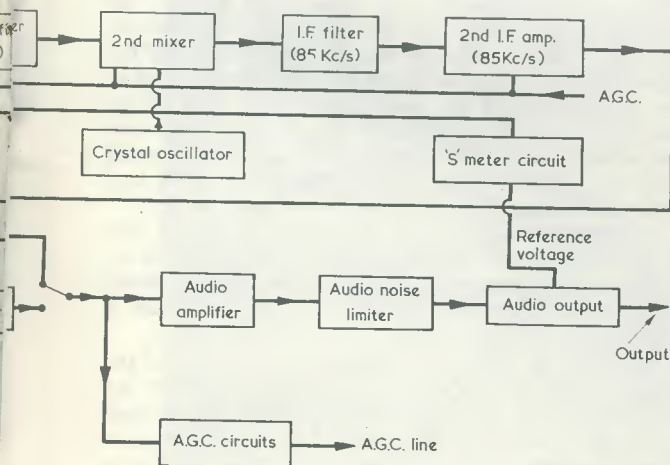


Fig. 1. Block diagram for the complete receiver

frequency output is at 1.62 Mc/s, and this may be obtained from either a high or a low impedance source. In order to reduce the possibility of interference by harmonics of the first intermediate frequency, an i.f. rejector circuit tuned to 1.62 Mc/s is included in the aerial circuit of the "front end" unit.

To ensure the best possible performance from the equipment, it is essential that a precision tuning drive assembly be used, and a suitable choice recommended by Electronics is the Eddystone type 898 drive assembly. This is a flywheel loaded system giving an overall reduction ratio of 110:1. Using this drive in conjunction with the amateur bands unit, a tuning rate better than 4kc/s per revolution (on the 1.8–2.0 Mc/s band) can be achieved. Naturally, a number of connections must be made to the "front end" unit and these are detailed in Fig. 3. This diagram also provides information about the "standby" system, which will be discussed in detail next month.

The capacitor C_1 shown in Figs. 2 and 3 calls for some comment. The function of this component is to act as a trimmer in the aerial circuit of the receiver in order to provide compensation for the reactive effects of aerials connected into the system. The inclusion of C_1 is optional, but it will be found that it is of some real assistance in peaking signals, particularly on the higher frequency bands. Details of this capacitor are given in the Components List, and it should be connected between the aerial gang of the tuning capacitor and chassis. If this trimmer is, in fact, included, then some retrimming of the front end unit circuits will be necessary. Details of this operation will be given later, but meanwhile it is essential to note that the internal adjustments within the "front end" unit must not be disturbed in any way until the receiver is completed. The "front end" unit is supplied pre-aligned and it is important to realise that many of the adjustments are, particularly in the case of the amateur bands unit, very critical. Constructors are very strongly advised to read the Operating Notes for the Qoilpax which are issued by Electronics before using the unit.

Following the "front end" unit comes an i.f. amplifier working at 1.62 Mc/s. See Fig. 4. This uses a 6BA6 (V_1), rather than a higher gain value such as an EF183. The gain in this portion of the circuit is limited deliberately to avoid the possibility of introducing cross-modulation effects in the following second frequency changer. An a.g.c. voltage is applied to this stage, as it is to a total of four stages in the receiver as a whole. The a.g.c. system is one of the more important features of the receiver and will be described in detail in next month's issue. The S-Meter circuit, part of which appears in Fig. 4, will be discussed in the next article.

Following the first i.f. amplifier comes the second frequency changer, V_2 . The principles of double conversion

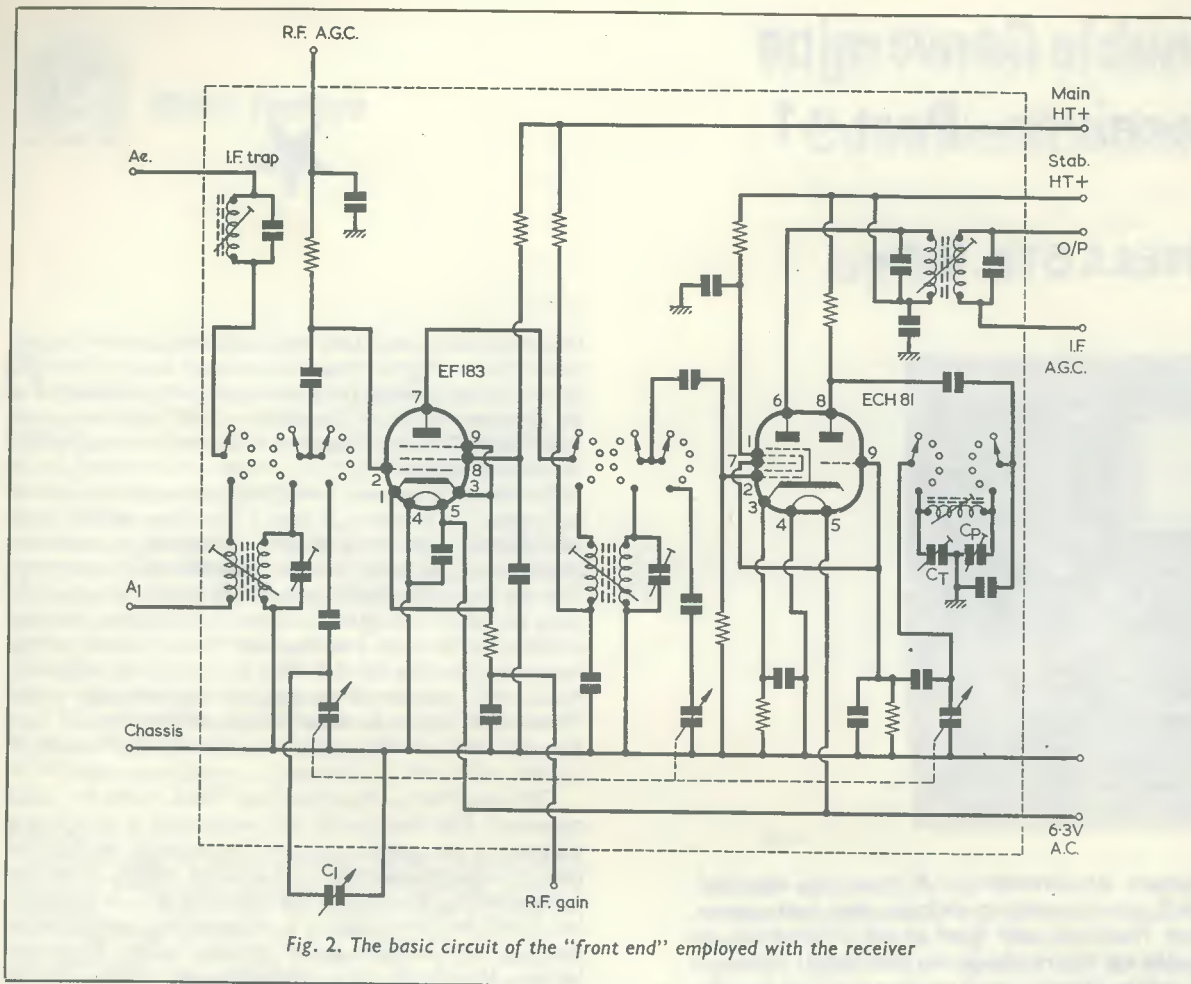


Fig. 2. The basic circuit of the "front end" employed with the receiver

are well known. A high intermediate frequency gives good protection against image responses, but poor adjacent channel selectivity. On the other hand a low i.f., while providing good selectivity, makes the elimination of images and spurious responses of that type very difficult.

The solution to the problem must therefore either be a compromise where an intermediate frequency is chosen that, while providing reasonable image protection, also provides acceptable selectivity, or, as in the present instance, the double conversion method must be used. Here, two intermediate frequencies are employed. One of these, at 1.62 Mc/s, is high, and therefore provides protection against images. The other is very much lower, at 85kc/s, and enables good adjacent channel selectivity to be achieved. It is also possible to construct a receiver having a high i.f. only, and then to produce the required selectivity by the use of crystal filters. Such filters are, however, expensive and can be difficult to obtain. Using the high quality i.f. transformers specified in the Components List, a bandwidth between 3dB points of under 3 kc/s can be readily obtained. The sensitivity of the receiver as a whole is better than 0.5 microvolts applied to the aerial sockets for a 6dB signal-to-noise ratio measured at the audio output.

SECOND FREQUENCY CHANGER

This is a triode-heptode configuration using a second

ECH81, V₂, and is shown in Fig. 4. The oscillator section is crystal controlled employing a crystal at a frequency of 1,535 kc/s. Such crystals may be available from time to time on the surplus market, though that used in the prototype receiver was specially ground for the author. Since the i.f. transformers specified can be tuned over the range 80-90 kc/s without significant loss of efficiency it is, therefore, possible to use crystals having frequencies in the range 1,530 to 1,540 kc/s, rather than the 1,535 kc/s unit just mentioned. The use of a crystal at 1,530 kc/s, would produce a second i.f. of 90 kc/s, while an i.f. of 80 kc/s would be obtained if the crystal resonated at 1,540 kc/s.

Although not checked by the author, it should also be possible to use crystals in the range 1,700kc/s to 1,710kc/s, these causing the triode to oscillate above 1.62 Mc/s. The use of such crystals may necessitate a reduction in the value of C₁₈.

The tuned circuit, L₁ C₁₈, in the anode network of the oscillator serves to reduce the harmonics generated by the system, and thus minimises the problem of spurious responses which might otherwise become significant. The anode voltage of the triode section is maintained at a relatively low level. This ensures stable operation, and the production of the correct injection voltage for efficient conversion. Some conversion gain is provided by the arrangement, and it is found possible to apply a.g.c.

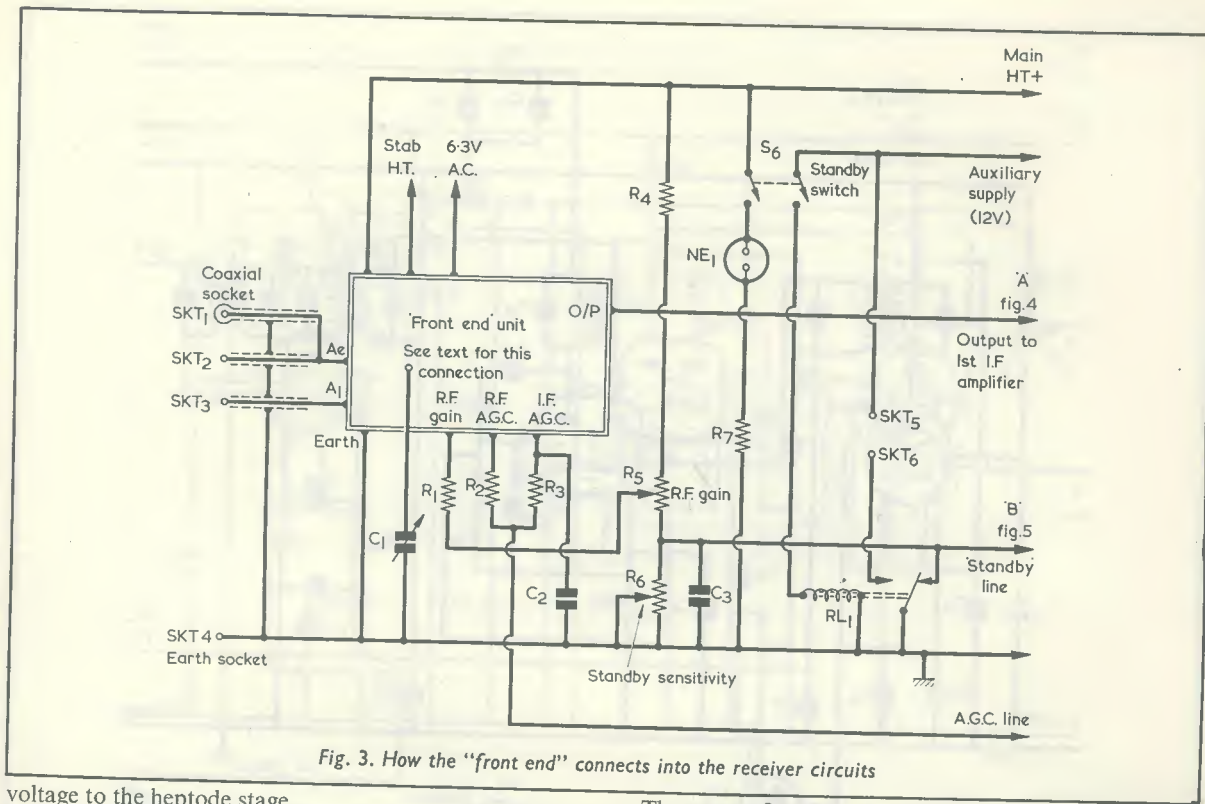
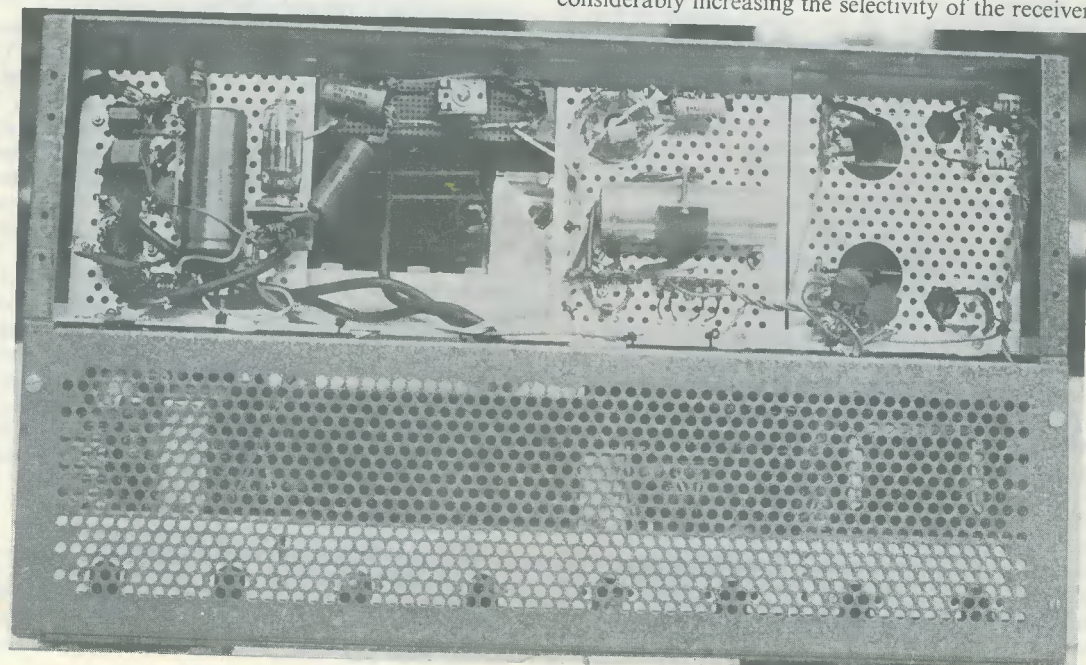


Fig. 3. How the "front end" connects into the receiver circuits

voltage to the heptode stage.

(The coil employed by the author for L_1 was the earlier Electronics type DLM14, this being a screened coil with adjustable dust core having a range of 50 to 75 μ H. The current Electronics dust-cored coil type SHQ-M/PC, in the same size can and with a centre inductance of 68 μ H, should be equally satisfactory.—EDITOR).

The output from the second frequency changer, now at a nominal frequency of 85 kc/s, is passed to the following i.f. filter. This filter, which is also shown in Fig. 4, consists simply of two high quality i.f. transformers, connected back-to-back and coupled by the very small capacitance given by C_{16} . There are thus four tuned circuits coupling the second frequency changer to the following stages, considerably increasing the selectivity of the receiver as a



Rear view of the receiver. The crystal calibrator trimmer appears in the upper centre

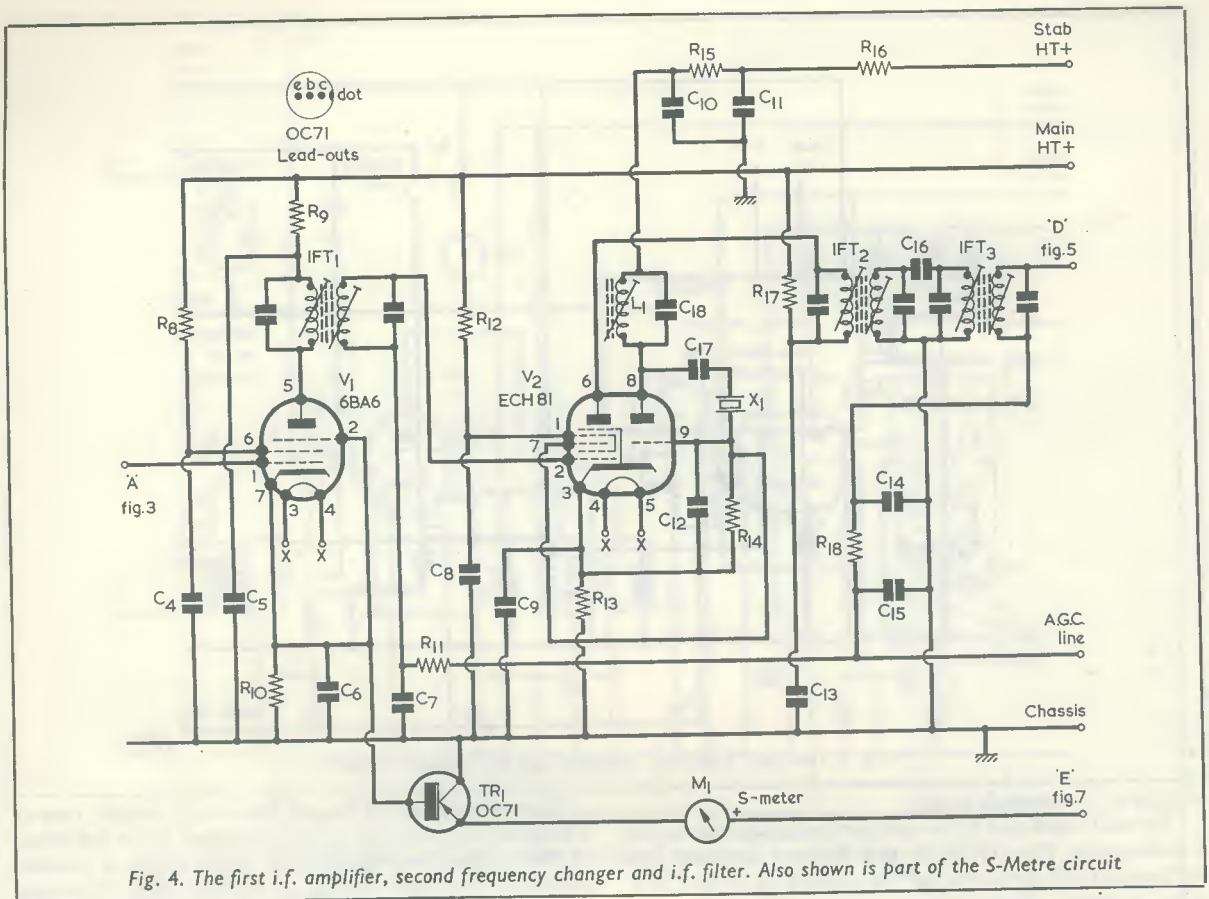


Fig. 4. The first i.f. amplifier, second frequency changer and i.f. filter. Also shown is part of the S-Metre circuit

whole.

The second i.f. amplifier follows immediately after the i.f. filter, and the circuit of this stage is shown in Fig. 5. This, of course, works at a frequency of 85 kc/s, and it uses an EF183 in a high gain configuration. Through smoothing of all power supply circuits and careful r.f. decoupling ensures that no trace of instability can be detected in the prototype. The detector circuits, of which there are two catering for a.m. and s.s.b. (Single Sideband) signals, are fed from this stage.

DETECTION

Simpler receivers normally cater for the reception of a.m. signals only. Often a beat frequency oscillator (b.f.o.), sometimes called a carrier insertion oscillator (c.i.o.), is included to enable reception of carrier wave (c.w.) and s.s.b. signals to be accomplished. In most cases, however, the output from the oscillator is very loosely coupled to the a.m. detector, resulting in the fact that the arrangement is suitable for c.w. reception, but quite unsatisfactory from the point of view of s.s.b. signals. Difficulty in receiving s.s.b. transmissions is almost always due to the inability of the b.f.o. to supply a sufficiently high injection voltage where it is needed at the a.m. detector.

This difficulty is overcome in the present receiver by employing separate detectors for a.m. and s.s.b./c.w. signals, as shown in Fig. 5. The narrow bandwidth presented by the receiver circuits means also that narrow band frequency modulated (n.b.f.m.) signals may be received using the a.m. detector and the process of "slope

detection." For a.m. signals a fairly conventional form of detector consisting of two germanium diodes, D_1 and D_2 , connected in a voltage doubler arrangement is used. A product detector, V_4 , with associated carrier insertion oscillator (whose output is injected at point "G") is provided for the reception of other forms of signal. Two detectors are necessary since a product detector is not suitable for a.m. reception. The type of detector required is selected by suitable switching circuits actuated by S_1 (a) (b) (c). An additional stage of audio amplification, given by V_5 , is found to be necessary following the product detector, since the output from this detector is somewhat lower than from its a.m. counterpart. This is due to the fact that, in order to prevent distortion being generated by the product detector, the input signal to it must be rather limited. No cathode bypass capacitor is provided for V_5 , as this valve offers sufficient gain without. The carrier insertion oscillator, V_6 in Fig. 6, uses a coil assembly which, besides the coil itself, also contains the frequency determining capacitors and valve grid resistor. Negative temperature compensation is incorporated within the unit, which is all contained in a standard can. Details of the unit are given in the Components List.

CRYSTAL CALIBRATOR

Also shown in Fig. 6 is the transistorised crystal calibrator circuit, which produces marker pips at 100 kc/s intervals up to more than 30 Mc/s. This particular circuit is of course quite optional, but it will be found to be of much assistance in calibrating the receiver, particularly if

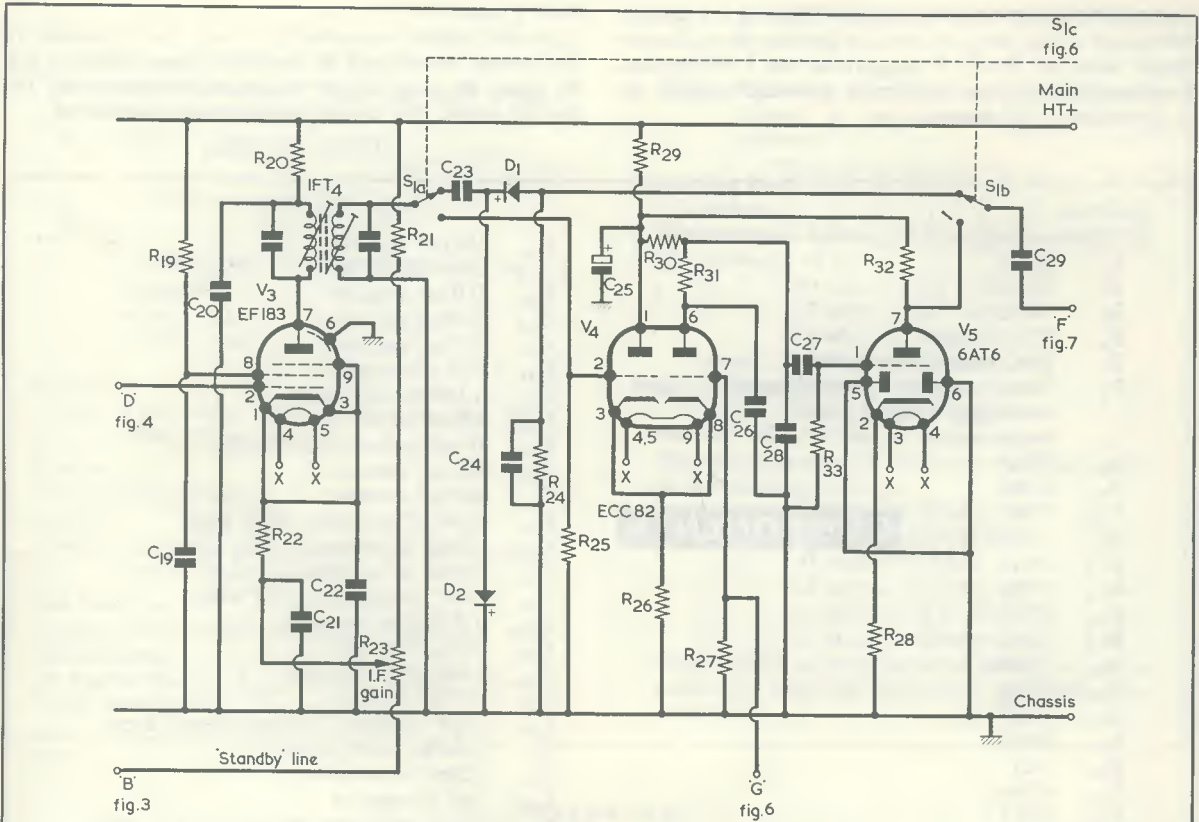


Fig. 5. The second i.f. amplifier and detector stages

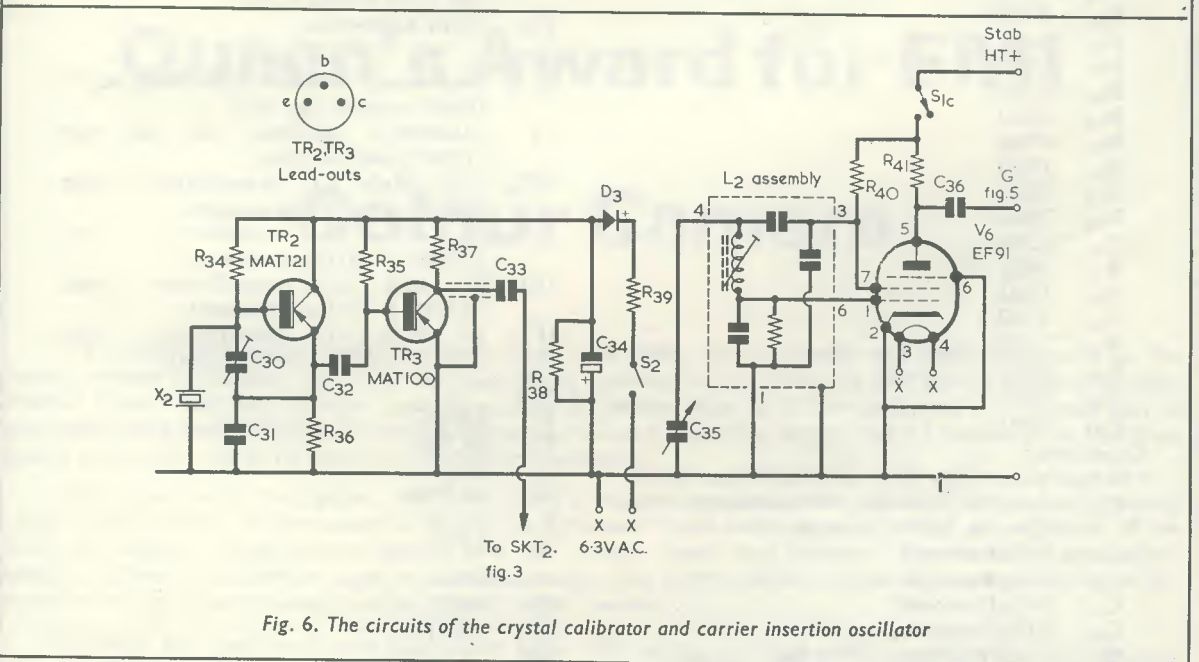


Fig. 6. The circuits of the crystal calibrator and carrier insertion oscillator

the general coverage "front end" unit is to be used. Two microalloy transistors are employed, the first as an oscillator and the second as a harmonic amplifier. The
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unit is powered from the main receiver heater supply line as shown. The output couples to socket SKT₂, which is mounted on the front panel. Variable capacitor C₃₀ is

employed to bring the crystal on exact frequency, a suitable method of doing this consisting of beating the calibrator output with the Radio 2 programme on 1,500 metres, employing a long wave receiver in the usual manner for an operation of this nature.

NEXT MONTH

In next month's concluding article, the remainder of the receiver circuits will be described. Since reference will be made to some of the diagrams accompanying the present article, this month's issue should be retained.

(To be concluded)

COMPONENTS

Resistors

(All fixed values $\frac{1}{2}$ watt 10% unless otherwise stated)

R ₁	220Ω
R ₂	470kΩ
R ₃	100kΩ
R ₄	25kΩ 2 watts
R ₅	10kΩ potentiometer, linear, 1 watt
R ₆	25kΩ preset potentiometer, panel mounting, linear, 2 watts
R ₇	Series resistor to suit NE ₁ (for 220 volts)
R ₈	47kΩ
R ₉	3.3kΩ
R ₁₀	120Ω
R ₁₁	100kΩ
R ₁₂	47kΩ
R ₁₃	270Ω
R ₁₄	47kΩ
R ₁₅	22kΩ
R ₁₆	220kΩ
R ₁₇	3.3kΩ
R ₁₈	100kΩ
R ₁₉	39kΩ
R ₂₀	1kΩ
R ₂₁	470kΩ
R ₂₂	120Ω
R ₂₃	25kΩ potentiometer, linear, 1 watt
R ₂₄	470kΩ
R ₂₅	470kΩ
R ₂₆	820Ω
R ₂₇	100kΩ
R ₂₈	3.3kΩ
R ₂₉	33kΩ
R ₃₀	47kΩ
R ₃₁	10kΩ
R ₃₂	33kΩ
R ₃₃	220kΩ
R ₃₄	2.2MΩ
R ₃₅	1MΩ
R ₃₆	12kΩ
R ₃₇	47kΩ
R ₃₈	2.2kΩ
R ₃₉	47Ω
R ₄₀	47kΩ
R ₄₁	22kΩ

Capacitors

(All fixed values 500V wkg. unless otherwise stated)

C ₁	4-12.5pF, variable, Eddystone type 580. Cat. No. E.580 (Home Radio)
C ₂	0.01μF ceramic
C ₃	0.01μF ceramic
C ₄	0.01μF ceramic
C ₅	0.01μF ceramic
C ₆	0.1μF polyester, 250V wkg.
C ₇	0.01μF ceramic
C ₈	0.01μF ceramic
C ₉	0.1μF polyester, 250V wkg.
C ₁₀	0.01μF ceramic

C ₁₁	0.01μF ceramic
C ₁₂	20pF silver-mica
C ₁₃	0.01μF ceramic
C ₁₄	0.01μF ceramic
C ₁₅	0.01μF ceramic
C ₁₆	5pF silver-mica
C ₁₇	1,000pF silver-mica
C ₁₈	150pF silver-mica
C ₁₉	0.1μF polyester, 250V wkg.
C ₂₀	0.01μF ceramic
C ₂₁	0.01μF ceramic
C ₂₂	0.047μF polyester, 250V wkg.
C ₂₃	100pF silver-mica
C ₂₄	500pF silver-mica
C ₂₅	16μF electrolytic, 350V wkg.
C ₂₆	1,800pF silver-mica
C ₂₇	0.01μF ceramic
C ₂₈	1,800pF silver-mica
C ₂₉	0.01μF ceramic
C ₃₀	50pF trimmer, "postage stamp" type
C ₃₁	1,800pF silver-mica
C ₃₂	120pF silver-mica
C ₃₃	5pF silver-mica
C ₃₄	250μF miniature electrolytic, 15V wkg.
C ₃₅	50pF, variable, Eddystone type 589. Cat. No. E.589 (Home Radio)
C ₃₆	100pF silver-mica

Inductors

L ₁	Iron cored inductor type SHQ-M/PC (Electroniques) (See text)
L ₂	(Assembly). Oscillator coil unit type HS085 (Electroniques)
IFT ₁	1.62 Mc/s i.f. transformer, type S2/DIF-1-16 (Electroniques)
IFT ₂	85 kc/s i.f. transformer, type S2/DIF-1-85 (Electroniques)
IFT ₃	85 kc/s i.f. transformer, type S2/DIF-1-85 (Electroniques)
IFT ₄	85 kc/s i.f. transformer, type S2/DIF-1-85D (Electroniques)

Valves

V ₁	6BA6
V ₂	ECH81
V ₃	EF183
V ₄	ECC82
V ₅	6AT6
V ₆	EF91

Semiconductors

TR ₁	OC71
TR ₂	MAT121
TR ₃	MAT100
D ₁	OA81
D ₁	OA81
D ₂	OA81
D ₃	OA81

Crystals

- X₁ 1,535 kc/s. 20pF load, ambient temp. operation (see text)
X₂ 100 kc/s. standard crystal

Meter

- M₁ "S" meter. 0-1mA moving coil

Switches

- S₁ 3-pole 2-way (break-before-make type essential)
S₂ s.p.s.t. toggle
S₆ d.p.s.t. toggle

Relay

- RL₁ Lightweight relay, 977Ω coil. Cat. No. Z70C. (Home Radio)

Sockets

- SKT₁ Coaxial socket
SKT₂—
SKT₆ Terminals with top socket. Belling-Lee type L.759 or similar

Dial Drive, etc.

- Slow-motion Drive Assembly. Cat. No. 898 (Eddystone)
6 knobs (for R₅, R₂₃, C₁, C₃₅, S₁ and "Front end" band switch)

Lamp

- NE₁ Miniature neon lamp assembly. (If series resistor is incorporated, R₇ may be omitted)

Front End Unit

Use either:—

Electroniques type GC166 (general coverage) to give coverage of:—

- 550 kc/s — 1.5 Mc/s
1.7 Mc/s — 4.1 Mc/s
4.0 Mc/s — 8.0 Mc/s
7.5 Mc/s — 15 Mc/s
14 Mc/s — 22 Mc/s
20 Mc/s — 30 Mc/s

Or:—

Electroniques type QP166 (amateur bands only) to give coverage of:—

- 1.8 Mc/s — 2.0 Mc/s
3.5 Mc/s — 4.0 Mc/s
7 Mc/s — 7.3 Mc/s
14 Mc/s — 14.4 Mc/s
21 Mc/s — 21.5 Mc/s
28 Mc/s — 30 Mc/s

Both of these units are interchangeable and can be employed with the Eddystone type 898 drive assembly.

Queen's Award for EMI Colour Camera

The outstanding success of EMI Electronics' Type 2001 colour camera has been recognised by the Queen's Award to Industry. Since it was launched in February of last year, the EMI colour camera has consistently made news with its sales successes. Just six weeks after its debut, orders for this camera and its associated equipment totalling £1 million had been received; after five months the £2 million mark had been passed and orders worth £3 were announced only recently.

A large measure of the camera's success is due to unique design features resulting in the most compact 4-tube colour camera yet produced for broadcast purposes. These include the "capstan" arrangement of the tubes, the direct-imaging optical system and the integral zoom lens package. The camera's operational stability and ease of operation, together with the outstanding quality of the signals originated, have led to the largest orders for colour cameras so far placed in this country.

EMI have now sold well over 100 of the Type 2001 colour cameras since their introduction just over fifteen months ago. The BBC alone have bought over fifty Type 2001 cameras and the new independent company, London Weekend, have recently ordered 22 channels ready for the start of commercial colour programmes. The 2001 was also used extensively during the world-wide television coverage of the recent Winter Olympics. The pictures it produced—some of which were received direct by satellite in the United States—attracted much favourable comment from many informed sources.



SELECTIVE AND SENSITIVE CRYSTAL SET

by P. A. DEWHURST

One of the more intriguing factors influencing the design of "crystal" sets (i.e. receivers employing a germanium diode and no amplification) is that they offer a signal at no cost in battery consumption. In this article our contributor describes experiments which result in a medium wave crystal receiver circuit having a performance considerably superior to that normally offered by receivers of this type

THERE IS ALWAYS A FASCINATION IN TRYING TO GET something for nothing, and this is doubtless why crystal sets always seem to arouse interest whenever they are mentioned. The present writer decided to see what could be done to improve the performance of the usual types of crystal set, having found that in his present locality (about 5 miles south of Oxford) such a receiver is of very little use.

First Experiments

The first thing to do was to determine what sort of results the ordinary circuit would give, and to take some reasonably precise measurements against which any later improvements could be judged.

The circuit employed for the initial tests is shown in Fig. 1. The earth connection was taken from the earth pin of a 3-way mains socket, as the writer lives in an upstairs flat. Coil L_1 , in Fig. 1, consisted of 70 turns of 26 s.w.g. enamelled wire, close-wound on a 1.5in diameter former.

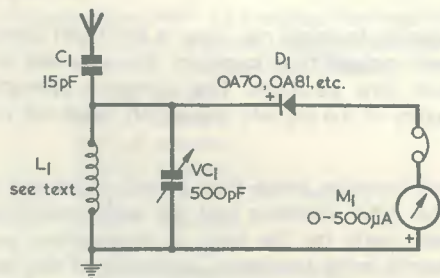


Fig. 1. A standard circuit for a "crystal set"

The first aerial tried was 150ft long, from a 45ft tree in the garden to the window, at which point the wire was about 25ft above the ground; and the following results were obtained. The Radio 3 programme on 464 metres gave a reading of $12\mu\text{A}$ in the meter and was a fairly strong signal of good programme value, but the London Radio 4 service on 330 metres and Midland Radio 4 service on 276 metres tuned as one signal, giving a reading of about $2.5\mu\text{A}$. This signal was just loud enough for listening in a reasonably quiet room, and there was some interference from the Radio 3 programme in the background. If C_1 was made any larger than 15pF there was too much interference from the Radio 3 programme when listening to the Radio 4 service, although of course the meter reading increased. Making C_1 smaller, in an attempt to get rid of the interference completely, merely rendered the Radio 4 signals too weak to be of any use. Tapping the aerial down the coil offered no improvement either.

The next aerial tried was the television aerial (with the connection taken to both the outer and the inner conductors of the coaxial cable). The TV aerial consists of the usual H-type array for B.B.C.1 and a multi-element beam for I.T.V. on the apex of the roof, with about 40ft of coaxial cable running down the roof and into the window. The following results were obtained. When the circuit was tuned to the Radio 3 programme a meter reading of $10\mu\text{A}$ was given with, again, quite a strong signal of good programme value, but the two Radio 4 services tuned together as before, giving a reading of approximately $1.5\mu\text{A}$ with some interference from the Radio 3 programme. For this test C_1 was 15pF, as in the previous case. Although the meter readings were slightly less than those given with the long horizontal aerial, no difference in signal strength could be detected by ear.

It was decided next to try a 20ft length of wire stretched out along the wall of the room just below the ceiling. C_1 was omitted for this test, the aerial being connected direct to the upper end of L_1 , and the following results were obtained. The Radio 3 programme gave a reading of $8\mu\text{A}$ —quite a good signal and quite satisfactory for normal listening—but the two Radio 4 services again tuned as one signal with the Radio 3 programme almost as loud, and did not deflect the meter needle. The Radio 4 signal was not loud enough for prolonged listening.

Three conclusions were drawn from these experiments. First, a long horizontal outdoor aerial does not give results that are very much better than a fairly short vertical aerial (the television aerial downlead), and so is hardly worth putting up in many cases. This is reasonable when it is considered that the B.B.C. uses vertical aerials for their medium wave transmitters. Second, a single tuned circuit does not enable one to make the most of the available signal and does not offer enough selectivity. Third, signals offering anything over $2\mu\text{A}$ or thereabouts in the meter give an acceptable listening level.

Final Circuit

After much experimenting with various circuits, that shown in Fig. 2 was found to be the most successful. In this circuit, coil L_1 consists of 80 turns close-wound of 26 s.w.g. enamelled wire on a 3in diameter former, with taps at 20, 40 and 60 turns. Thus, one may have in circuit either 20, 40, 60 or 80 turns, depending on the length and capacitance to earth of the aerial in use. This coil should take care of most aerial lengths. Fine

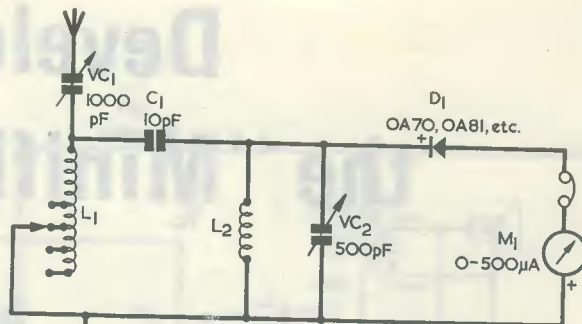
tuning of the aerial circuit is performed with VC₁, which consists of a 500+500pF 2-gang capacitor with both sections in parallel. The desired tapping on L₁ is that which gives the required signal with VC₁ fairly well meshed.

Coil L₂ consists of 70 turns of 26 s.w.g. enamelled wire close-wound on a 1.5in diameter former. It is important to note that the axes of L₁ and L₂ must be at right angles to each other, as the only coupling between the two coils should be that provided via C₁.

The following results were obtained with this circuit. (No results are given for the long horizontal aerial as by this time it has been taken down.) Using the television aerial, again with the earthing point taken from the 3-way mains socket, the Radio 3 programme on 464 metres gave a meter reading of 110µA, and provided a very strong signal which could be heard 10 to 15ft away from the headphones. The two Radio 4 services could now be separated and the one on 330 metres gave a reading of 20µA together with a strong signal amply loud for most listening conditions, while the 276 metre transmission gave a reading of 7.5µA with a reasonably good signal, also quite loud enough. Both Radio 4 signals were completely free of interference. The Radio 1 programme on 247 metres was now obtainable (at the time of carrying out the tests, this was rather a weak signal in the writer's locality) but gave no observable meter reading. This signal was just strong enough for listening in a quiet room. The 40 turn tap of L₁ was employed for all signals with the television aerial.

The 20ft indoor aerial was then tried and gave the following results. The Radio 3 programme required 80 turns, the whole of L₁, and gave a reading of 12µA together with a good signal. Both the Radio 4 services required 60 turns in L₁ and the 330 metre transmission gave about 2.5µA and a reasonable signal, while the 276 metre transmission gave about 2µA and an audible signal suitable for a reasonably quiet background (e.g. listening in bed, etc.). The 247 metre transmission was not audible, as was expected.

This circuit has also been tried in the North of England, in a locality where the Radio 3 programme on 464 metres and the North Radio 4 service on 434 metres are inseparable on the normal crystal set unless the aerial is tapped down the coil until the signals are extremely weak. The new circuit gave strong signals on each programme using a 50ft outdoor aerial (Radio 3 programme, 145µA; Radio 4 service, 75µA) and it was easy to separate the signals completely.



L₁, L₂, VC₁ - see text

Fig. 2. This is the circuit which was finally developed, and it gave results considerably better than are provided by a normal crystal receiver

It must be admitted that the circuit of Fig. 2 is a little more tricky to tune up than an ordinary crystal set, but it is thought that the results more than justify the extra complication. One soon gets used to tuning two circuits at the same time and to the fact that they interact slightly (that is, the tuning of VC₁ slightly affects the tuning of VC₂ and vice versa). This effect could be reduced by lowering the capacitance of C₁, but at the cost of a reduction in signal strength. Besides, the effect is not troublesome.

No details are given for the long wave band, as this has not been tried, but doubtless similarly spectacular improvements in headphone strength could be made by applying the same principles.

Best results will be obtained using high impedance headphones, but low resistance ones will work reasonably well. It is important that the crystal diode be a first grade component. Types such as the OA70, OA81, etc., will all work well.

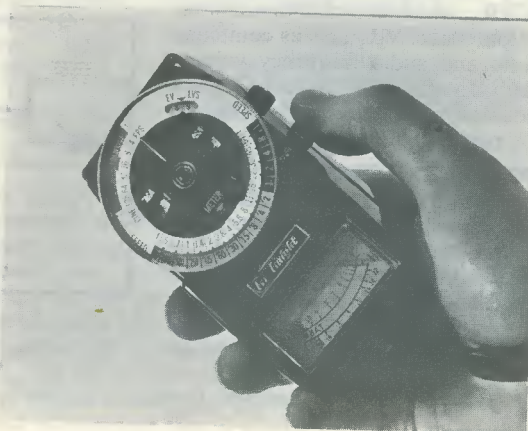
For those who intend to operate the circuit of Fig. 2 not too far from the ground, better results may be obtained by making a proper low resistance earth connection.

In most cases it should be found that several Continental stations are receivable after dark, particularly Radio Luxembourg and some of the German transmitters.

It is not necessary, of course, to use the microammeter, but it is useful for making precise measurements and comparisons.

KNIGHT-KIT KG275A EXPOSURE METER

The Knight KG-275A Exposure Meter, one of the "Knight-Kit" construction kits now being marketed in the UK and Europe exclusively by Electroniques (prop. STC Ltd.). "Knight-Kits" are easy to assemble kits which enable anyone, regardless of their technical knowledge, to construct professional standard electronic apparatus. The KG-275A is an ultra sensitive device featuring cine and E.V. scales and capable of responding to 0.014 foot/candles of incident or reflected light.



Developing the "Miniflex" Circuit

by

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

This article describes a development of the author's successful "Miniflex" circuit which, by taking advantage of silicon transistors, offers a reduction in components and a very useful battery economy feature. This medium wave 3-transistor receiver is intended for use with its own built-in loudspeaker, and its high performance is largely due to the ingenious reflexing of the first two stages. If desired, additional components may be added to provide reception at 1,500 metres on the long wave band

IN A RECENT ARTICLE¹ THE AUTHOR DESCRIBED A SMALL personal receiver which used a new reflex circuit. Six stages were provided with very few components, and loud speaker operation was made possible with an external unit. Fig. 1 shows the circuit with the speaker in use.

For readers who do not have the earlier article to hand, the circuit can be briefly described as follows. TR₁ is a common collector high frequency amplifier, followed by TR₂ as a high frequency common emitter amplifier. The signal is demodulated by D₁ which is a high resistance detector—normal silicon or germanium diodes will not work in this circuit—and is then passed back to TR₁ and TR₂ acting as a super alpha pair at audio frequencies. A step up transformer is used to match the low impedance output of TR₂ to the input impedance of TR₃, which is a common emitter output stage. VR₁ acts as combined radio and audio frequency volume control and reaction control. C₁ gives a capacitive tap into the tuned circuit for reaction purposes.

DESIGN DEVELOPMENT

Since the previous article was written, experiments have been undertaken with a view to developing the design to give best results in a version using a built-in speaker. Fig. 2 shows the circuit finally adopted. An important advantage

of the revised design is that it provides a form of economic operation which enables good volume and quality to be obtained from local stations together with reduced battery current on weaker stations, or on local stations turned down to a low volume level. This will be described later.

A slight snag with the original design was a tendency for the receiver to "spill over" for a minute or two after first switching on when tuned to a weak station demanding a critical reaction setting. The disadvantage is of minor importance when ear-phones are used as the receiver is

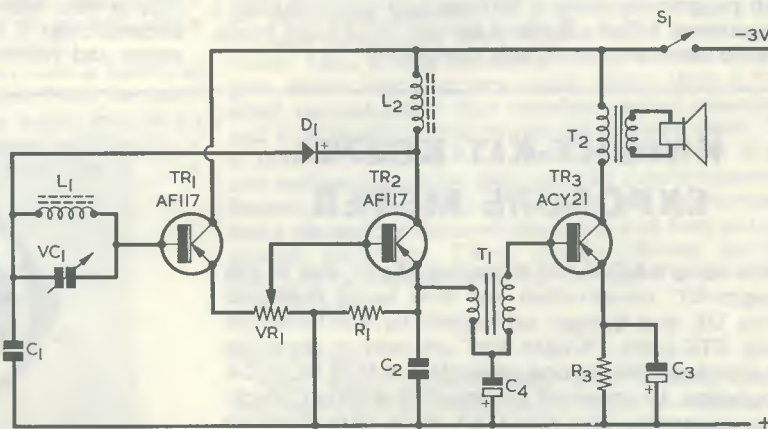


Fig. 1. The original "Miniflex" circuit, connected for loudspeaker operation

¹ Sir Douglas Hall, "The 'Miniflex' Dual Purpose Personal Receiver", *The Radio Constructor*, June 1968.

then of necessity close to the operator; but it is a nuisance when using a speaker. However, with the very low leakage current exhibited by silicon transistors, and by using a wirewound volume control with its greater stability, this effect has disappeared in the new version.

A further advantage for a loudspeaker design accrues from using silicon transistors for TR₁ and TR₂. The comparatively large voltage needed between base and emitter of a silicon transistor means that at the end of the line there is more voltage available between emitter and collector of the output transistor, and its emitter resistor can be reduced in value. This results in greater output for the same current, or greater economy for the same output. In fact, it was found that it was not possible to use a silicon transistor in the output stage without increasing the battery above the specified 3 volts, since there was insufficient voltage between base and emitter of the output transistor to allow a silicon device to pass enough current for satisfactory output, even with the emitter resistor short circuited. A germanium transistor is therefore used for TR₃, and the emitter resistor is reduced from the 39Ω of the previous design to 15Ω.

In Fig. 1, a resistor of 470Ω is used to provide suitable base bias for TR₃. With silicon transistors for TR₁ and TR₂, a resistance of 150Ω is required. By selecting a suitable transformer this resistance is provided by a proportion of a winding directly between the emitter of TR₃ and the negative supply line. The Ardenite D3026 transformer used is intended as a step down device for a Class B output stage giving a ratio of 1.6:1. Connected as shown in Fig. 2 it provides a step up of voltage in the ratio of 1.5:2, and the components R₁ and C₄ of Fig. 1 are no longer required. C₃ in Fig. 1 is also dispensed with since with the small emitter resistor of 15Ω, the negative feedback which results can be tolerated and, indeed, helps to give good quality.

A final basic modification is in the output transformer chosen. With TR₃ passing rather less current, and having rather greater voltage across it, a somewhat higher ratio is required than in the Fig. 1 design. The Colne Electric transformer now specified has a ratio of 6.4:1 and is capable of passing the necessary current without saturation. A very small transformer (or one with a higher primary resistance than 2Ω) should be substituted.

INHERENT ECONOMY

Perhaps the most interesting of the advantages in the

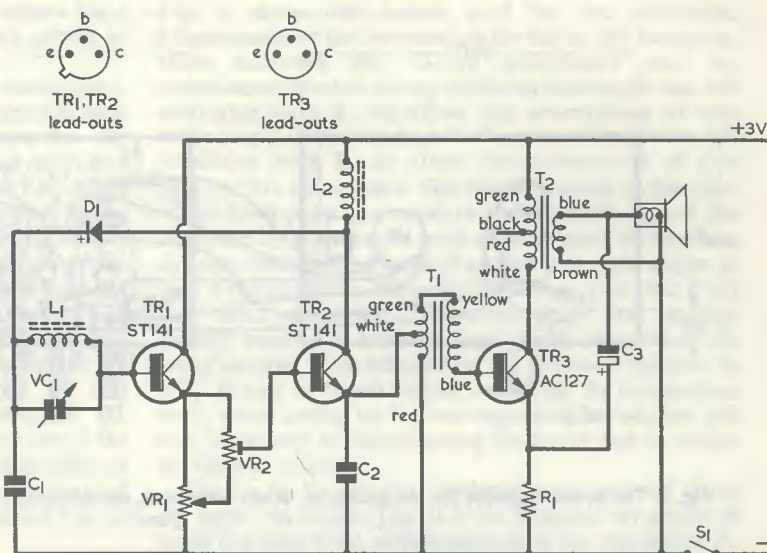


Fig. 2. The developed version, also for loudspeaker operation, employing silicon transistors in the first two stages

Resistors

- R₁ 15Ω 10% ¼ watt
- VR₁ 5kΩ potentiometer, wirewound
- VR₂ 500Ω preset potentiometer, skeleton type

Capacitors

- C₁ 0.005μF
- C₂ 0.01μF
- C₃ 200μF electrolytic, 3V wkg.
- VC₁ 300pF variable. "Dilecon", Cat. No. 2094 (Jackson Bros.)

(N.B. C₂ may require adjustment if the long wave circuit is added.)

Inductors

- L₁ Aerial coil on 6in x ¾in dia. ferrite rod (see text)
- L₂ 2.5mH r.f. choke (Repanco)
- T₁ Transformer, Ardenite type D3026. Cat. No. TRC25A (Home Radio)
- T₂ Transformer, Colne Electric type 04059 (Henry's Radio)

Semiconductors

- TR₁ ST141 (Sinclair)

- TR₂ ST141 (Sinclair)

- TR₃ AC127

- D₁ Diode type M3 (Available as "half-wave meter rectifier" from Henry's Radio, under Cat. No. MR50 from Home Radio)

Switch

- S₁ s.p.s.t. on-off, toggle switch

Battery

- 3-volt battery, No. 800 (Ever Ready)

Loudspeaker

- Elliptical, 8in x 5in, 3Ω

Miscellaneous

- Tagboard
- Knobs
- Plywood (see text)
- Wire, etc.

Additional components for reception on 1,500 metres.

- VC₂ 500pF trimmer
- S₂ 2-pole 2-way switch, miniature slide
- L₃ Long wave aerial coil on 8 x ¾in dia ferrite rod (see text)

new circuit is the inherent economy feature already mentioned. It was pointed out in the earlier article that the supply current passed became less as the volume was turned down. This still applies, in the present design, except in so far as TR₁ is concerned when the potentiometer VR₂ is fitted. Current through this transistor will then tend to rise with a reduction in the setting of VR₁, but the relatively large current which flows through TR₃ will, of course, predominate.

Let us suppose that a strong carrier is tuned in. A

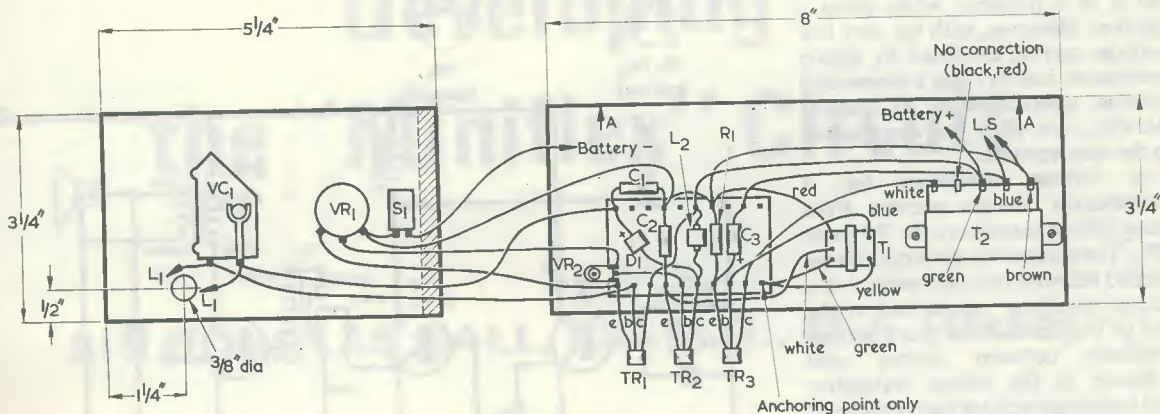


Fig. 3. The layout employed for the prototype. When assembled, the left-hand panel is secured to the edge of the right-hand panel

voltage will be developed by D_1 which will increase the current passed through TR_1 . This, in turn, will increase the current passed through TR_2 and, particularly, TR_3 . Although this effect occurred to some extent with the design of Fig. 1, it is now much more marked because of the lowering of the value of the output emitter resistor. The result of all this is that, when listening to a powerful local station, TR_3 passes a large current and is capable of giving good output. When volume is reduced, either by selecting a weaker station, or by turning down the volume control, current is reduced, together with power handling capability. Measurement showed that when listening to the local station, with volume set high, a little over 30mA passed through TR_3 , maximum undistorted output being about 38mW. Tuning to a weaker station, without moving the volume control, reduced the current passing through TR_3 to 15mA and power output available to about 20mW. Tuning in the local station again, and reducing volume to "bedside level" cut the current passed by TR_3 down to 8mA only, though quality at this reduced volume level remained satisfactory.

Although this effect offers a rather similar result to that obtained with Class B output stages, in that the current passed increases with volume, there is little really in common, as with Class B amplification the current passed is determined by the amplitude of the demodulated signal and is independent of the strength of the carrier. The current changes constantly throughout the programme; whereas with this design the current passed depends on the setting of the volume control and the amplitude of the r.f. signal picked up by the ferrite aerial, and it is steady for any fixed setting of the volume control or amplitude of incoming r.f. signal. There is no question that greater efficiency in the way of power delivered for current passed is given by the Class B method; but the author considers that for a given power output, better quality results from the system used in this circuit since there is no constantly fluctuating current with a consequent fluctuation of voltage as soon as the battery begins to age, and there is not the distortion which so often results from bias arrangements within the Class B network being imperfect. It might also be mentioned that 38mW with an 8in by 5in speaker probably gives greater acoustic output—which is what we are really interested in—than 200mW

from a miniature speaker. Certainly it will sound vastly better.

The use of a No. 800 cycle lamp battery is a further economy as it has an excellent power to price ratio. A reasonably good indication of the relative capacities of different sized batteries, provided they are made of the same basic materials and that the current to be drawn from them is consistent with the size of their cells, is given by their weight. It is interesting to note that the approximate price per ounce for a No. 800 battery is 2½d, as against 3d for a No. 126 (which uses identical cells), 3d for a PP9, 4d for a No. 1289, 5½d for a PP7 and no less than 1s 8d for a PP3!²

REGENERATION

In describing the "Miniflex" personal receiver it was stated that it was important to arrange that there was no coupling between the aerial coil and the r.f. choke. Later experience has shown that while oscillation can readily be obtained over the lower wavelength part of the scale even if a small amount of out-of-phase coupling is present yet, for full regeneration to be available at wavelengths above about 400 metres, a minute amount of in-phase coupling is desirable. In the personal receiver the components were cramped, and the correct orientation of the choke, which was fairly critical, was thought to give nil coupling. It now appears that if the two coils are separated by more than about 3½in, or if L_2 is completely screened, it is impossible to obtain best results above 400 metres. It is recommended that the choke should be about 2½ to 3ins from the aerial rod whereupon orientation will be found easy to adjust for consistent results throughout the tuning range.

When the circuit of Fig. 2 is first built up, VR_2 should be omitted, the lead from the slider of VR_1 being taken direct to the base of TR_2 . L_1 which covers medium waves, should have 60 turns of 32 s.w.g. enamelled wire, close-wound on a paper sleeve fitted over a 6in by ¾in diameter ferrite rod. To start with, L_2 should have its windings at right angles to those of L_1 , but when the receiver is ready for testing, L_2 should be twisted one way and the other until oscillation is obtainable throughout the range, with VR_1 fairly near its maximum position. It will be found that correct orientation has a much greater effect towards the long wavelength end of the band, and it

should be possible to find an angle which allows for a reasonably consistent oscillation point at any setting of the tuning control.

Provided that the setting for oscillation is consistent—i.e. VR_1 requires little movement from one position near its maximum, whatever the setting of VC_1 may be—the inclusion of VR_2 should be tried. This should result in a much larger proportion of the movement of VR_1 being useful, and should give a very gradual approach to the oscillation point, thereby making the reception of distant stations easier. The most likely optimum position of the slider of VR_2 is close to the end of the track which connects to the slider of VR_1 , but any position can be tried for best results. It is possible, however, that with some transistors, or with an unsuitable layout, the oscillation point will not be sufficiently consistent, before VR_2 is fitted, for that component to be useful. In these circumstances the inclusion of VR_2 will tend to increase the variation of the setting of VR_1 which is required for oscillation at different settings of VC_1 . In this event, VR_2 can be omitted altogether. It is a refinement, and not an essential part of the circuit.

COMPONENT DETAILS

It will be seen that the electrolytic capacitor C_3 does not bypass R_1 directly, but through the secondary of T_2 . This gives a measure of positive feedback of the a.f. signal and results in a small but useful increase in volume. Owing to the damping effect of R_1 it is unlikely that any noticeable distortion will be introduced, but if distortion should appear (due to a transistor in the TR_3 position offering an unusually high amplification) this can be cleared by inserting a 25Ω or 50Ω preset variable resistor between the emitter of TR_3 and C_3 . The variable resistor should be adjusted for best results.

Before turning to constructional matters, two important points concerning components have now to be dealt with. The first of these is that it is *essential* that the specified D3026 transformer be used for T_1 , as the d.c. resistance of its secondary plays a vital part in the circuit. The author knows of no other transformer having exactly the characteristics required here. The reader should not, in consequence, accept any so-called “substitute” for the D3026—the transformer specified *must* be used.

Secondly, the reader must not use any transistor in the TR_1 and TR_2 positions other than the Sinclair ST141. The writer has checked “comparable” silicon transistors in the circuit but these have not functioned satisfactorily. The Sinclair ST141 *must* be used for TR_1 and TR_2 .

SUGGESTED LAYOUT

This article is primarily intended for readers who like to arrange their own layout, having been given the essential information on the design. Nevertheless, to give a guide,

³ Incidentally, readers who have made the Spontaflex S.A.4 receiver (see “The ‘Spontaflex’ S.A.4 Transistor Portable” in *The Radio Constructor* for May 1968) and use it a good deal may have found that the PP7 battery specified does not last very long. If the speaker is turned through 180° and T_1 has its primary leads extended by a few inches and is fitted in the position previously occupied by the battery, a PP9 battery can be fitted in the space vacated by T_1 . Running costs will be considerably reduced by this modification.

Fig. 3 shows the layout used for the prototype. Components are first mounted on the 8in by $3\frac{1}{4}$ in baseplate, these including the 10-way groupboard and the components fitted to its tag. Sufficient lead length was left available with L_2 to allow the orientation of this component fitted to its tags. Sufficient lead length was left available with L_2 to allow the orientation of this $5\frac{1}{2}$ in by $3\frac{1}{4}$ in front panel. The shaded section to the right of the front panel is secured to the left hand edge of the baseplate by woodscrews (plus suitable small brackets, as desired) whereupon the panel surface is at right angles to that of the baseplate. The panel components are then fitted and wired as shown. The ferrite aerial rod projects directly backwards from the front panel, its forward end being secured with adhesive in the $\frac{3}{8}$ in hole adjacent to VC_1 . It may be found helpful to reverse the connections to L_1 when setting up for best regeneration, and the coil can, of course, be moved along the ferrite rod to obtain the desired coverage.

The 8in by 5in elliptical loudspeaker is mounted along the upper 8in length (Fig. 3) of the baseplate by means of small brackets fitted, approximately, at the two points A. The battery stands on top of output transformer T_2 .

As may be seen, the whole assembly can be fitted in a cabinet in which one long side has an aperture for the loudspeaker and one end has a panel at which the controls appear. But, as was just stated, this article is primarily intended for readers who like to make up their own layout. That shown in Fig. 3 represents a suggested approach, and any alternative layout giving reasonable and sensible component positioning could be used instead.

ADDING LONG WAVES

Although initially intended for medium wave reception the design, as described in this article so far, may be easily adapted for long wave reception on 1,500 metres as well, should this be desired by the constructor. The additional components required are a 500pF trimmer (VC_2), a wave-change switch (S_2), and a second ferrite aerial (L_3). The associated diagrams appear in Figs. 4 and 5, the latter being based on the layout of Fig. 3. Constructors will probably find it helpful to build the medium wave version first and get this into full operating condition

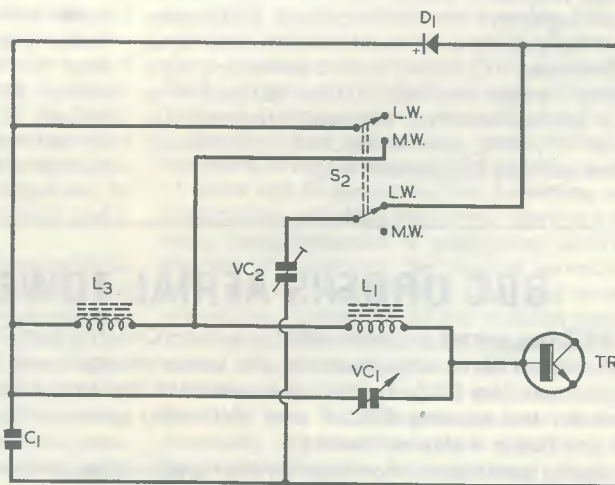


Fig. 4. The additional circuitry needed for reception on 1,500 metres. When the long wave band is selected, VC_2 is effectively connected across L_2

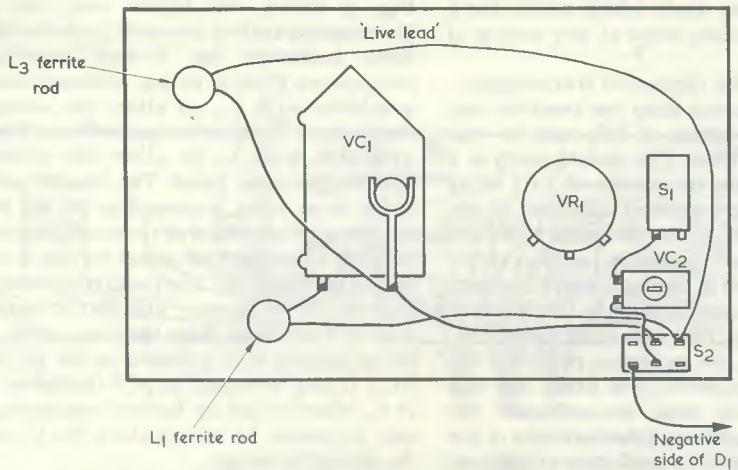


Fig. 5. Reception on 1,500 metres necessitates adding L_3 , VC_2 and S_2 to the panel in the positions illustrated here. Also shown is the extra wiring required

before adding the long wave circuitry. Adding the long wave components may necessitate a change in value in C_2 .

For long wave reception a second ferrite rod, 8in long by $\frac{3}{8}$ in diameter, is fixed with adhesive at a suitable hole in the panel in the approximate position shown in Fig. 5. It should lie between the speaker and the battery when the panel is screwed to the base board. The coil, L_3 , consists of 250 turns of 32 s.w.g. enamelled wire close-wound on a paper sleeve, with its turns in the same direction as those of L_1 . The lead-out wire indicated "live lead" in Fig. 5 then corresponds with the lead of L_1 which connects to the base of TR_1 . The lead of L_1 which connects to the moving vanes of VC_1 in Fig. 3 is now disconnected from this point and connected instead to S_2 , as in Fig. 5. This diagram also indicates the point on the panel at which S_2 is fitted. The added trimmer, VC_2 , is secured to the panel in the position shown, and its function is to tune the r.f. choke L_2 to approximately 1,500 metres when S_2 is set to the long wave position. In practice, VC_2 will tune L_2 to a slightly lower frequency, as the load for TR_2 collector needs to be capacitive to allow reaction to function properly and for stability to be maintained. In order to set up for 1,500 metres, VC_2 should first be screwed up tight and the Radio 2 programme on 1,500 metres tuned in by VC_1 . VC_2 is then slackened off, any small adjustments to the setting of VC_1 being made as required, until stability is just maintained with VR_1 at maximum.

There is an additional lead from S_2 to the negative end of D_1 , and this must be kept away from any components or wires connected to the base of TR_1 . Even so, there will remain some slight coupling due to stray capacitances within S_2 and in the wiring, and it may be found that reaction is no longer smooth at the low wavelength end of the medium waveband. In this case matters can be corrected by reducing C_2 to 8,200pF or even 6,800pF. However, the capacitance of C_2 should not be made too low or there will be a loss of sensitivity and difficulty in obtaining oscillation at the long wavelength end of the medium waveband. Slight readjustment of the orientation of L_2 may also prove necessary here.

If hand capacitance effects become evident with the long wave components fitted, a layer of metal foil can be placed between the panel and the material used for the wavelength scale, etc., a lead from this foil being taken to the negative supply line. Care must be taken to see that the foil does not touch the spindle or locking nut of VC_1 .

Turning to general points concerning the receiver, the writer would finally like to state that the design will be found to give really good quality and ample volume from local stations. Also, it will receive very many others, though the weaker ones will be at reduced volume. The receiver is very economical to use. The author is still trying to resist the temptation to use the name "Siliflex" for this silicon version of the "Miniflex."



BBC ORDERS AERIAL TOWER FOR LARNE

The BBC has placed an order with Cornubian Construction Company Limited, of Danbury, Essex, for the erection of a new 152-ft. aerial tower at the Larne television and VHF radio relay station. This new tower will carry the UHF aerial for BBC-2, which is expected to start from Larne in the autumn of this year. It will also carry new aerials for the existing BBC-1 and VHF radio services: Radio 2 (Light Programme), Radio 3 (Third Network) and Radio 4 (Home Service).

All existing services will continue on their present frequencies; BBC-2 will be transmitted on Channel 45. For good reception of BBC-2 it is essential to have the correct type of aerial and to ensure that it is carefully positioned. For Larne, the aerial must have vertical rods and must be suitable for the BBC-2 channel, 45, and for the other three channels, 39, 42 and 49 which are assigned to this station for future UHF services.

IN LAST MONTH'S ISSUE WE EXAMINED THE MANNER IN which the tuning of superhet signal frequency and oscillator tuned circuits is carried out by means of a 2-gang capacitor. We saw that in conventional superhets the oscillator frequency is higher than the signal frequency, whereupon the oscillator tuned coil is given a lower inductance than the signal frequency tuned coil, and the maximum oscillator tuning capacitance is made lower than the maximum signal frequency tuning capacitance. The normal method of providing the reduced maximum capacitance whilst using a 2-gang capacitor having the same capacitance in both sections is to insert a fixed series padding capacitor in the oscillator tuned circuit.

We shall now carry on to other aspects of the signal frequency and oscillator tuned circuits.

FERRITE FRAME AERIALS


Nearly all modern medium and long wave superhets intended for domestic use employ a ferrite frame aerial in place of an aerial coil assembly coupling to an aerial wire. The ferrite frame aerial consists of a winding on a rod or slab of high permeability ferrite material and its inductance is the same as the tuned winding of the aerial coil it replaces. When the ferrite frame aerial is used with a valve superhet, it appears in the basic circuit shown in Fig. 1 (a).


circuit of a superhet is to adjust the iron dust core of the coil. In Fig. 1 (a) the ferrite frame aerial winding replaces the tuned winding of the signal frequency tuned circuit, and it will similarly require padding adjustments. These are made by physically sliding the coil along the ferrite rod. To facilitate this adjustment the coil is wound on a thin-walled sleeve or former which is a sliding fit on the ferrite rod or slab. See Fig. 1 (b). To increase inductance the coil is moved towards the centre of the rod or slab, and to decrease inductance it is moved away from the centre.

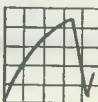
Some commercially manufactured receivers adopt a different method of adjusting ferrite frame winding inductance, the technique used being illustrated in Fig. 1 (c). Here, the tuned winding is mounted in a fixed position on the rod whilst a "short-circuited turn" of wire capable of being slid along the rod is fitted between the coil and the nearer end of the rod. The short-circuited turn reduces the effective length of the ferrite rod, with the result that when it is moved towards the winding the inductance of the latter reduces whilst, when it is moved away from the winding, the inductance of the latter increases. The ferrite frame winding is designed to initially offer greater inductance than is required of the tuned circuit in which it appears when no short-circuited turn is

UNDERSTANDING RADIO

Basic Superhet

$$f = \frac{1}{2\pi\sqrt{LC}}$$






by W. G. Morley

In this diagram the ferrite frame aerial winding is tuned by the signal frequency section of the 2-gang capacitor, and couples direct to a control grid in the mixer valve. Such a method of connection is satisfactory because the control grid of the valve offers a very high impedance to chassis and does not damp the tuned circuit given by the ferrite frame winding and its tuning capacitor. In a transistor receiver the same tuning arrangement is employed but, because the mixer transistor offers a low impedance to chassis, a separate coupling winding on the ferrite rod is used to feed this transistor.

A ferrite frame aerial is capable of picking up medium and long wave signals to which it is tuned with a sensitivity adequate for all normal entertainment requirements, provided that it is not used in surroundings which give a high level of screening, such as inside a car. (In the latter instance, it is usual to provide the ferrite frame aerial with a separate coupling winding which can be connected to an aerial mounted externally on the car, or to provide some alternative form of circuit for coupling an external aerial into the receiver.)

We saw last month that the normal method of carrying out the padding adjustment for the signal frequency tuned

is fitted to the rod. Fitting the short-circuited turn and moving it to the desired position then brings the tuned winding inductance down to the desired value. The short-circuited turn, incidentally, is normally a length of tinned copper wire with its two ends soldered together. It is placed in the groove of a grommet, as in Fig. 1 (d).

Ferrite frame aerials for medium and long wave reception have separate medium and long wave coils fitted at either end of the ferrite rod. According to the type of wavechange switching employed, there is a possibility of some interdependence of positioning occurring between the two. For instance, the medium wave coil may be in series with the long wave coil when long waves is selected, whereupon movement of the medium wave coil along the rod can affect the overall inductance given on long waves. If, again, the long wave coil is short-circuited when medium waves is selected, its position along the rod can similarly have an effect on medium wave inductance. Normally, this interdependence is not very troublesome, but it should still be borne in mind when carrying out padding adjustments on a receiver with a ferrite frame aerial. It is worthwhile ensuring that a long wave padding adjustment has not upset a previous medium wave padding

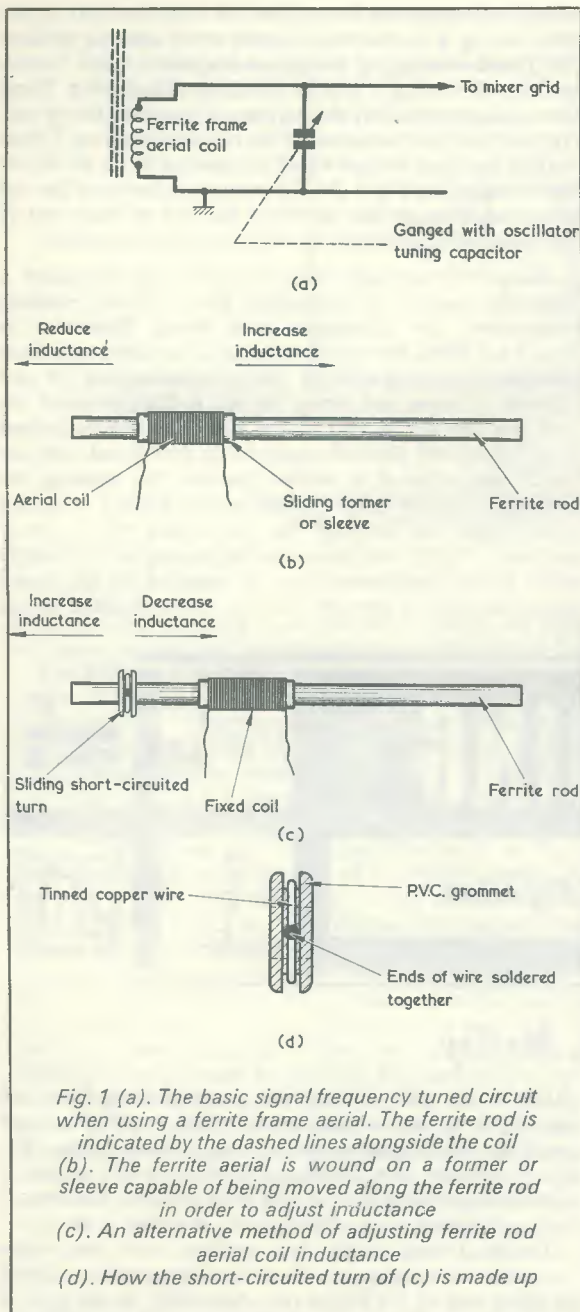


Fig. 1 (a). The basic signal frequency tuned circuit when using a ferrite frame aerial. The ferrite rod is indicated by the dashed lines alongside the coil
 (b). The ferrite aerial is wound on a former or sleeve capable of being moved along the ferrite rod in order to adjust inductance
 (c). An alternative method of adjusting ferrite rod aerial coil inductance
 (d). How the short-circuited turn of (c) is made up

adjustment and vice versa. If the receiver is a commercially manufactured model, the service manual will state the order in which padding adjustments should be carried out.

THREE-GANG OPERATION

We have considered superhet tracking when a 2-gang tuning capacitor is employed, noting that one section tunes the signal frequency tuned circuit whilst the other section tunes the oscillator tuned circuit. If the superhet has an r.f. amplifying stage before the mixer a 3-gang capacitor is required. The first section of this then tunes the tuned circuit coupling the aerial to the r.f. amplifier (or it tunes a ferrite frame aerial coupling to the r.f. amplifier), whilst the second section tunes the tuned

circuit between the r.f. amplifier and the mixer. Both the tuned circuits are kept at the same frequency, as in a straight receiver. The third section of the 3-gang capacitor then tunes the oscillator tuned circuit, in the same manner as with the oscillator section of the 2-gang capacitor (i.e. the tuned circuit has a lower inductance coil and a series padding capacitor). Thus, adding an r.f. stage requires that an extra ganged section be added to the tuning capacitor, this tuning the additional aerial coil at signal frequency.

SECOND CHANNEL INTERFERENCE

Whilst a superhet receiver, by virtue of its highly selective intermediate frequency amplifier, is capable of offering better selectivity than a straight receiver, it can suffer from several forms of interference which arise directly from the superhet method of operation and which do *not* occur in a straight receiver.

The first of these forms of interference to be considered can be readily demonstrated by a numerical example. Let us assume that we have an a.m. medium wave superhet with an i.f. of 460kc/s and that we wish to receive a signal having a carrier frequency of 1,000kc/s. In consequence, we tune our receiver so that its oscillator frequency is 1,460 kc/s, whereupon the incoming 1,000kc/s carrier beats with the oscillator frequency in the mixer to produce a difference frequency of 460kc/s. This frequency relationship is illustrated in Fig. 2 (a). The 460kc/s difference signal from the mixer is next accepted by the i.f. amplifier and fed to the detector, after which the modulating a.f. is amplified and passed to the loudspeaker. The signal frequency section (or sections) of the ganged tuning capacitor will, of course, be resonant at 1,000kc/s so that the desired aerial signal is selected and applied to the mixer at good amplitude.

Let us next assume that a second signal is picked up by the aerial, that it has a carrier frequency of 1,920kc/s, and that it is sufficiently strong to "break through" the signal frequency tuned circuit and reach the mixer. As we may see from Fig. 2 (b), this second signal is similarly removed from the oscillator frequency by 460kc/s. The mixer will produce a difference frequency of 460kc/s with this second signal as well, and the difference frequency will also pass into the i.f. amplifier. The consequence is that the required signal at 1,000kc/s suffers interference from the unwanted signal at 1,920kc/s. As is evident from Fig. 2 (b), the interfering signal is spaced away from the required signal by twice the intermediate frequency.

The simple example just given shows that a superhet is particularly susceptible to interference from signals which are spaced away from the required signal by twice the intermediate frequency. When, as normally occurs, the oscillator frequency is higher than the signal frequency, the signal capable of causing interference is twice the intermediate frequency *above* the required signal. This class of interference is known as *second channel interference* or *image interference*, both terms being self-explanatory.

Second channel interference can also be evident when the interfering signal is sufficiently close to twice the intermediate frequency away from the desired signal to allow it to pass through the i.f. amplifier. In Fig. 2 (c) we assume that the interfering signal has a carrier frequency of 1,922kc/s, whereupon the difference with oscillator frequency becomes 462kc/s. This frequency will also be accepted by the i.f. amplifier, and the audible consequence will be a continual 2kc/s tone from the loudspeaker

resulting from the beating together of the 460 and 462kc/s difference frequencies.

Let us see what happens if, with signal and interference signals as in Fig. 2 (c), we slightly detune the receiver, causing its oscillator to run at 1,459kc/s. The result is shown in Fig. 2 (d), where we have a difference frequency with the required signal of 459kc/s, and a difference frequency with the interference signal of 463kc/s. Both difference signals can be accepted by the i.f. amplifier, and the a.f. beat note between them now rises to 4kc/s.

In Fig. 2 (e) we slightly detune the receiver in the opposite direction, so that its oscillator runs at 1,461kc/s. This time the two difference signals both become equal, at 461kc/s, whereupon the resultant a.f. beat note drops to zero frequency.

These numerical examples lead us to the practical effects given in an a.m. superhet by second channel interference. If conditions are such that one amplitude modulated transmission suffers second channel interference from another, the most noticeable consequence is that an a.f. beat note is produced due to the beating together of the difference frequencies resulting from the two carriers. This a.f. beat note, as is illustrated in Figs. 2 (c), (d) and (e), may be varied in pitch by adjusting the receiver tuning about its correct setting. In practice it will be a little difficult to tune the receiver so that the beat note approaches the zero frequency case given in Fig. 2 (e) or, indeed, falls below the lowest audio frequency that can be heard by the ear. As may be seen from the diagrams the a.f. beat note resulting from the second channel interference shifts by 2kc/s for every 1kc/s change in oscillator frequency so that, for an inaudible beat note to be obtained the oscillator frequency would have to be maintained within plus or minus some 25c/s of the frequency which results in zero a.f. beat frequency.* If the interfering signal is passed to the mixer at sufficient strength relative to the desired signal its modulation will also be heard, the sidebands beating with the carrier and sidebands of the desired signal to produce a distorted version of the original sound.

Thus, second channel interference exhibits itself, in less severe cases, as an a.f. beat note which varies in pitch as the receiver tuning is adjusted. In more severe cases, the modulation from the interfering signal also becomes audible.

The mixer stage, on its own, cannot discriminate between the required signal and the second channel signal. It is the function of whatever signal frequency tuned circuits exist between the aerial and the mixer to ensure that the interfering signal does not reach the mixer at sufficient level to cause interference, and this fact leads us to an interesting appraisal of superhet tuned circuits which we have not so far discussed. We have mentioned earlier that the signal frequency tuned circuit (or circuits) "selects" the desired signal, but we can now define this role in greater detail. A basic requirement of the signal frequency tuned circuit (or circuits) is that it must always pass the desired signal to the mixer at an amplitude which is sufficiently large, when compared with any second channel interfering signal, for second channel interference to be non-existent or, at least, negligibly small. So far as simple tuned circuit arrangements of the type encountered in domestic receivers are concerned, it is usually necessary for the signal frequency tuned circuits to be accurately trimmed and padded before this basic requirement can be fully met. If the signal tuned circuits are out of alignment

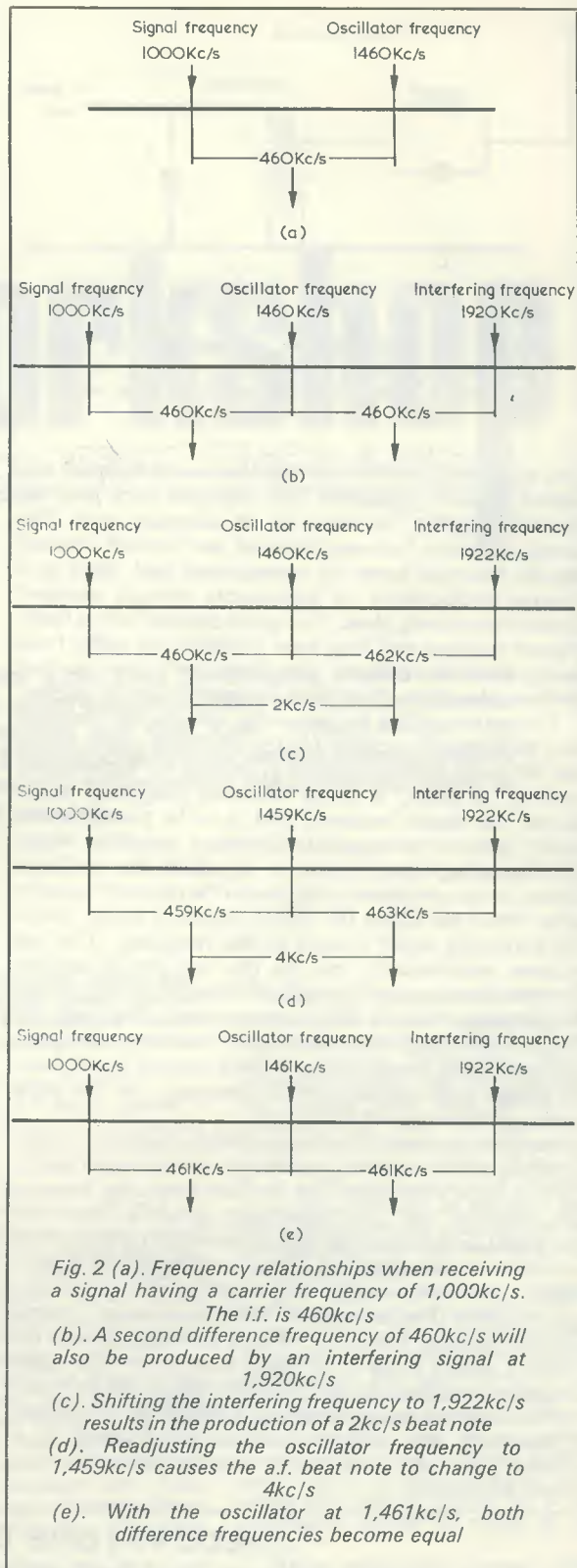


Fig. 2 (a). Frequency relationships when receiving a signal having a carrier frequency of 1,000kc/s. The i.f. is 460kc/s
 (b). A second difference frequency of 460kc/s will also be produced by an interfering signal at 1,920kc/s
 (c). Shifting the interfering frequency to 1,922kc/s results in the production of a 2kc/s beat note
 (d). Readjusting the oscillator frequency to 1,459kc/s causes the a.f. beat note to change to 4kc/s
 (e). With the oscillator at 1,461kc/s, both difference frequencies become equal

* This assumes that the lowest audible frequency is 50c/s.

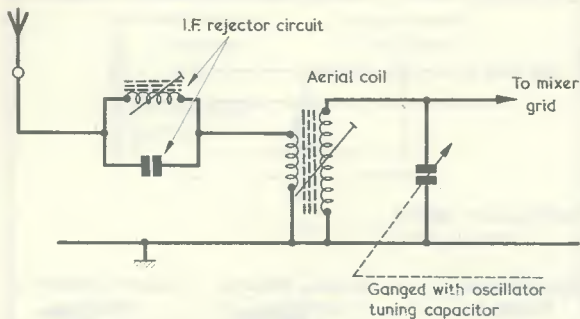


Fig. 3. I.F. breakthrough interference may be considerably reduced by inserting a rejector circuit tuned to the intermediate frequency in series with the receiver aerial input

they will still offer about the same amount of rejection to a second channel signal but they may not then pass the desired signal to the mixer at an adequate level. The amplitude ratio between required and second channel signals becomes lower in consequence and there is a greater probability of noticeable second channel interference taking place. This point explains why a badly aligned medium and long wave superhet can suffer from background beat notes (or "whistles") on received stations, these clearing after it has been correctly aligned.

To continue along the same vein, altering the trimmers and padding adjustments for the oscillator tuned circuit has the same subjective effect as turning the main tuning control. In effect, it is the oscillator frequency which selects the signal frequency that is to be passed to the highly selective intermediate frequency amplifier. When aligning a superhet, therefore, we adjust the oscillator circuit so that reception is obtained at the correct frequency, after which we adjust the signal frequency tuned circuit for maximum signal strength at that frequency. This last process automatically ensures that we obtain greatest freedom from second channel interference as well. More complex superhets, in the communications class, may not be quite as reliant on accurate signal frequency alignment for reasonable freedom from second channel interference as occurs with simple domestic receivers, but the same basic relationship still holds true.

It will be apparent that the possibility of second channel interference in a superhet can be reduced by using a higher intermediate frequency. The frequency spacing between the required and the interfering signal is then also increased, whereupon the signal frequency tuned circuits are more readily capable of suppressing the second channel signal. Some specialised short-wave receivers employ intermediate frequencies of 1.6Mc/s, causing second channel spacing to become 3.2Mc/s, as compared with the 920kc/s offered by an i.f. of 460kc/s. At short-wave signal frequencies of the order of 10 to 30Mc/s or so, the increased second channel spacing provides a significant advantage. (Frequently, the 1.6Mc/s i.f. stages are followed by a second mixer and a second i.f. amplifier operating at a lower frequency).

OTHER FORMS OF INTERFERENCE

Another form of interference peculiar to the superhet is *i.f. breakthrough*. If an interfering signal whose frequency is within the band of frequencies accepted by the i.f. amplifier "breaks through" to the mixer, then it will be passed to the i.f. amplifier and cause interference with all other signals picked up by the receiver. Typically, the carrier of the interfering signal will beat with the intermediate frequencies resulting from desired signals, resulting in a whistle continuously varying in pitch as the receiver tuning is adjusted. The effect is similar to that given by tuning a straight receiver with a reaction circuit which is too far advanced except that, unless the interfering signal happens to be at the centre of the i.f. passband, zero frequency of the a.f. beat does not coincide with the position of correct tuning. Note that the rate of change of whistle frequency, as receiver tuning is adjusted, is half that for second channel interference. This fact can be helpful when trying to diagnose the cause of background whistles in a superhet.

Normally, the signal frequency tuned circuits before the mixer should offer sufficient rejection at the intermediate frequency to prevent i.f. breakthrough. With medium and long wave receivers using intermediate frequencies of 450 to 475kc/s the possibility of i.f. breakthrough is greatest at the low frequency end of the medium wave band, where signal frequency may be of the order of 500kc/s. In receivers employing separate wire aerials an i.f. wavetraps, or rejector circuit, is sometimes inserted in series with the aerial input, as in Fig. 3. This is tuned to the intermediate frequency and offers greatest series impedance at that frequency, thereby reducing the i.f. breakthrough. Receivers with ferrite frame aerials do not normally employ i.f. wavetraps.

Another form of superhet interference is given when interfering signals produce a difference frequency equal to the i.f. by beating with harmonics of the oscillator frequency. Normally, however, the selectivity of the signal frequency tuned circuits should be adequate to ensure that such interfering signals do not reach the mixer at sufficient strength to produce the interference.

A term commonly encountered when interference is discussed is *adjacent channel interference*. This is merely the interference which results when the carrier frequency of the interfering transmission is close to that of the desired signal, and can be eradicated only by providing the requisite overall selectivity in the receiver. It is not peculiar to the superhet and occurs also with a straight receiver. When two a.m. carriers are sufficiently close together they may produce an audible beat note behind either transmission. If this beat note is encountered when tuning a superhet it may be identified as adjacent channel interference (as opposed to second channel interference or i.f. breakthrough) because the frequency of the a.f. beat note is constant and cannot be altered by adjusting the receiver tuning.

NEXT MONTH

In next month's issue we shall turn our attention to the mixers employed in current valve receivers.



EDDYSTONE DIE-CAST BOXES

These aluminium alloy boxes make ideal cabinets for small and compact ancillary equipments and they are available direct from Home Radio (Mitcham) Ltd. in four differing sizes—see Home Radio Catalogue, page 26. In forthcoming issues, we will be featuring several constructional articles using these boxes.

In your

workshop



Last month, Dick encountered an a.m./f.m. transistor radio which refused to operate on the f.m. band, whereupon Smithy seized the chance to pass on some general information on the f.m. "front ends" in transistorised a.m./f.m. receivers. Smithy continues on the same subject this month and the pair finally arrive at a triumphant repair of the fault in Dick's receiver.

Editor's Note

Due to last-minute pressure on our space last month, we have had to split the latest "In Your Workshop" episode into two parts. Readers will recall that Dick, after a strenuous evening with his student friends at Joe's Caff the night before, tackled a transistorised a.m./f.m. set which was dead on the f.m. band.

We rejoin the pair whilst Smithy concludes his discussion on transistorised f.m. "front ends" and refers to the rejector circuit included to combat 10.7 Mc/s breakthrough and which was shown in Fig. 3 (published last month).

As they say in the ladies' magazines: now read on.

REJECTOR CIRCUIT

"As you like," said Smithy absently, "but, once more, we're straying from the subject again. Which is this f.m. front end!"

"Haven't we finished with it yet?"

"Not quite," said Smithy. "There are a few more bits and pieces left to

deal with. For instance, there's normally another tuned circuit between the collector of TR₁ and the emitter of TR₂. In our circuit, this is shown as L₄ and C₈."

"What's its function?"

"To act as a 10.7 Mc/s rejector," replied Smithy. "If you didn't include a circuit of this nature it would be quite possible for a 10.7 Mc/s signal picked up on the aerial to break through to the emitter of TR₂ at sufficient strength to cause interference. The rejector circuit prevents that. In our case we've got quite a simple series rejector tuned circuit but you'll find a slightly more complicated approach in some f.m. front ends. However, the alternative schemes still use a single coil and this still has the same function, that of rejecting 10.7 Mc/s signals. The extra coil tends to puzzle some people when they encounter it on first looking at an unfamiliar transistor f.m. front end. But all that has to be remembered is that it's intended for 10.7 Mc/s rejection."

"There's something else I've just thought of," said Dick. "How do you take the i.f. output from the collector

of TR₂?"

"Usually," replied Smithy, "by means of a common-or-garden 10.7 Mc/s i.f. transformer which, in our circuit, is L₆L₇. If the first f.m. i.f. transistor is also the mixer/oscillator for medium and long waves, the secondary of that i.f. transformer couples to its base via the f.m./a.m. switching in the receiver. If the f.m. front end has its own first i.f. amplifier, then the secondary of the 10.7 Mc/s i.f. transformer just goes straight into its base. In our case we've got the switching arrangement."

"Do all receivers use a simple 10.7 Mc/s i.f. transformer?"

"Not all," replied Smithy. "There are some models which use alternative approaches. The most dissimilar circuit you'll encounter is a single coil used in a pi-tuned circuit. (Fig. 5). This resonates with the capacitance to deck at the mixer/oscillator collector and with a physical capacitor at its other end, and it's peaked up to give maximum transfer of signal at 10.7 Mc/s."

"How about the 2-gang tuning capacitor for the f.m. circuits?"

"That," remarked Smithy, "is nor-

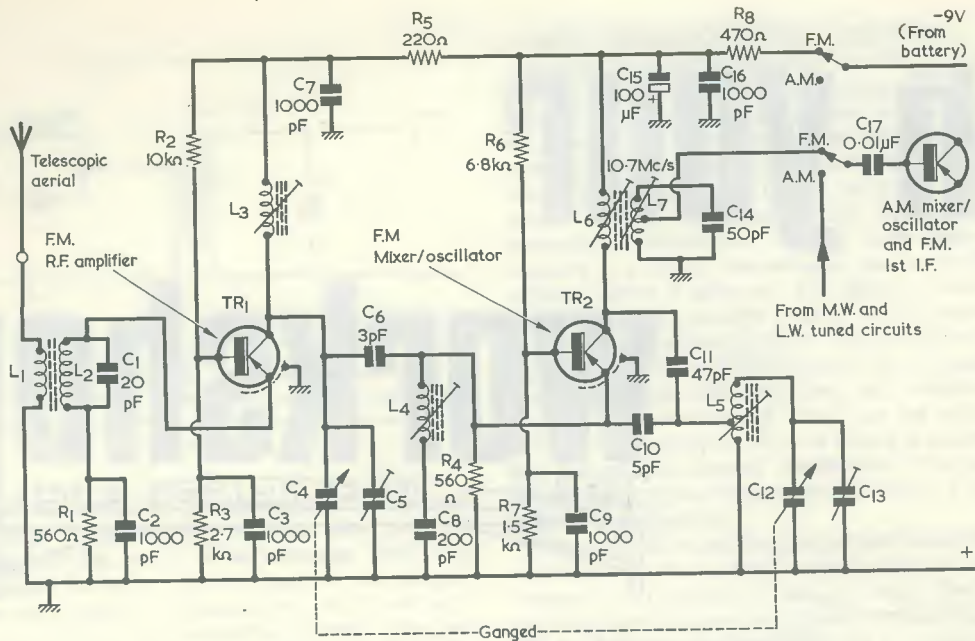


Fig. 3. Simplified circuit, with representative component values, illustrating basic commercial practice for f.m. "front end" design. There will be slight differences in actual commercial circuits encountered, largely in coil chassis returns, tuning capacitor padding, and the like

(Fig. 3 is reproduced here for the convenience of readers)

mally given by two separate low-capacitance sections which are added to the higher capacitance sections employed for medium and long waves. You can soon see what's used here just by looking inside the set you're fixing!"

"Of course," agreed Dick. "I should have realised that! I must say, Smythy, that you're being very liberal with your technical gen this morning."

"Liberal, eh," repeated Smythy thoughtfully. "Now that word reminds me of something! What was all this political guff you were rabbiting on about when you first came in this morning?"

"I was trying to tell you," remarked Dick aggrievedly, "but all you were interested in at that time was in getting me to start work."

"Perhaps I was," admitted Smythy. "Since then, though, my curiosity has got the better of me. Just what *did* happen last night?"

"Well," said Dick, "it's as I was telling you. I was in Joe's Caff with my mates when I raised this business about how we should all get to know more about politics so that we could use our votes properly. The students happened to be in as well, and so I decided to get them to join the discussion."

"Is that how you got your black eye?"

"Oh no," said Dick, shocked. "The students were very sensible indeed, and they discussed everything *most* amicably. About half of them belong to one party and the remainder are split between two other parties, but they didn't squabble amongst themselves about their different views, or anything like that. It was a real pleasure to listen to them when they got warmed up. All pukka debating society stuff, with everyone giving their own opinions and no arguments whatsoever. Dead enlightening I found it."

"It's certainly nice to hear that," remarked Smythy, in an interested tone of voice. "And I'm always intrigued in finding out how the younger generation sort out the political questions of the day. Which party do the majority of the students support?"

"You mean the half of them?"

"Yes."

"They," replied Dick, "are all Marxists."

Smythy swallowed.

"Oh," he said. "Well, that still leaves the rest of the students. Who do they support?"

"Most of the rest," said Dick, "are Trotskyites."

Smythy appeared to be having difficulty with his breathing.

"And the remainder?"

"Oh, they're in a minority," said Dick carelessly.

"Yes, but who do they support?"

"Nobody," said Dick. "They're Anarchists!"

"Ye gods," murmured Smythy. "Well, at any event, you *were* able to discuss things quietly. So how did you get that black eye?"

"As luck would have it," Dick remarked bitterly, "it was last night that the rougher element decided that they would come back to Joe's place after all; and they came in just as our discussion had really got into its stride. There was one quiet minute, after which all hell broke loose—and that's when I got my black eye, mate!"

"But why," persisted Smythy desperately, "should there have been all this trouble when the rougher element moved in?"

"It's their politics, Smythy," explained Dick patiently, "You see, they're all Conservatives."

Smythy turned his eyes up to the ceiling.

"I must," he said brokenly, "have heard everything now. Still, if all this rumpus was going on, why didn't Joe come out and stop it?"

"He couldn't."

"Why on earth not?"

"Joe can't get involved in any trouble," replied Dick. "He's got his commitments to consider."

"Commitments?"

"That's right. You see, he's a corporal in the I.R.A."

EXCESS CURRENT

"Let us," said Smithy weakly, "get back to this set of ours. We still haven't fixed the fault in it yet!"

"No, we haven't have we?" remarked Dick brightly. "All this gossip about last night put it clean out of my head."

"Well, let's get it back into your head again," replied Smithy. "Dash it all, I've just realised that I haven't even tried the set out yet to see what it sounds like."

He moved closer to Dick's bench, pressed the medium wave button on the receiver and swung its tuning dial. The receiver gave a satisfactory performance at all points of the dial. The same occurred after Smithy pressed the long wave button. Smithy next pressed the f.m. button.

The receiver became silent. Smithy picked it up, turned its volume to full and held its speaker against his ear.

"There's a fair bit of background hiss," he remarked critically, "but nothing else. It's difficult to determine from background noise whether the i.f. stages of an f.m. set are working or not, because of the a.m. limiting given by the discriminator, but this hiss is certainly loud enough to indicate that the a.f. stages, at any rate, are good and lively. So the set doesn't go completely dead when the f.m. button is pressed."

"The i.f. stages worked O.K. on medium and long waves," volunteered Dick. "And, since the same transistors are used for f.m. i.f. amplification I would guess that the i.f. amplifier is O.K. on f.m. as well."

"That's reasonable enough, I suppose," conceded Smithy. "It's impossible to assume that the i.f. stages are entirely above suspicion so far as the 10.7 Mc/s signal is concerned, but it's fairly safe to say that the fault is more likely to be elsewhere. Therefore it's most probably in the f.m. front end or the a.m./f.m. switching circuits. As service engineers, we should start off by checking for the most probable troubles first. Did you measure battery voltage?"

"I did," replied Dick proudly. "It's the first thing I do with all faulty transistor sets. There's a good fat 9 volts plus in the battery for all three wavebands, including f.m."

"Did you," continued Smithy, "check battery current?"

"I hadn't," admitted Dick, "got around to that yet."

"We'll make that the next thing to do," said Smithy. "It may give us a lead before we start digging around in the innards."

Without delay, Dick pressed the receiver off button, selected a suitable current range on his testmeter and clipped its leads in series with one of the connections to the battery.

"Turn the volume fully back," commanded Smithy, "and press the long wave button."

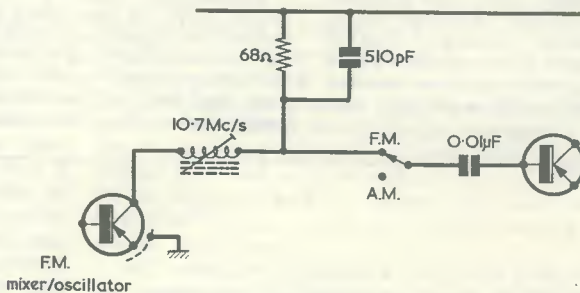


Fig. 5. An alternative 10.7 Mc/s output circuit to that shown in Fig. 3. The single coil is tuned at one end by the capacitance from transistor collector to chassis and, at the other end, by the 510pF capacitor

Dick did as he was bid and looked at his meter.

"14mA," he called out.

"Medium waves?"

Dick leaned forward and pressed the medium wave button.

"The same. 14mA!"

"Now try the f.m. button."

Dick pressed the button in question. "Blimey," he exclaimed. "The meter needle's shot up to 32mA!"

"Good show," said Smithy. "Switching in f.m. shouldn't cause the quiescent current to go up by more than some 3 or 4mA or so, because all that's added, so far as battery consumption is concerned, is the current drawn by the f.m. front end. So we've got a definite lead there."

"In this case," put in Dick, "the current on f.m. goes up by 18mA."

"Which," remarked Smithy with satisfaction as he examined the receiver circuit diagram, "is a very comfortable figure indeed. Especially when one notices that the decoupling resistor in the supply to the f.m. front end is 470Ω, and that this connects direct to the battery. A dead short to chassis immediately after that resistor will cause an increased current of just around 18mA to flow from a 9-volt battery."

Smithy prepared to return to his bench.

"I'll leave it with you now," he remarked. "See if you can find a short-circuit to chassis after that 470Ω resistor. Ohmmeter checks are pretty well all you should need from now on!"

FAULT CLEARED

Smithy walked back to his bench, and a peaceful five minutes passed whilst Dick got to grips with the f.m. board in his receiver.

Suddenly, a triumphant call rose from his side of the Workshop.

"I've found it, Smithy!"

"Good show," replied the Serviceman. "Where was it?"

"The collector and shield lead-outs of the f.m. mixer/oscillator transistor were touching together. (Fig. 6). The transistor must have been carelessly inserted in the board at the factory, because the shield lead had a little bend in it instead of going straight down to its hole in the board. I only needed to straighten it up a little with a screwdriver and the short cleared completely."

Dick reconnected the battery and pressed the f.m. button. The set now functioned perfectly.

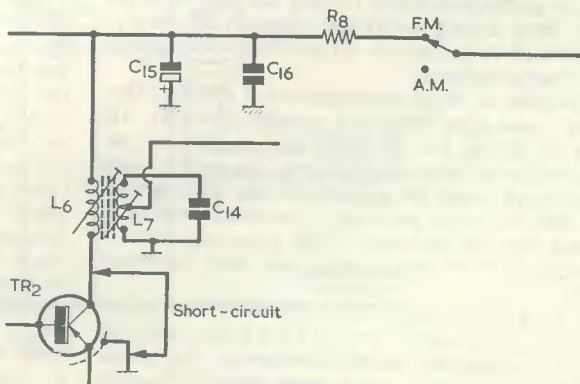


Fig. 6. It was a short-circuit between collector and shield lead-outs of TR₂ which caused the fault in Dick's receiver. The extra current consumed from the 9-volt battery on f.m. was limited by R₈ to 18mA, L₆ inserting negligible resistance

As, exultantly, Dick later returned the receiver to the "Repaired" rack, Smithy frowned pensively. For a fleeting moment, he wondered whether the owner of that a.m./f.m. receiver would accept a bill with only two items.

One item, for 1% of the full amount, would cover the time taken for Dick to insert his screwdriver blade between the two transistor lead-outs and clear the short-circuit; whilst the other item, for 99% of the full amount, would cover the time taken for

instruction.

Smithy grinned to himself as he chased the fugitive thought away. Too much of that 99% would have to be allocated to *political* instruction!



STARTING THEM YOUNG

by N. V. KING, B.Sc., Dip.Ed.

One way for the radiophile father to set his son along the right path in our hobby is to present him with a simple kit to assemble. On this occasion the father made certain of complete success by not only providing the parts from his own spares but by also pre-testing the circuit and writing the instruction booklet

A FEW MONTHS AGO I HEARD A RECORD BY VERA Lynn, and it brought back exciting memories of hearing her on the first receiver I ever made. There is no music so sweet as that heard on earphones from your very own set. I was eleven; the war was on, I was evacuated, there were no tools and I used to drill holes with a red-hot poker and wind giant coils on whatever cardboard tubes I could salvage from the bathroom. With a long aerial and reaction we used to get results which to our uncritical ears were comparable to the old man's superhet.

In the middle of these reminiscences I realised that one of my own sons was now eleven-years-old. He had made up plastic kits of tanks and aeroplanes; he was handy with the balsa wood cement; he used pounds of my nails and yards of my timber for making this and that; but his only electrical experience was with torches and bicycle dynamos. The time was ripe. I decided to start him on a radio kit and see what happened.

With a shed full of fairly old radio stuff plus a few more modern components to hand, I felt I had sufficient material to commence with. To ensure successful results, I therefore made up a kit of my own and dressed it up to look like the real thing.

EDUCATIONAL PRINCIPLES

Boys can be quite different from their fathers, and it

may well be that the hobby will hold no magic whatever. The worst that can happen then is that the set will only be completed with Dad's assistance and will be used for listening to pop music in bed at illicit hours. But even then I think the effort is worth it—it will have been yet one more experience to help build confidence.

But the boy must be given a chance; he must be left alone to get on with it, to make mistakes and dry joints, to find out by *doing*. By all means answer all questions as they come up—as simply as possible—but anything in the nature of a lecture on principles and practice of radio construction, except when asked for, can spell death to the flowering of the hobby. In my own case this advice has been very hard to apply (what a temptation to draw graphs of valve characteristics as applied to leaky grid detection!) but my forbearance has been amply repaid, for in three months since the birthday presentation of the kit the boy in question has made half a dozen sets of one sort or another. There was the "portable"—a huge box that could only be heard, and then faintly, on top of an 800ft hill; and there was the 2-valve mains set that was so loud that it always woke the baby. He has learnt some of the difficulties involved in trying to make a set work in a car. But my spares box is a shadow of its former self, and this prospect must be faced with equanimity.

THE TYPE OF CIRCUIT

For the kit design, I decided on soldered joints at the onset. Even my rather outdated spares did not include enough components with nut and bolt terminals to make a 1-valve circuit. Again, because of the state of my own spares and the lack of a cheap 2 volt smooth heater supply, I used a mains valve. The exact type does not matter of course, but the KTW63 that I employed was quite suitable. In view of the danger of mains voltages, I included in the kit a 6.3 volt mains transformer which I connected to a mains lead and plug; this I mounted ready on the chassis and covered with a plastic case leaving only the two heater tags exposed. For h.t. I put a small 90 volt battery in the kit.

For his later sets I have made up a completely sealed power pack which delivers from clearly marked terminals 6.3 volts a.c. and about 120 volts smoothed h.t.; but I did not wish to go to this trouble until I was sure that the hobby had caught on. Moreover, an eliminator would have made the kit itself enormous. It is extremely important to stress the danger of shock from the mains, and I shall not let the boy loose with a straightforward mains set until I am quite convinced that he knows what he is doing.

I used a Repanco medium and long wave coil type DRR2, but as the tags were rather close together I felt it advisable to glue this to a larger tagboard and wire it up to the tags myself with colour-coded wires so that he would not have to bring his inexperienced soldering iron near the fine windings and the plastic former. Nostalgia more or less dictated that the set should be a 1-valve type with reaction. The circuit, as I presented it to my son, is shown in the accompanying diagram.

KIT DETAILS

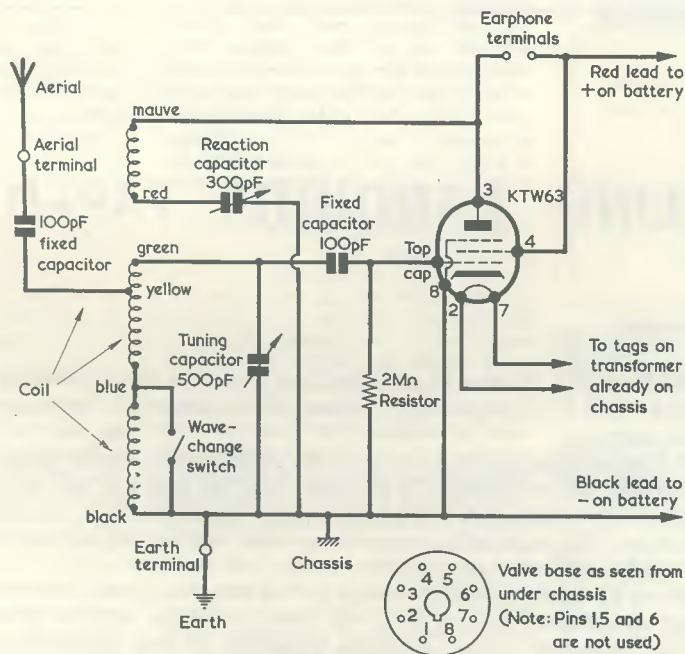
Bearing in mind that the set might be extended later

by the addition of an output valve and speaker, and then perhaps to a 3-valve t.r.f., I stripped an old t.r.f. set of my own down to the chassis. I next made up the kit set myself first as a check on components, using the original 2-gang capacitor and the middle of the three valve holes, drilling new holes as necessary. I mounted the mains heater transformer under the chassis at the output end and, as I mentioned earlier, connected it up to its mains lead and protected it from wandering hands with plastic insulating material, leaving only the output tags exposed.

As I tested the set under a heavy veil of secrecy, with the earphones clamped once more to my head, my youth came flooding back. . . .

Then, with reluctance, I took it completely down again except for the heater transformer, and lettered all the holes with a felt pen so that I could describe exactly where to put each component in my instruction booklet. I also left the nuts and bolts loosely in place in their appropriate chassis holes. The aerial, earth and earphone sockets, which were riveted, I removed, replacing the rivets with nuts and bolts. The coil connections needed no lettering as the wires connecting it to its tagboard were colour coded—blue for wave-change switch, black for chassis, and so on.

Next I turned my attention to finding a suitable box: a Christmas cracker box proved exactly right. It is important to have room to spread all the components out, so that each one can be clearly labelled in the box where it rests. I cut out a shallow tray from white cardboard, making suitable slots for the larger parts like the chassis, 2-gang capacitor and earphones, and fitted this tray into the cracker box. Then I mounted everything that would be needed except soldering iron and solder, using Sellotape. I typed out the names of everything, and taped these in place taking great care to avoid ambiguity. To the top of the cracker box I pasted a large sheet of paper on which I had drawn



The simple presentation used for the "U-Ma-Kit" circuit diagram. The coil is a Repanco type DRR2

banks and racks of radio equipment seldom seen outside the B.B.C., and on top of this pasted the figure of a boy I had cut from a comic. I chose him for the look of delighted expectation in his eye, and placed him so that he appeared to be about to get weaving on the equipment in view. Finally, I was unable to resist printing neatly across the top of the whole thing: "The U-Ma-Kit Electronic Radio Receiver". This seemed to me to give just the right final touch.

INSTRUCTION PAMPHLET

The success of the kit can stand or fall by the quality of the accompanying instructions, and I devoted a lot of care to this task. I wrote it out as if, with no previous knowledge, I were making the kit up from scratch myself; then I rewrote it, corrected it, modified it, and finally got it typed. It was important not to be put off by its final length, so long as it was clear, well-ordered, and simple. Our children have been conditioned to follow long instructions by some of the plastic construction kits on the market, which are often a model of clarity. In composing the instructions it is best to avoid technical terms except the names which are written alongside the respective parts in the box. Also, a clear diagram can do the job of hundreds of words more easily.

I tried to make my pamphlet, which was stapled between coloured cardboard covers, look as professional as possible. I did not want the boy to feel that his father was breathing down his neck with every connection he made.

The pamphlet contained the following sections:

1. *Introduction* (which included the words, "... giving a boy hours of pleasure and a deep understanding of radio practice. . . .")
2. *Assembling the components on the chassis* (remembering

that even simple jobs like putting the knobs on the spindles must be covered).

3. *Wiring the set up* (and this is the hardest part, both to write and for the boy to follow. The circuit diagram must be included, and it must be large and clear, with the name of every symbol written alongside. The valve base connections must be given in a separate diagram, using pin numbers which correspond with the numbers written round the valve on the circuit diagram. There is no point in confusing the issue at this stage with the words grid, anode, etc. I also made the suggestion that as each wire was soldered in place the circuit should be gone over in the appropriate place with coloured pencil; otherwise, especially on the chassis side, it is difficult to know when the job is finished).
4. *Connecting up the battery, aerial, etc., and trying the set out.* (Once again, nothing can be taken for granted. You have to search your memory to recall exactly *HOW* you find and tune in a signal.)
5. *Other experiments* (This included cutting down selectivity by connecting the aerial directly to the top of the grid winding, altering the value of the grid capacitor, and trying out the set after dark.)

SUCCESS FIRST TIME

The only help that I gave, apart from encouragement, was the supervision of the first two or three soldered joints. I do not know which of us was more thrilled when the set worked first time. I found though that for a week or so after the completion of the set, all the boy did was listen to it; but once I started leaving a few copies of *The Radio Constructor* around the house he soon retired to the shed and, before long, at every meal-time his mother was complaining that she "never heard anything but boring radio chat."

What more could an enthusiast ask?



BLIND LANDINGS TAPED

EMI Electronics have supplied 33 type L4 portable tape recorders to the Ministry of Technology for use with blind landing systems. The L4 is being installed aboard BEA's fleet of 21 Tridents and other aircraft which use the I.L.S. guidance system.

RF signals beamed from a ground transmitter give the approaching aircraft guidance information in the vertical and horizontal planes. The information is analysed and fed into the auto-pilot, which automatically trims the aircraft on its designated flight path. The L4 is used to monitor the I.L.S. signals and also rf interference on the wavelengths employed. The recorded tape is subsequently used for comparison with ground monitoring equipment to assist the RAE's evaluation programme for the I.L.S. system.

The recorders used are a slightly modified version of the L4A twin-track machine, operating at $1\frac{7}{8}$ i.p.s. Both tracks are recorded simultaneously one with the lateral guidance and the other with pitch guidance information. The L4 is an extremely rugged machine, powered by leak-proof rechargeable batteries, and weighs only $10\frac{3}{4}$ lbs. It was developed by EMI to produce high-quality recordings for broadcasting and scientific purposes.

Radio Topics

By Recorder

AS YOU STRUGGLE TO GET YOUR CAR through the packed streets of London, do not finally despair. Succour is at hand in the shape of our old friend, the ubiquitous computer.

The Marconi Company has just won a contract from the Greater London Council for a computer display system which will extend the existing Ministry of Transport experimental facilities for the computer control of road traffic in West London. A Marconi Myriad II computer is to be used and this, in conjunction with graphical displays type X2000, will provide operators in the existing control centre at New Scotland Yard with additional information on traffic conditions at the road junctions under control.

Street Display

The new system will display plans of any section of the street network on c.r.t. monitors. Street names, pedestrian crossings, the location of traffic detectors and all other essential features will be shown, together with continuously updated data on the traffic situation as it exists at each moment. Information will be displayed in written form on the screens, or as a graphical presentation, as selected by the operator. The installation will also be used to provide routine statistical analysis of the performance of the traffic control system,

and for the "post mortem" examination of unusual traffic situations.

It is stated that this is the first time that electronic graphical display systems have been applied to road traffic control, and that the Marconi installation will provide the first example of a display system which could become commonplace in the 1970's. The present capability of the Marconi Company in this field is based on the many years of experience the Company has acquired in civil and military air traffic control.

The new Marconi contract represents a second stage in the planned G.L.C. development programme for the control of traffic over a very wide area of London, and involves hundreds of additional intersections. Apart from analysis and display, the system to be installed is capable of directly controlling further installations, along the lines of the Ministry of Transport's West London experiment.

In addition to the Myriad computer and displays, the order, valued at nearly £135,000, includes disc and tape backing stores and all other peripheral equipment.

This new installation certainly represents a very welcome step forward in the fantastically complicated problem of avoiding road chaos in our largest city. And it also notches up yet another victory for the computer in its attempts

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G. A. Frenchski

I see that another *Radio Constructor* design has been reproduced in abridged form (and with full and proper acknowledgement to source) in the Soviet monthly magazine *Radio*. In this instance it is G. A. French's "Suggested Circuit No. 197" which was published in our April 1967 issue, and it reappears in the March 1968 copy of *Radio*.

"Suggested Circuit No. 197" described a high resistance voltmeter which, using a single OC202 silicon transistor as d.c. amplifier, offered a sensitivity of 200k Ω per volt. The design had two preset potentiometers and one panel-mounted potentiometer, these having values of 5k Ω , 500k Ω and 25k Ω respectively; and it is interesting to observe that, in the Russian version of the circuit, these are changed to 4.7k Ω , 470k Ω and 24k Ω . It would appear that the Russians favour the use of potentiometers manufactured to preferred figure values, as opposed to our own habit of continuing to make most of our potentiometers to round figure values.

Printed Circuit Kit

To hand is a sample printed circuit kit from G.S.P.K. (Electronics) Ltd., of Harrogate. Many readers are interested in making their own printed circuits and so I pass on details here.

The kit is delivered in a plastic case which may also be brought into service, if desired, as a container for the copper etching process. Included are three

good-quality blank copper laminate sheets, each measuring 5 $\frac{1}{4}$ by 3 $\frac{3}{4}$ in, together with a brush and two bottles. One of the bottles contains resist while the other contains etching fluid.

The instructions are very simple. The laminate should first be cut to size, scrubbed with Vim or an equivalent and rinsed well. When dry, the desired circuit is then painted with resist on to the copper and this is allowed to dry in its turn. The laminate is then immersed in the etching fluid until all the unwanted copper is removed whereupon, after final cleaning and drying, the circuit is ready for use.

The price of the kit is £1 5s. 0d. plus 3s. 6d. postage and packing, and it is available from G.S.P.K. (Electronics) Ltd., Hookstone Park, Harrogate, Yorks.

Plenty of Choice

We certainly have plenty of components to choose from these days so far as the making of amateur experimental equipment is concerned. We can choose from all the valves that are available, from all the transistors—whether p.n.p. or n.p.n. and germanium or silicon—and, even, from a gradually increasing range of integrated circuits. No to mention the unijunctions and field effect transistors which can now also be bought at quite low cost. In the present issue, for instance, G. A. French (who seems to be getting a lot of mentions this month) describes a simple but very practicable bit of gear employing two f.e.t.'s which retail at around the ten bob mark each.



Assembling the Knight Oscilloscope type KG-635, one of the many "Knight-Kit" electronic construction kits now exclusively marketed in the UK by *Electroniques* (prop STC Ltd.).

"Knight-Kits" are easy to assemble kits which enable anyone, regardless of their technical knowledge, to construct professional standard electronic equipment. The KG-635, which takes about 20 hours to build, is a d.c. coupled instrument having d.c.-5.2 Mc/s bandwidth.

I must confess that the experimental circuits which intrigue me most of all are those which incorporate components of different categories, as are given when, say, transistors are employed with valves to the greatest mutual advantage. In this respect, I've had a sneak preview of next month's "Suggested Circuit", and this presents a design in which the ionisation of a neon bulb at its striking potential actuates a relay by way of two transistors connected in cascade. I won't give any further details now, but this approach certainly represents a good example of different classes of components being usefully brought together in a single working circuit.

We tend to look upon individual pieces of electronic gear as being either all solid-state, all vacuum, or all electro-mechanical, but to my mind this represents a wasteful approach. All the different types of component have their own specific advantages, and a really clever design is one which makes use of these advantages even if the result is completely "hybrid". After all, the mongrel may not win many prizes, but he's nearly always the one who has the greatest staying power and absence of temperament!

Push Buttons

The older hands may remember the considerable fuss that was made before the war when sound radio manufacturers introduced receivers with what was, at that time, the marvellous innovation of push button tuning. Instead of having to turn a knob to select the required station on these sets it was merely necessary to press one of a row of buttons. This, then, either switched in the signal frequency and oscillator tuned circuit components needed for the desired signal or, in more ambitious models, caused a motor to turn the tuning capacitor to the requisite position.

The push button idea was well received by the public and was, indeed, an excellent thing. The only trouble is that the industry had had a push button fixation ever since, and continues to incorporate push buttons on new equipment when a rotary switch or similar type of control would be much more sensible. Whereas the old radio sets were large and heavy and could stand the most ham-handed of jabs at their buttons without jibbing, modern equipment can not. There have been, for instance, quite a few light-weight TV receivers introduced over recent years in which channel selection is by means of push button, but which have suffered from the snag that the cabinet has to be held tightly with the free hand when pressing the button or it otherwise topples over! And now, one of the biggest names in the hi-fi manufacturing world has produced a pre-amplifier which is liable to shift all over the place when one of the function buttons on its front panel is depressed unless, once

again, its case is steadied by the remaining hand.

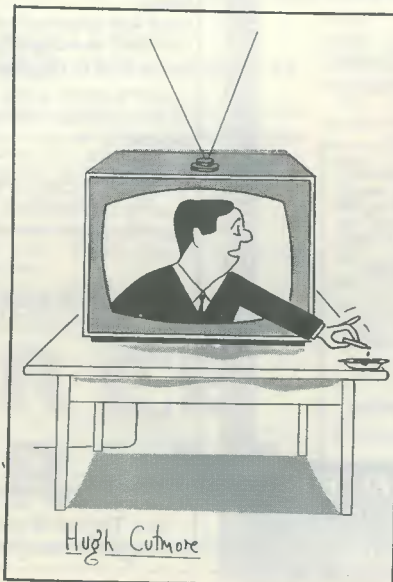
The whole point of having push button is, surely, that they can be pressed by a finger of one hand. If, to press the button, two hands are needed the entire advantage of press button operation becomes lost, and it would be far, far better to revert to a rotary switch. Let's hope that, one of these days, this simple basic fact will filter through to those responsible for the design of our domestic electronic equipment.

Soldered Socks

There are all sorts of things to watch out for when pursuing the hobby of radio construction including, in particular, the hazards attendant on soldering.

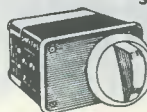
One of the lesser known of the latter is liable to occur if you are wearing the thin nylon socks which are so popular these days. We all of us, either intentionally or accidentally, occasionally knock excess solder from the soldering iron on to the floor. If, however, the molten solder happens to drop instead on an ankle or instep clad in a thin nylon sock you jolly soon know all about it! A large blob of solder will become inextricably entangled with the nylon material before it sets and it will also attempt to form a good eutectic joint with the skin underneath. At the same time, the sock keeps the hot solder hard against the skin unless you can manage to hold the nylon away until it has cooled. A final annoyance is that it is often very difficult to remove the solder from the sock later, with the result that you become lumbered with footwear having its own inbuilt glitter.

The moral of all this is the obvious one. If you *do* flick solder on to the floor, make certain that your feet are kept well out of the way!



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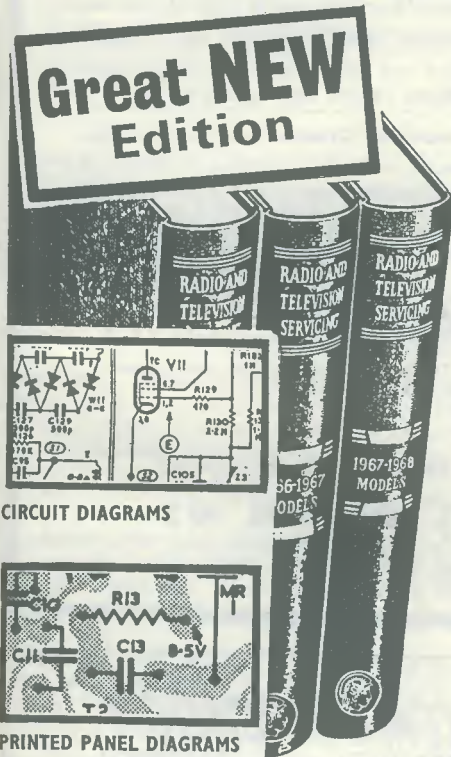
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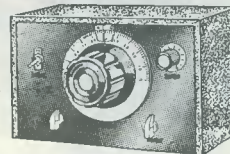
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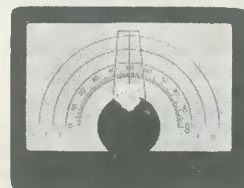
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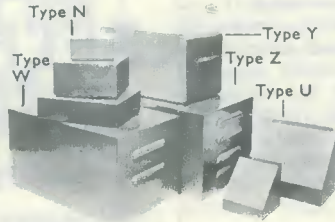
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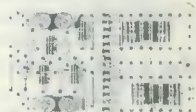
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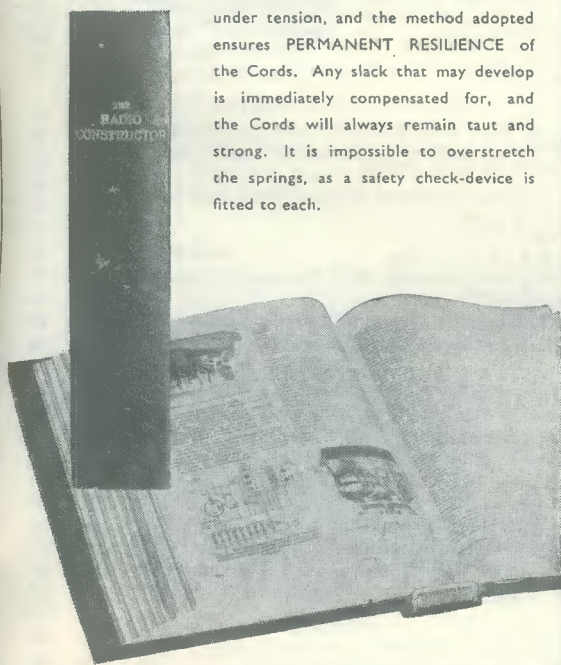
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Combined AF/RF Signal Tracer, by <i>W. Kemp</i>	44	Aug. '67
Electronic D.C. Meter Amplifier/Converter, by <i>W. Kemp</i>	526	Apl. '68
Electronic Oscilloscope Switch, by <i>L. J. Aston</i>	220	Nov. '67
General Purpose Meter-Oscilloscope Calibrator, by <i>W. Kemp</i>	74	Sept. '67
Inductance Test Unit, by <i>G. A. Stanton, G3SCV</i>	533	Apl. '68
Oscilloscope Voltage/Time Calibrator, by <i>H. T. Kitchen</i>	618	May '68
S.C./O.C. Tester Using an I.C., by <i>G. A. French</i>	271	Dec. '67
Simple F.E.T. Voltmeter, by <i>G. A. French</i>	736	July '68

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The Beta Meter, by Sir Douglas Hall, K.C.M.G., M.A. (Oxon)	153	Oct. '67
Versatile Multimeter, by P. J. LeRiche	346	Jan. '68
Versatile Signal Generator, by S. J. Kearley	468	Mar. '68
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Aerial Tuner for 80/160 Metres, by F. G. Rayer, G3OGR	735	July '68
Hand Held 2-Way Radiophone, by F. G. Rayer, G3OGR	282	Dec. '67
The "Jupiter" 10 Watt 80/160 Metre Bands Transmitter, by F. G. Rayer, G3OGR	662	June '68
40 Watt 80 Metre Phone Transmitter, by F. G. Rayer, G3OGR	160	Oct. '67
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2 Decibel Table	iii	Feb. '68
3 Frequency/Wavelength Conversion Chart	473	Mar. '68
4 International Morse and N.A.T.O. Telephony Codes	491	Mar. '68
5 Capacitive Reactance—Audio Frequencies	541	Apl. '68
6 Capacitive Reactance—Radio Frequencies	559	Apl. '68
7 Inductive Reactance—Audio Frequencies	609	May '68
8 Inductive Reactance—Radio Frequencies	627	May '68
9 Eureka Resistance Wire	695	June '68
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CAN ANYONE HELP?

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402	Feb. '68	464	Mar. '68	538	Apl. '68
606	May '68	670	June '68	742	July '68

Marconi CCTV to Help Train Eye Surgeons

Moorfields Eye Hospital in City Road, London, one of the leading centres for eye surgery in the world, has equipped its new four-theatre surgical suite with Marconi closed-circuit television, in order to provide more effective training facilities for student surgeons.

Each of the new theatres has a V321 camera and a reference monitor incorporated into the opposite ends of a counterbalanced ceiling-mounted boom. The television operator, standing at the foot of the operating table, can, with reference to the monitor, move the camera by remote control into a position over the patient's head. The resulting pictures of the patient's eye are relayed via the television control centre above the theatres, to display monitors in the viewing gallery and in lecture rooms in the main hospital block.

Two further V321 camera channels have been supplied by Marconi's to the Hospital's second suite in Holborn, to serve exactly the same purpose.

The television presentation suite, alongside the viewing gallery in the City Road branch of the Hospital, features the television control room, a sound and vision switching centre, a Videotape recording room and an interview studio. Two Marconi V322B Studio Viewfinder Vidicon cameras enable lectures, interviews or comments on operations to be transmitted to the lecture halls. Composite training programmes incorporating live operations, slides and interviews, together with pre-recorded film, will be produced and co-ordinated in this presentation suite.

RC/DS/10

RADIO CONSTRUCTORS DATA SHEET

10

U.K. AMATEUR (SOUND) FREQUENCY BANDS

Nominal Wavelength	Frequency Limits (Mc/s)	Classes of Emission (simplified description)	Maximum d.c. Input Power
160m	1.8 — 2		10 watts
80m	3.5 — 3.8		
40m	7 — 7.1		
20m	14 — 14.35		150 watts
15m	21 — 21.45		
10m	28 — 29.7		
4m	70.1 — 70.7 ¹	c.w., m.c.w., d.s.b., s.s.b., f.s.k., f.m. telephony	50 watts
2m	144 — 146 ²		
70cm	427 — 450		
	1,215 — 1,325		
	2,300 — 2,450		
	3,400 — 3,475		
	5,650 — 5,850		150 watts
	10,000 — 10,500		
	21,000 — 22,000		
	2,350 — 2,400 ³	Pulse mod., telephony or telephony	25 watts mean, 2.5 kilowatts peak
	5,700 — 5,800 ³		
	10,050 — 10,450 ³		
	21,150 — 21,850		

The Table gives abbreviated information taken from the G.P.O. publication "How To Become A Radio Amateur". For full details, intending amateur transmitters must refer to this publication, which is available from Radio and Broadcasting Department, General Post Office, Armour House, St. Martin's-le-Grand, London, E.C.1.

¹ Frequency limitations in some areas.

² Aeronautical spot frequencies to be avoided.

³ No frequency in this band to be used without prior consent of the P.M.G.

SOLID STATE HIGH FIDELITY AUDIO EQUIPMENT

POWER AMPLIFIERS — PRE-AMPLIFIERS/CONTROL UNITS — POWER SUPPLIES

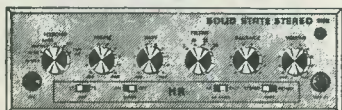
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MP3



SP4-A



SP6-2

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- SP6-2 mono/stereo (takes mag. pick-up as well) **£15.10.0** p.p. 5/-
- MPA12/3 12 watt amplifier 3 to 5 ohm output **£4.10.0** p.p. 2/6
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- MPA25 25-30 watt amplifier for 71-16 ohm speaker **£7.10.0** p.p. 3/6
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- MU24/40 choke version **£4.10.0** p.p. 3/6
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2A	MP3 + MPA12/15 + MU40	£16.0.0 p.p. 5/-
4	MP3 + (2) MPA12/15 + MU40	£21.2.6 p.p. 7/-
6	MP3 + MPA25 + MU60	£18.15.0 p.p. 7/-
8A	SP4-A + (2) MPA12/15 + MU40	£26.0.0 p.p. 8/6
10	SP6-2 + (2) MPA12/15 + MU40	£29.5.0 p.p. 8/6
12A	SP4-A + (2) MPA25 + (2) MU60	£35.10.0 p.p. 10/-
13	SP6-2 + (2) MPA25 + (2) MU60	£38.17.6 p.p. 10/-

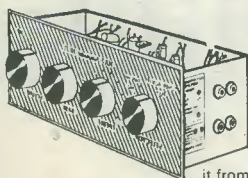
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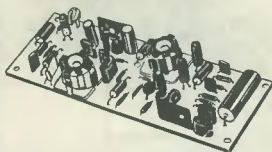
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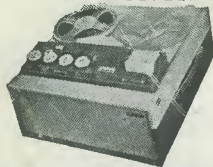
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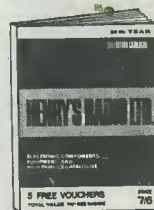
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