

THE Radio Constructor

RADIO
TELEVISION
AUDIO
ELECTRONICS

VOLUME 17 NUMBER 4
A DATA PUBLICATION
PRICE TWO SHILLINGS

November 1963

**GENERAL
COVERAGE
*Communications***

RECEIVER

a
Double Superhet
Design



6-Transistor
Superhet Radio

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Unit

• Bench Power
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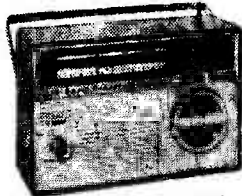
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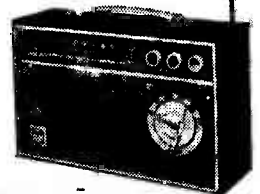
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- ★ I.F. Frequency 470 kc/s
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- ★ 350 Milliwatt output into 4" high flux speaker
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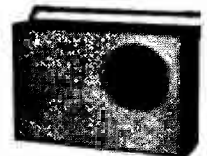
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Wired Amplifier complete with 4 valves, Front Panel, Knobs **£5.12.6** + 3/6 carr.

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Accessories—Mike, Spare Reel Tape, Screened Lead, Plugs, etc. **£1. 1.0** + 2/- carr.

COMPLETE KIT comprising items above **15 gns.** + 10/- carr.

Leaflet, Circuit and Instruction 2/- post free

New Boxed	Valves	Reduced Bargain Prices
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Famous Mfr. Bulk Purchase—Genuine recommended Tape Bargain. Uncond. Guar. Fitted Leader & Stop Foils (except 3"). Standard (PVC base) Long Play (PVC base) D'ble Play (Mylar base)
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 Post and Packing—3" Reels 6d. Each additional Reel 3d. 4" to 7" Reels 1/- Each additional Reel 6d.
EMPTY TAPE REELS (Plastic): 3" 1/3; 5" 2/-; 5 1/2" 2/-; 7" 2/3
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Soldering Irons. Mains 200/220V or 230/250V. Solon 25 watt Inst., 22/6. Spare Elements, 4/6. Bits, 1/- 65 watt, 27/6 etc.
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3 VALVES 3 WATT

3 ohm and 15 ohm Output A really first-class Amplifier giving Hi-Fi quality at a reasonable cost. Mullard's latest circuit. Valve line-up: EF86, EL84, EZ81. Extra H.T. and L.T. available for Tuner Unit addition. This is the ideal companion Amplifier for FM tuner units.

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Volume Controls—SK-2 Megohms, 3" Spindles Morganite Midget Type, 1 1/2" diam. Guar. 1 year. 1.0G or 1.1H resist. less Sw. 3/-. D.P. Sw. 4/6. Twin Stereo less Sw. 6/6. D.P. Sw. 9/6 (100 k. to 2 Meg. only).

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Brand New—BVA 1st Grade		
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Contemporary style, rexine covered cabinet in two-tone maroon and cream. Size 15 1/2" x 14 1/2" x 8 1/2", fitted with all accessories including baffle board and Vinair fret. Space available for all modern amplifiers and auto-changeers, etc. Uncut record player mounting board, 14" x 13" supplied Cabinet Price 59/6. Carr. and Ins. 5/-.

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EZ80 and Twin stage ECL82 with vol. and neg. feedback tone control. A.C. 200/250V with knobs, etc., ready wired to fit above cabinet. £2.17.6. P. & P. 1/6. 7" x 4" Speaker and trans, 22/-. P. & P. 2/-.

COMPLETE R/PLAYER KIT. As ill. inc. BSR UA14 Unit. New Bargain Price Now Only £11.10.0, 7/6 carr.



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PVC CONNECTING WIRE—10 colours (or chassis wiring, etc.)—Single or stranded conductor, per yd., 2d. Sleeving 2d. yd.

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 Midget Driver Trans. 3.5:1 6/9
 Ditto O/Put Push-pull 3 ohms 6/9
 Elect. Condensers—Midget Type 15V 1mfd-50mfd, ea. 1/9. 100mfd. 2/-.

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 Condensers—150V, wkg. .01 mfd. to .04 mfd., 9d. .05 mfd., .1 mfd., 1/-, .25 mfd., 1/3. .5 mfd., 1/6, etc.

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JASON FM TUNER UNITS

Designer-approved kit of parts: FMT1, 5 gns. 4 valves, 20/-.
 FMT2, £7. 5 valves, 35/-.
 JTV MERCURY 10 gns. 3 valves, 22/6.
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NEW JASON FM HANDBOOK, 2/6. 48 hr. Alignment Service 7/6. P. & P. 2/6.

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Brand New. Mfrs. surplus list grade 1 OC44 & 2 OC45, 13/6.
 1 OC181D & 2OC81, 13/6.
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 † Meg. VOL Controls D.P. Sw. 1/6 fitted spindle. Famous Mfrs. 4 for 10/- post free.



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HI-FI AMPLIFIERS TUNERS RECORD PLAYERS

S-33



S-99



GL-58



HA-12



HI-FI 6W STEREO AMPLIFIER. Model S-33. 3 watts per channel 0.3% distortion at 2.5W/chnl., 20dB N.F.B. Inputs for Radio (or Tape) and Gram, Stereo or Monaural, ganged controls. Sensitivity 200mV. **£13.7.6**

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GARRARD AUTO/RECORD PLAYER. Model AT-6. With R 105 cartridge. **£13.12.1** With Decca Deram pick-up **£14.6.1**

SUGDEN MOTOR UNIT "CONNOISSEUR CRAFTSMAN". Heavy duty motor operating at 33½ and 45 r.p.m. Very heavy 12" turntable. Virtually no rumble. **£16.6.6**

HI-FI MONO AMPLIFIER. Model MA-5. A general purpose 5W Amplifier, with inputs for Gram., Radio. Presentation similar to S-33. **£10.19.6**

HI-FI MONO AMPLIFIER. Model MA-12. 12W output, wide freq. range, low distortion. **£11.9.6**



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O-12U



S-3U



C-3U

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V-7A



RF-1U

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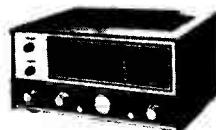
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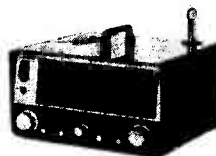
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RA-1

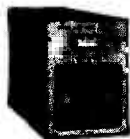
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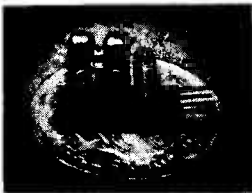
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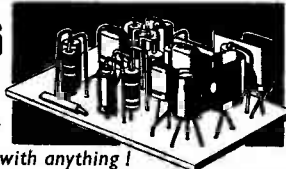
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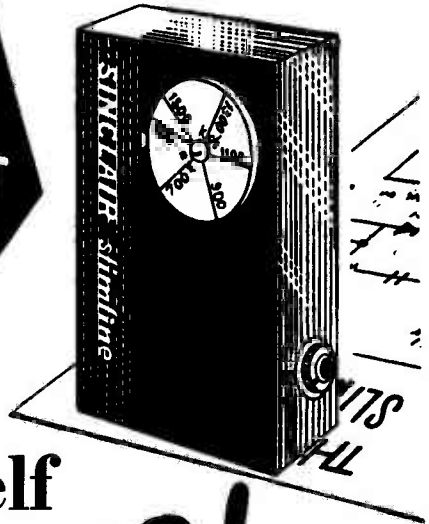
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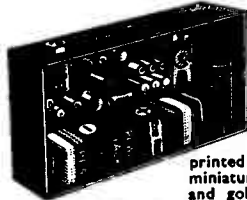
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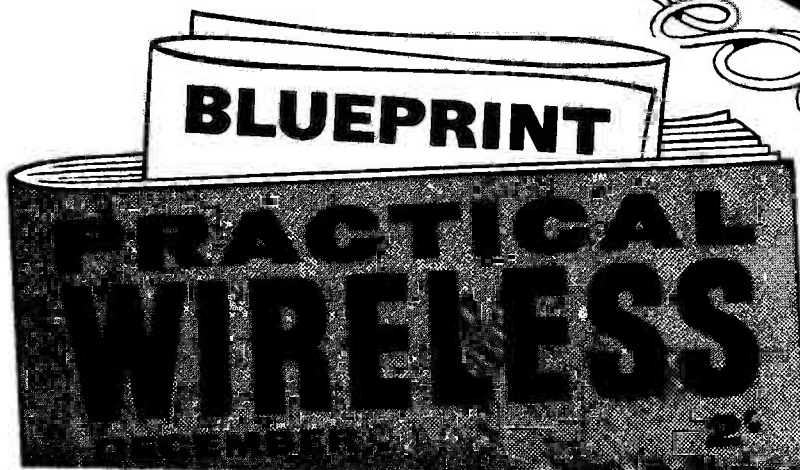
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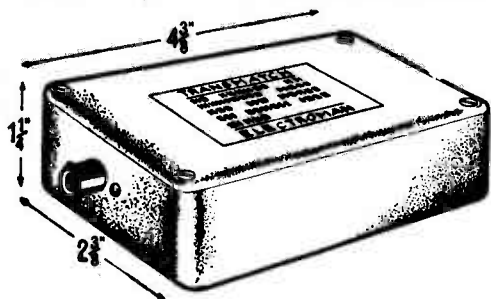
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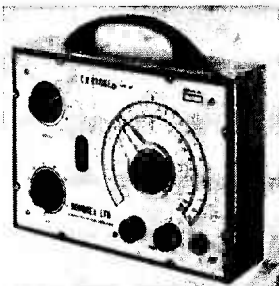
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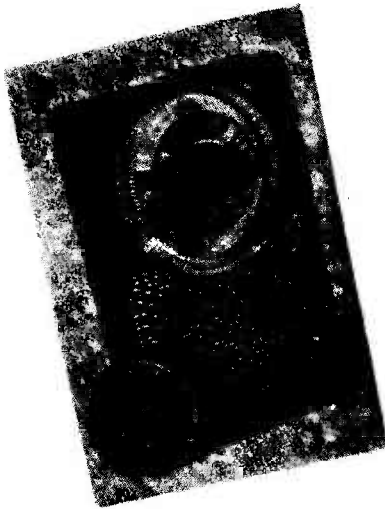
TECHNICAL QUERIES must be submitted in writing. We regret that we are unable to answer queries, other than those arising from articles appearing in this magazine; nor can we advise on modifications to the equipment described in these articles.

CONTRIBUTIONS on constructional matters are invited, especially when they describe the construction of particular items of equipment. Articles should be written on one side of the sheet only and should preferably be typewritten, diagrams being on separate sheets. Whether hand-written or typewritten, lines should be double spaced. Diagrams need not be large or perfectly drawn, as our draughtsmen will redraw in most cases, but all relevant information should be included. Photographs should be clear and accompanied by negatives. Details of topical ideas and techniques are also welcomed and, if the contributor so wishes, will be re-written by our staff into article form. All contributions must be accompanied by a stamped addressed envelope for reply or return, and should bear the sender's name and address. Payment is made for all material published.

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6-Transistor Superhet Pocket Radio

By A. E. Stubbs

THE AIM BEHIND THE DESIGN DESCRIBED HERE WAS to build a transistor pocket radio with a reasonable loudspeaker output. Dissatisfied with the performance of sets using three or four transistors it was decided that a six transistor superhet was the only solution. After some research, a circuit using very small components was found, and this is shown in Fig. 1.¹ The extremely small size of the transformers, loudspeaker and tuning capacitor employed in the circuit enabled the radio to be built in a very small space. Indeed, it represents the smallest home-constructed superhet radio incorporating a speaker that the writer has encountered at the time of writing.

The Circuit

It will be seen from Fig. 1 that the receiver is a conventional six-transistor superhet. A ferrite slab aerial is used. This is tuned by CV₁, and the step-down coupling winding supplies the signal to the base of TR₁. This transistor operates as a self-oscillating frequency changer, oscillation being produced by collector to emitter coupling via the oscillator coil L₂. Correct alignment is achieved by adjustment of the 6pF trimmers in parallel with each gang of the tuning capacitor.

The intermediate frequency is obtained by mixing the input signal and local oscillator frequency at TR₁. The 465 kc/s signal now passes through IFT₁ to the base of TR₂. D.C. bias on the base of TR₂ is varied by an a.g.c. voltage from the detector, D₁, this being applied via decoupling components R₁₆ and C₁₁. TR₃ provides further amplification at the intermediate frequency. Detection is performed by diode D₁ and this is followed by C₁₂ and RV₁. C₁₃ now takes the signal to the a.f. amplifier TR₄, which is a conventional driver transistor supplying the phase-splitting transformer T₁. C₁₅ eliminates high frequency hiss and improves the balance between bass and treble in the speaker. A Class B output stage is used, with the output transistors biased almost to cut-off point at about 0.2 volts negative with respect to chassis.

¹ Fig. 1 is based on a circuit recommended by Technical Suppliers Ltd. for use with subminiature T.S.L. components.

C₁₆ further helps to keep transistor hiss to a minimum. The output transformer feeds the 10Ω miniature speaker with about 200mW of output power. C₁₇ provides decoupling for the i.f. strip. The whole set is powered by a 9-volt battery, which lasts about 60 hours at maximum volume.

C₅ and C₉, the 3pF neutralising capacitors, are not essential, but the purist may wish to include them if he can find room! I.F. gain can be improved by reducing R₄ to as little as 33kΩ, but this necessitates increasing C₁₅ to 0.01μF (in which case C₁₆ can be omitted). The original circuit employs an OC44 and two OC45's, an OC71 and two OC72's, but it is worth mentioning that high frequency transistors such as the OC170 in the r.f. and i.f. positions improve gain and stability considerably. Almost any of the usual output transistors could be used, and an OC75 works particularly well in the TR₄ position. The speaker is a 1½in, 10Ω unit.

Components List

Semiconductors

TR ₁	OC44	
TR ₂	OC45	
TR ₃	OC45	
TR ₄	OC71	
TR ₅	OC72	} matched pair
TR ₆	OC72	
D ₁	OA91	

Miscellaneous

- Speaker, 10Ω impedance, 1½in dia., type LP45F. (Technical Suppliers Ltd.)
- Battery, 9 volt, type PP3
- Earpiece socket
- Tuning knob and scale (see text)
- Cabinet and component boards (see text)

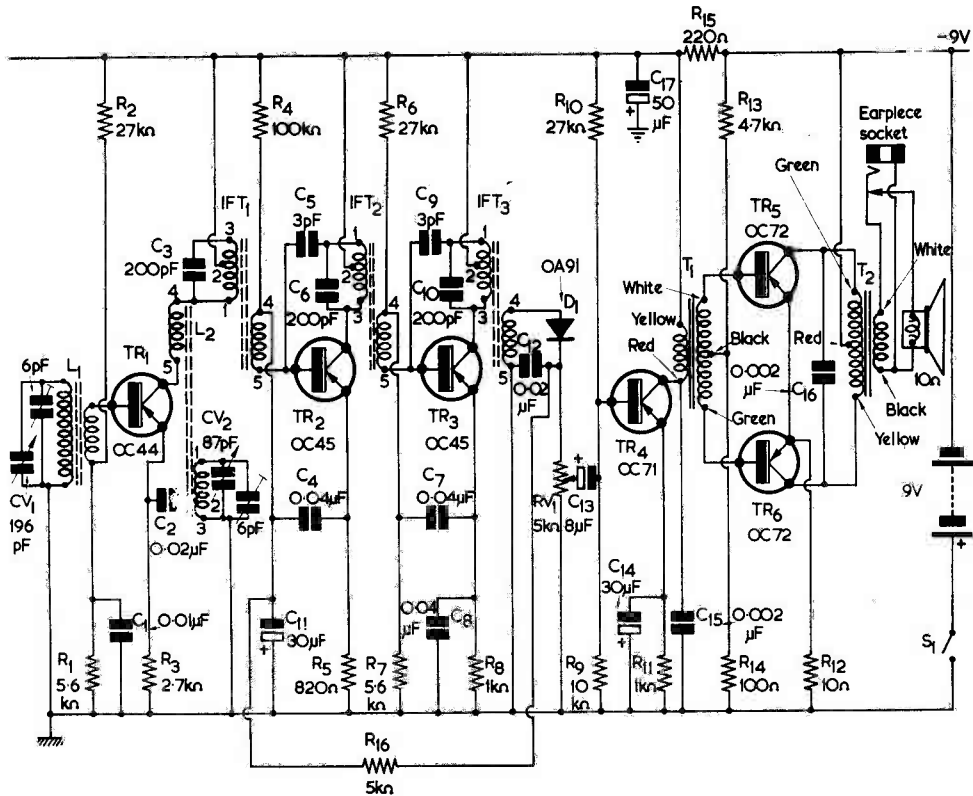


Fig. 1. The circuit of the subminiature receiver. Switch S_1 is ganged with the volume control RV_1 . The two 6pF trimmers are mounted on CV_1 , CV_2

Resistors

(All fixed resistors $\frac{1}{4}$ or $\frac{1}{10}$ watt 10%)

R_1	5.6k Ω
R_2	27k Ω
R_3	2.7k Ω
R_4	100k Ω
R_5	820 Ω
R_6	27k Ω
R_7	5.6k Ω
R_8	1k Ω
R_9	10k Ω
R_{10}	27k Ω
R_{11}	1k Ω
R_{12}	10 Ω
R_{13}	4.7k Ω
R_{14}	100 Ω
R_{15}	220 Ω
R_{16}	4.7k Ω
RV_1	5k Ω potentiometer, log track. Edge control with switch

Capacitors

(All capacitors should be miniature types. In some instances, space may be saved by using ceramic instead of paper capacitors at decoupling positions)

C_1	0.01 μ F paper
C_2	0.02 μ F paper
C_3	200pF silver mica

C_4	0.04 μ F paper
C_5	3pF ceramic (see text)
C_6	200pF silver mica
C_7	0.04 μ F paper
C_8	0.04 μ F paper
C_9	3pF ceramic (see text)
C_{10}	200pF silver mica
C_{11}	30 μ F electrolytic 6V wkg.
C_{12}	0.02 μ F paper
C_{13}	8 μ F electrolytic 3V wkg.
C_{14}	30 μ F electrolytic 6V wkg.
C_{15}	0.002 μ F paper or ceramic
C_{16}	0.002 μ F paper or ceramic
C_{17}	50 μ F electrolytic 9V wkg.
CV_1 , CV_2	196+87pF sub-miniature twin-gang capacitor type PVC-2M. (Technical Suppliers Ltd.)

Inductors

(All inductors are subminiature components, and are available from Technical Suppliers Ltd.)

L_1	Medium wave ferrite frame
L_2	Oscillator coil (red)
IFT_1	First i.f. transformer (orange)
IFT_2	Second i.f. transformer (white)
IFT_3	Third i.f. transformer (black)
T_1	Driver transformer type TR190/EIP
T_2	Output transformer type TR190/EIE

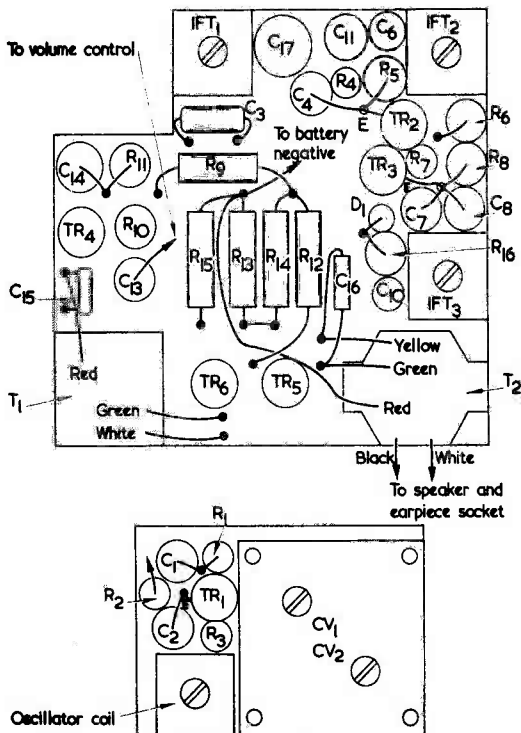


Fig. 2. Two Paxolin boards are employed in the receiver, the component sides of which are shown here. The component side of the larger board is towards the front of the receiver, whilst the component side of the smaller board is towards the rear. The speaker magnet takes up a position at the approximate centre of the larger board. It will be noted that the emitters of TR₁, TR₂ and TR₃ connect into circuit on the component side of the board. Capacitors C₅ and C₉ do not appear in this diagram (see text). Also not shown is C₁₂, which is attached to the volume control tags

Despite its small size this speaker has a large magnet and speech coil which can cope adequately with the power available. Quiescent current is about 5mA, increasing to 30mA at full volume.

Construction

The components are mounted on two Paxolin boards. These being cut and drilled as shown in Figs. 2 and 3. A socket for earpiece listening is provided, and some constructors may wish, as the writer did, to connect similar sockets at the output from the detector and input to the amplifier. The quality of sound at the detector is exceptionally good, and is suitable for tape-recording, for feeding a larger amplifier, or for personal listening.

In order to save space the components are mounted vertically and secured by passing their leads through holes in the board and bending or soldering the leads immediately on the underside of the board. Care should be taken not to damage the components when bending the leads. Some form of heat shunt is essential when soldering transistor

leads, especially when these have been shortened.

9BA screws are needed for securing the tuning capacitor, and the ferrite aerial assembly can be fastened down with a rubber band. Care must be taken with the aerial coil as the thin litz wires are easily broken. Holes with a diameter of $\frac{1}{8}$ in are the best size for component leads, but this size of drill should be used with care in an ordinary hand brace. Saw cuts at the edge of the board will accommodate the i.f. transformer lugs adequately. The connections to the oscillator coil and i.f. transformers are shown in the diagrams as they appear in the original design, but the writer found that both windings on the oscillator coil had to be reversed (the connection to tag 2 remaining unaltered) before the set would function. The volume control is held in position by a short length of rigid copper wire (16 s.w.g.) which connects it to the positive line on the mains chassis. A piece of insulating tape prevents the volume control short circuiting to the r.f. assembly. C₁₂ does not appear on the layout diagram, this component being attached to the

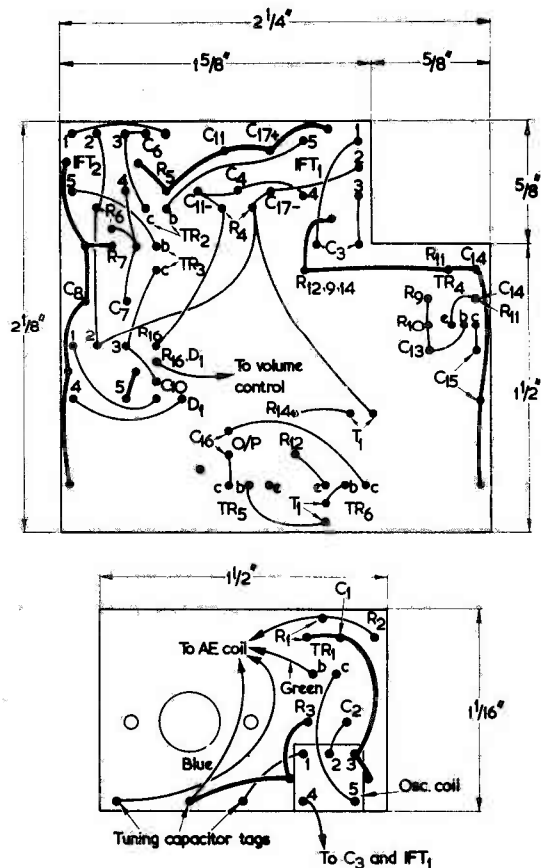


Fig. 3. The layout of the principal wiring on the reverse side of the boards. This diagram is intended to provide guidance, and final wiring should be checked against the circuit diagram

volume control taps. The smaller Paxolin board is held in the cabinet by two 6BA bolts, which locate with two nuts glued in the case. The speaker magnet should fit snugly in the centre of the components on the larger board, whereupon the whole assembly can then be fitted into the case. One small plastic angle bracket was found sufficient to hold the main chassis in place. This was fixed to the case with Araldite and to the chassis by a small nut and bolt between the output transistors. There should now be just enough room next to the tuning capacitor for the battery, and this can be connected by means of two clips removed from an old battery of the same type.

Case

A plastic soap-box could be improvised to make quite a suitable case for this receiver, although some difficulty may be experienced in finding one of suitable size. The case employed by the writer was built from Formica. Six pieces of Formica (or Paxolin) $\frac{1}{8}$ in thick are cut to the following dimensions:

- 1 piece $2\frac{1}{2} \times 3\frac{3}{4}$ in—back of case
- 2 pieces $2\frac{1}{2} \times 1\frac{1}{8}$ in—ends of case
- 2 pieces $3\frac{3}{4} \times 1\frac{1}{8}$ in—sides of case
- 1 piece $2\frac{1}{2} \times 1\frac{1}{8}$ in—part of front of case.

A piece of speaker grille measuring $2\frac{1}{2} \times 2\frac{1}{4}$ in forms the remainder of the front of the case.

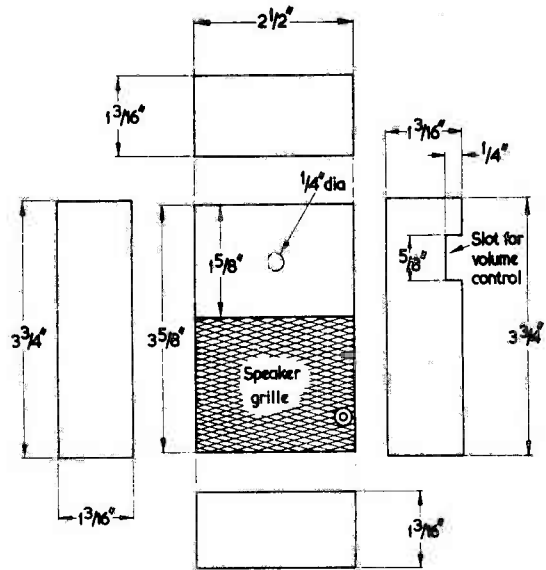


Fig. 5. Details of the cabinet built for the prototype. The edges of the speaker grille are folded down and glued to the inside of the case

In one of the long, narrow pieces a slot must be cut to accommodate the volume control flange, and holes must be drilled elsewhere for fixing screws and the tuning capacitor spindle. (See Fig. 4). Araldite epoxy resin is used to fix these pieces together. The joints are preferably made individually and clamped in position while left overnight to set. The back is held on to the case by means of counter-sunk 6BA screws at each corner which locate with nuts glued with Araldite in each corner of the case. If a silver (aluminium) speaker grill is used, the case can be painted with black enamel paint to give quite an attractive finish.

Alignment and Adjustment

Alignment of the i.f. strip is preferably done with the aid of a signal generator, and those who own one will be familiar with the procedure. Otherwise it is suggested that the following method is used. Tune to any station and adjust the i.f. transformers for maximum volume, starting with IFT₃. Alignment will not yet be fully completed, as the a.g.c. has probably come into operation, so a very weak signal has next to be selected and the i.f. transformers readjusted for maximum volume. The radio can be now fitted into the case and a suitable dial attached. Turn the dial until it indicates a station at the high frequency end of the waveband such as Radio Luxembourg. The oscillator trimmer is now adjusted until that station is heard. Next turn the dial to indicate a station at the low frequency end of the band, such as the Third Programme, and adjust the oscillator coil until that station is heard. Returning to the high frequency end, it will be found that the station chosen there has "moved", so the process is repeated until both stations appear at the correct settings of the dial. Using the same

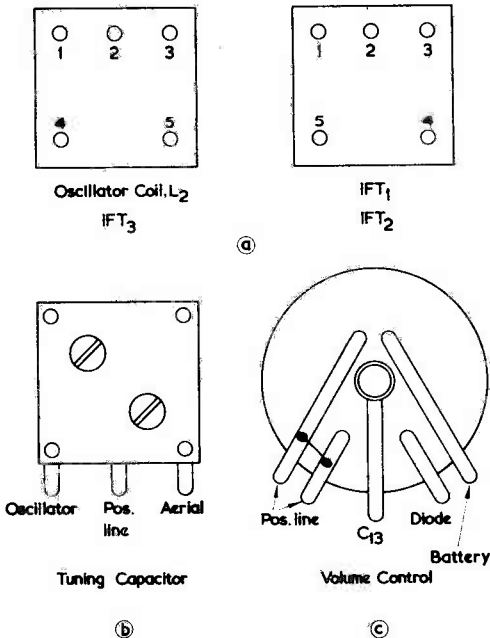


Fig. 4. The tag layout for (a) the i.f. transformers and oscillator coil, (b) the tuning capacitor, and (c) the volume control employed by the writer. Alternative volume controls may differ in tag layout to that shown here

two stations the aerial trimmer is adjusted for maximum volume at the high frequency end of the band and the aerial coil is slid along its ferrite slab until maximum volume is obtained at the low frequency end of the band.² The back of the case can now be attached and set is ready for use.

Performance

The performance of the completed set is comparable with, and indeed better than, many manufactured radios of similar size. There is ample

² The tuning scale employed by the writer consisted of a piece of gummed paper having the various stations printed on it. Such scales may be available from some suppliers as part of receiver kits. —EDITOR.

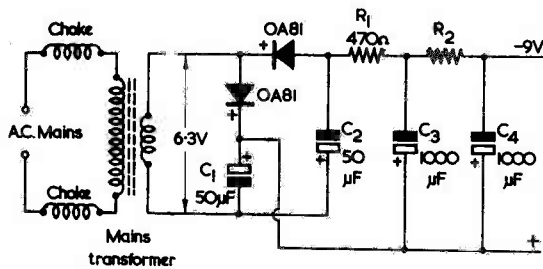


Fig. 6. A suitable mains pack for the receiver

Components List (Fig. 6)

Resistors

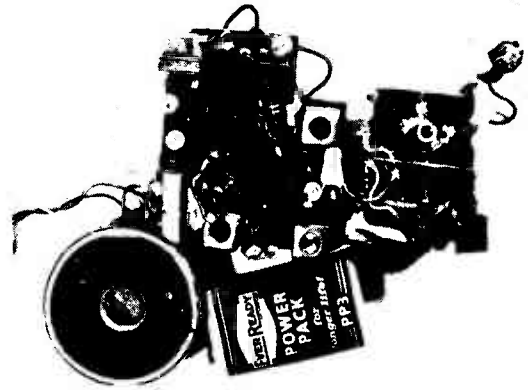
- R₁ 470Ω ½ watt
- R₂ See text

Capacitors

- C₁ 50µF electrolytic, 15V wkg.
- C₂ 50µF electrolytic, 15V wkg.
- C₃ 1,000µF electrolytic, 15V wkg.
- C₄ 1,000µF electrolytic, 15V wkg.

Inductors

- Mains transformer: heater transformer with 6.3 volt secondary
- Chokes (see text)



The wiring side of the smaller board, and the component side of the larger board

volume to fill an ordinary room, even on Continental stations. The quality of the sound is reasonable, though by no means hi-fi. When used in the open air, the speech from the set was clearly audible at a distance of 100ft. Next to compactness, the second virtue of this set is sensitivity. Typical superhet selectivity therefore enables many Continental stations to be received. Because of the high gain in the i.f. strip and the presence of a.g.c., Radio Luxembourg is received with only very slight fading.

The tiny speaker does not really do justice to the rest of the set so, when used in the home, it is a good idea to connect a larger speaker to the earpiece socket. By this means much more sound, at a surprisingly good quality, is obtained.

Power Supply

In order to drive this radio from a.c. mains the circuit shown in Fig. 5 was used. A heater transformer with a 6.3 volt secondary winding is employed in a voltage doubler circuit. The values of the electrolytic capacitors are not critical. No value is given for R₂ as this will depend on the transformer used. In the prototype, mains hum gave no trouble but there was some mains-borne interference. This was overcome by inserting a choke (consisting of a few dozen turns of enamelled copper wire wound on an old resistor) in each mains lead. Mullard OA81 diodes will pass sufficient current to drive the radio.

Mullard Introduce Solid Electrolyte Aluminium Capacitors

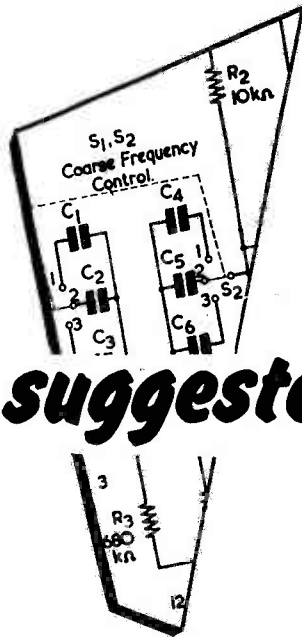
Aluminium foil capacitors with solid electrolyte—the first to be marketed in this country—have been introduced by the Mullard Component Division.

The new capacitors which are designed for professional equipment, use manganese dioxide in place of the usual liquid electrolyte. As a result their impedance characteristic at high frequencies is better than that of conventional electrolytics, particularly at low temperatures and, because the electrolyte cannot dry up, their electrical stability during service life is improved.

The electrical characteristics of solid aluminium capacitors are similar to those of solid tantalum capacitors for which, in many applications, they afford an economic replacement.

The present range covers values from 12µF 40V d.c. to 100µF 4V d.c. housed, according to capacitance and voltage rating, in insulated aluminium cans of four sizes. The smallest can measures 6.4mm by 14mm and the largest 10.3mm by 21mm.

Working temperature range for all values is -80°C to +85°C.



The circuits presented in this series have been designed by G. A. French, specially for the enthusiast who needs only the circuit and essential data

suggested circuits

No. 156 Low Cost Light Beam Counter

IN "SUGGESTED CIRCUIT" NO. 139¹, the author described several methods by means of which a light dependent resistor could be employed to control a relay. The relay then operated an external circuit either when the light dependent resistor was illuminated, or when its illumination was interrupted.

At a later date, circuits of this type were referred to in "In Your Workshop"², in which it was stated that a relay controlled by a light dependent resistor could, in turn, actuate an electro-magnetic counter. The latter would then indicate the number of times a light beam was interrupted. A device of this nature can, of course, be employed for counting goods, or persons, passing a particular point.

Both these articles aroused interest amongst readers, and it was decided, as a result, to devote the present contribution in the "Suggested Circuit" series specifically to a practical light beam operated counter.

Circuit Approach

The circuit described here has been primarily designed to meet the requirement of low cost, and it is not capable of counting at the same high

¹ "Suggested Circuit" No. 139, "Light Dependent Resistor Control Circuits", June 1962 issue.

² "In Your Workshop", June 1963 issue.

speed as can more sophisticated and costly equipment. Both the electro-magnetic counter and the light dependent resistor are sluggish in operation, and the maximum speed offered by the prototype was four counts per second when the light beam was interrupted for approximately 75% of each cycle. It would appear to be safe to assume, from this performance, that devices employing the circuit should be capable of counting any object which interrupts the light beam for a minimum of some 250 milliseconds, the following illuminated period being at least 80 milliseconds. It will be noted that the device is more sluggish for the non-illuminated condition than for the illuminated condition. The non-illuminated condition corresponds to operation of the electro-magnetic counter armature, and the sluggishness is due, partly, to the time taken for the armature to move to the energised position and, mainly, to the time needed by the light dependent resistor to achieve increased resistance.

The electro-magnetic counter used in the circuit is a low-cost ex-Post Office unit available as surplus equipment.³ This counter, which

³ The type employed is an electro-magnetic counter with 2,300Ω coil and is available from Samsons (Electronics) Ltd., 9 and 10 Chapel Street, London, N.W.1, at 12s. 6d. plus 2s. postage and packing.

does not have a zero re-set facility, operates at a nominal 50 volts energising potential and has a maximum speed of some 10 to 15 counts a second. The light dependent resistor employed is the ORP12, which requires only a low level of illumination, and which offers a resistance change from 10MΩ or more in the non-illuminated condition to 75 to 300Ω when fully illuminated. The increase in resistance given when illumination ceases does not take place immediately, and a fall in current through the ORP12 from 100% to 15% may take, typically, about 100 milliseconds. For relatively low levels of illumination, current increase (corresponding to resistance decrease) may take place over even longer periods, and a rise from 20 to 100% may take as long as 700 milliseconds, or even more. For relatively high levels of illumination, however, current increase is quite rapid, and this condition was evident in the prototype.

As was explained in "Suggested Circuit" No. 139, an ORP12 can control a relay directly. It was decided, initially, to check a circuit in which the ORP12 controlled a relay, whose contacts then operated the electro-magnetic counter. This circuit worked quite well but, since it was difficult to run the ORP12 so that it was on the steeper part of its current decrease/time characteristic,

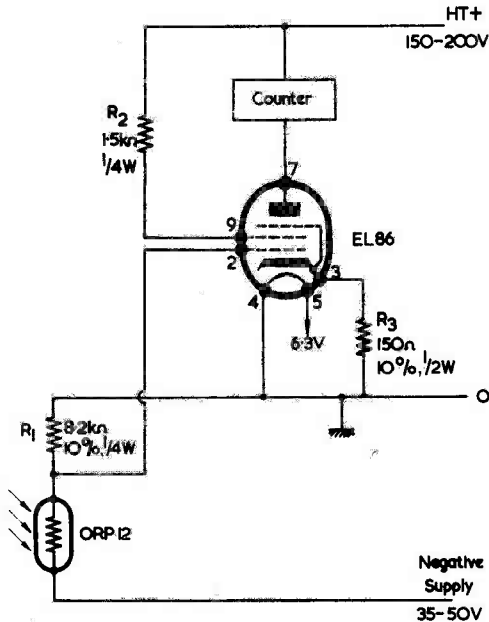


Fig. 1. The circuit of the light beam operated counter

whilst still working within its maximum dissipation figure, the idea was abandoned because the maximum counting speed was too low.

It was next decided to replace the intermediate relay with a valve. As the 50 volt energising requirement of the electro-magnetic counter necessitates, in any case, the use of a mains transformer and rectifier circuit, it was felt that the introduction of a valve represented no great disadvantage, since the only major further requirement was a heater supply. Such a heater supply would, in any case, be very convenient for supplying the illuminating lamp also.

The valve selected was an EL86, this being an output valve intended for use in single-ended push-pull output stages, and which is capable of providing anode currents well in excess of that needed to operate the electro-magnetic counter at anode voltages of the order of 100 only. Furthermore, the EL86 is available at quite low cost through advertisers in this magazine.

The Prototype Circuit

The circuit employed in the prototype is shown in Fig. 1.

In this diagram, the light dependent resistor is normally illuminated by a beam of light, with the result that it has a low resistance. In consequence, a high negative voltage appears at the lower end of R_1 . This negative voltage is applied to the

grid of the EL86 and causes it to pass a low anode current. If the light beam illuminating the light dependent resistor is interrupted, its resistance increases. The negative voltage on the lower end of R_1 then drops, causing the EL86 to pass an increased anode current and energise the coil of the electro-magnetic counter. When the light beam interruption ceases, the light dependent resistor is fully illuminated once

more. Its resistance drops, whereupon the grid of the EL86 assumes its previous high negative voltage and anode current decreases. The counter armature releases, and its mechanism indicates the next digit in order. This operation is repeated each time the light beam is interrupted, the number of interruptions being registered by the counter.

The value of R_1 , in conjunction with the applied negative voltage, offers a relatively high counting speed when the light dependent resistor has a resistance of approximately $1k\Omega$ in the illuminated condition. Maximum dissipation in the ORP12 occurs under half-voltage conditions, when its resistance is equal to that of R_1 . Assuming an applied negative voltage of 50, this corresponds to a dissipation of 76mW, which is comfortably below the limiting value of 100mW at 50°C specified for the ORP12.

Practical Points

The electro-magnetic counter should be capable of operating at a coil current of 16 to 20mA. If this is not achieved initially, the armature restoring spring anchorage should be carefully adjusted, as shown in Fig. 2. It may be found, also, that a reduction in armature restoring tension causes a slight improvement in counting speed even if the operating current falls, initially, between 16 and 20mA.

The power supply requirements are not critical. The h.t. positive voltage should lie between 150 and

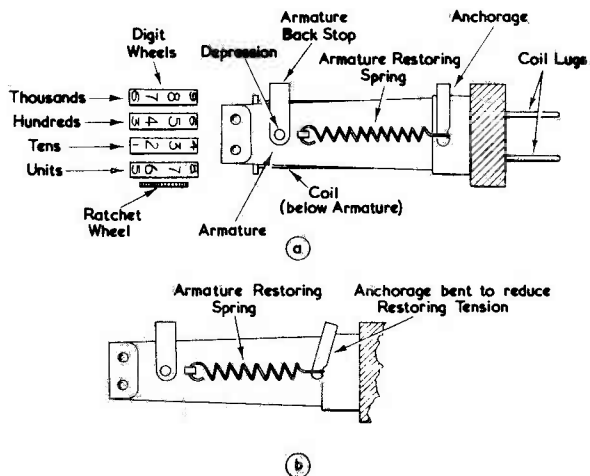


Fig. 2 (a). The internal layout of the electro-magnetic counter
(b). Showing, in exaggerated form, how the armature restoring spring anchorage may be adjusted to reduce restoring tension

200, and should not fall below 150 when the counter armature is operated. Some 50mA of h.t. current should be available. The negative supply for the ORP12 and R_1 should be regulated such that it does not fall below 35 volts when the ORP12 is illuminated, nor rise above 50 volts when the ORP12 is in the non-illuminated condition. The EL86 heater requirement is 6.3 volts at 760mA.

The Light Beam

The manner in which the ORP12 is operated with respect to the light beam depends largely upon the ideas of individual constructors. Nevertheless, some hints are given here.

It is first of all necessary to shield the ORP12 from ambient light, and this may be conveniently achieved by mounting it in a tube whose open end is directed towards the source of light, as in Fig. 3 (a). If necessary, the light may be concentrated on the light dependent resistor by fitting a convex lens at the open end of the tube, as in Fig. 3 (b). The lens should be mounted away from the light-sensitive area of the ORP12 by a distance which is somewhat less than its focal length in order to ensure that the light is spread over the sensitive area. If the lens were spaced away by exactly its focal length, the source of light would be focused on to a small part of the sensitive area only.⁴ A cheap "magnifying glass" lens will be quite adequate for the purposes required here. Extra concentration of light may be obtained by mounting a reflector behind the lamp.

If the objects to be counted are very small, it may prove helpful to cause them to pass through a focal point, as in Fig. 3 (c). The objects being counted will then interrupt the beam more reliably, and for a longer period of time.

⁴ The focal length of a convex lens can be found by causing it to focus the image of an electric light bulb on to a piece of paper. The distance between the lens and the paper is then the focal length.

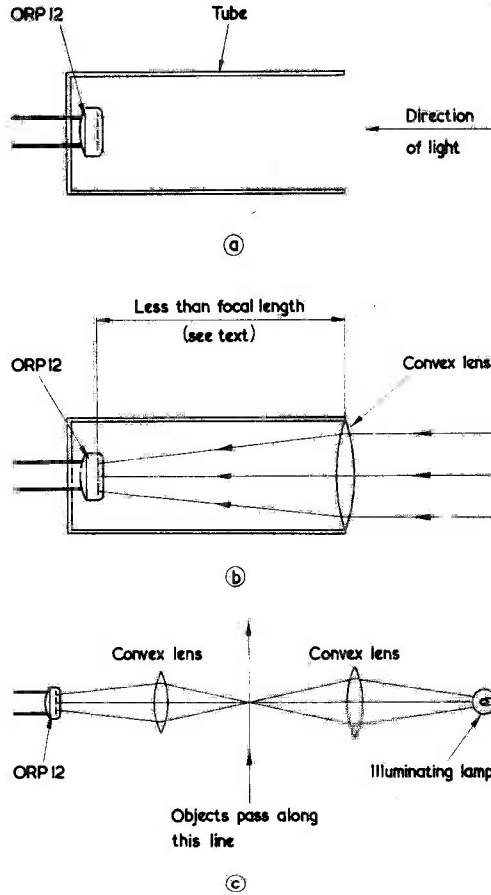


Fig. 3 (a). To reduce the effect of ambient light, the ORP12 may be mounted in a tube. The internal sides of the tube should, preferably, be painted matt black.
 (b). Fitting a convex lens to the ORP12
 (c). A suggested layout for counting objects of small size

For correct operation of the circuit, the ORP12 should be illuminated such that it offers a resistance of approximately $1k\Omega$. This resistance may be measured with the aid of a testmeter switched to the appropriate ohms range. With the

prototype, a resistance of $1k\Omega$ was achieved very easily with a single lens, as in Fig. 3 (b). The lamp was a cycle dynamo bulb rated at 6 volts 0.3 amp, and it was mounted, without a reflector, some 2ft away from the lens.

Award for Outstanding TV Paper

British Institution of Radio Engineers announces that the Associated Rediffusion Premium, for the outstanding paper in 1962 on advances in the technique of television broadcasting, has been awarded to I. J. P. James, B.Sc., M.I.E.E., M.Brit.I.R.E., and W. A. Karwowski, B.A., both with the Research Laboratories of Electric & Musical Industries Limited, for their joint paper, *A Constant Luminance Colour Television System*.

First large-scale demonstration of EMI's new type of colour television camera and signal processing system, which give good colour pictures using only the amount of illumination required in a monochrome TV studio, were recently given to members of the European Broadcasting Union in London.

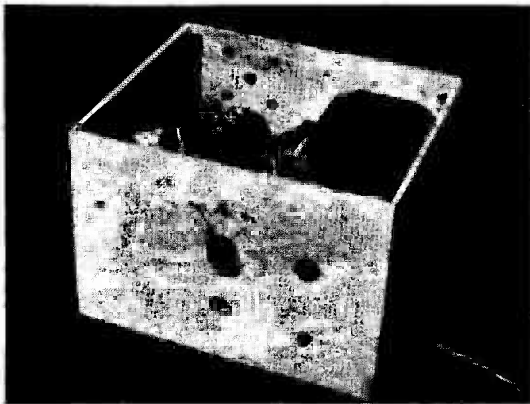
CRYSTAL MARKER UNIT

F. G. RAYER

THE CRYSTAL MARKER DESCRIBED HERE HAS A harmonic amplifier, and can be used for calibration in the range 100 kc/s to 30 Mc/s. The output exceeds $100\mu\text{V}$ at 30 Mc/s, and is greater than 10mV at 10 Mc/s, into 75Ω , and so it is sufficiently strong for easy detection. As a further aid to identification of the signal, a neon modulator is provided. A 3-position switch allows standing by with heaters on but h.t. off, and either modulated or unmodulated outputs. This feature is very useful when checking other sources of r.f. against the marker.

An accuracy better than 0.00001 on the fundamental is easily obtained, which is greater than is needed for any normal purpose. The marker may be used for accurate calibration of receivers and signal generators, or for the checking, adjustment, or calibration of transmitter variable frequency oscillators, grid dip oscillator, wavemeters, and any similar equipment.

The circuit is shown in Fig. 1, and the original was made, as far as possible, from available components. V_1 is a KTW61, and other valves of similar type, such as the 6K7 and EF39, are satisfactory. The 100pF pre-set capacitor provides slight frequency adjustment, for beating against



Front panel view of the Crystal Marker

the B.B.C. 200 kc/s Light Programme transmission or MSF. V_2 is the harmonic amplifier, with grid rectification bias. Here, an SP61 was used. Other high slope valves, including miniatures, are suitable. V_3 is a 6X5 because this type was to hand. Other rectifier valves, with a suitable heater winding, would of course be equally satisfactory. Metal rectifiers are also suitable.

If a power pack is available separately, this can be used. An alternative is to provide terminals or sockets on the marker unit, so that its power pack can be used for occasional operation of other equipment.

The CV286 neon acts as an h.t. indicator, glowing when h.t. is on.¹ When the switch $S_{1(a)}$ is in the clockwise position, providing modulation, the $0.25\mu\text{F}$ capacitor C_5 charges and discharges, causing the neon to flash. The neon pulses are passed to V_2 control grid, and the modulation is audible each time the marker signal is tuned in.

Construction

It is not proposed to give detailed building instructions, because the size and shape of the chassis, and exact location of parts, are not very important. The original was constructed on a chassis 9in by $7\frac{1}{2}$ in and housed in a box $6\frac{1}{2}$ in deep. The layout of components, and wiring, are shown in Figs. 2 and 3.

A few points require special attention, irrespective of the chassis size and other details.

C_1 needs to be rigidly mounted, but insulated from the chassis. This item was a surplus capacitor with two 6BA threaded bushes, and was fitted to a bracket bolted to the side of the chassis. An ordinary capacitor can be mounted with Paxolin washers, the fixed plates being taken to V_1 control grid. A slot may also be sawn in the spindle for screwdriver adjustment through a hole in the panel. An insulated extension spindle, with control knob, might be adopted.

The crystal was a type Q5 made by Quartz Crystal Co. Ltd. This fits an octal holder and connections are made to pins 1 and 5.²

The capacitor C_5 must be of good quality, as a leaky component will prevent the neon striking. The exact capacitance is not very important. A neon indicator lamp was tried instead of the CV286. This flashed in the required manner, but did not produce the necessary modulation due to its relatively slow discharge. The CV286 thus seems to be required. C_7 should be a mica type capacitor.

The neon fits a B7G holder, which is attached to a bracket so that the valve is horizontal behind a $\frac{1}{2}$ in diameter hole in the panel. The neon can thus be observed, and it acts as an h.t. and modulation indicator.

C_9 is also a mica type. Grid and anode circuits of the valves should be reasonably clear of each

¹ The nearest commercial equivalent for the CV286 is the 150A2. However, pin connections for this may vary from those shown in Fig. 1.—EDITOR.

² The Quartz Crystal Co. Ltd., Q.C.C. Works, Wellington Crescent, New Malden, Surrey.

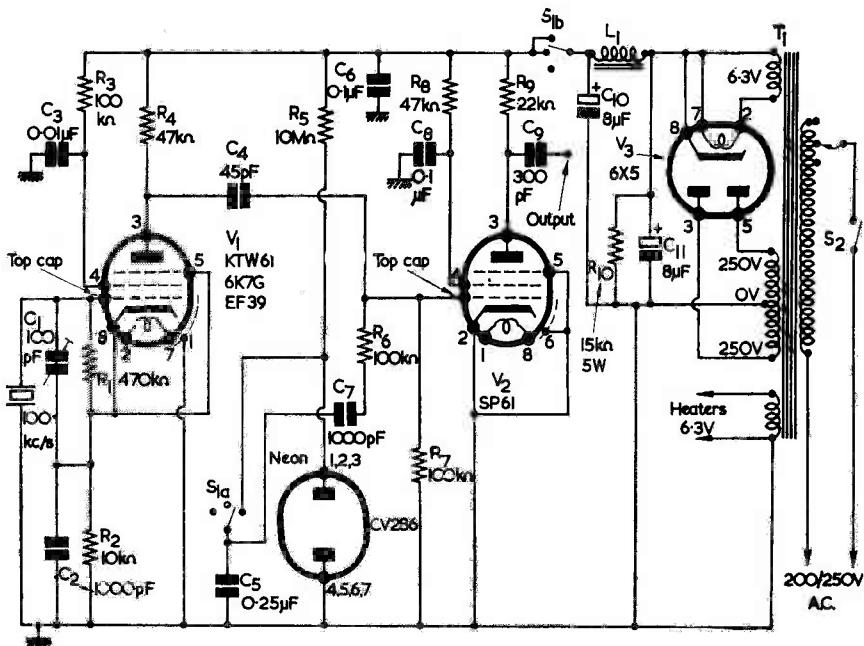


Fig. 1. The circuit of the crystal marker

Components List

Resistors

(All resistors $\frac{1}{2}$ W 20% unless otherwise stated)

R ₁	470k Ω
R ₂	10k Ω
R ₃	100k Ω
R ₄	47k Ω
R ₅	10M Ω
R ₆	100k Ω
R ₇	100k Ω
R ₈	47k Ω
R ₉	22k Ω
R ₁₀	15k Ω 5W

C₈ 0.1 μ F

C₉ 300pF

C₁₀ 8 μ F, electrolytic

C₁₁ 8 μ F, electrolytic

Valves

(Valve types quoted are those employed in the prototype. Alternative types are discussed in the text)

V₁ KTW61 (or 6K7G or EF39)

V₂ SP61

V₃ 6X5

Neon CV286

Capacitors

(All fixed capacitors 350V wkg.)

C ₁	100pF, air spaced, pre-set
C ₂	1,000pF
C ₃	0.01 μ F
C ₄	45pF
C ₅	0.25 μ F
C ₆	0.1 μ F
C ₇	1,000pF

Inductors

L₁ Smoothing choke

T₁ Mains transformer (see text)

Switches

S₁(a) (b) 2-pole 3-way rotary switch

S₂ On-off switch

other. Two separate on/off switches would be satisfactory, instead of the 2-pole 3-way rotary switch S₁(a), (b)

A half-wave power pack would suffice, if components for it were to hand. H.T. requirements are under 15mA, at about 250V.³

³ The 6X5 could have its heater fed from the same 6.3 volt winding as V₁ and V₂ if desired. In this case, the link between pins 7 and 8 should be broken. See Fig. 3.

If desired, the first stage can be checked by taking a lead from C₄ to the receiver aerial terminal, and listening for the marker signal. This will be c.w.

The neon should glow, when h.t. is available. It should blink repeatedly, with the switch S₁(a) (b) in the modulation position.

The output from C₉ should be very much greater than that from C₄, especially on higher frequencies,

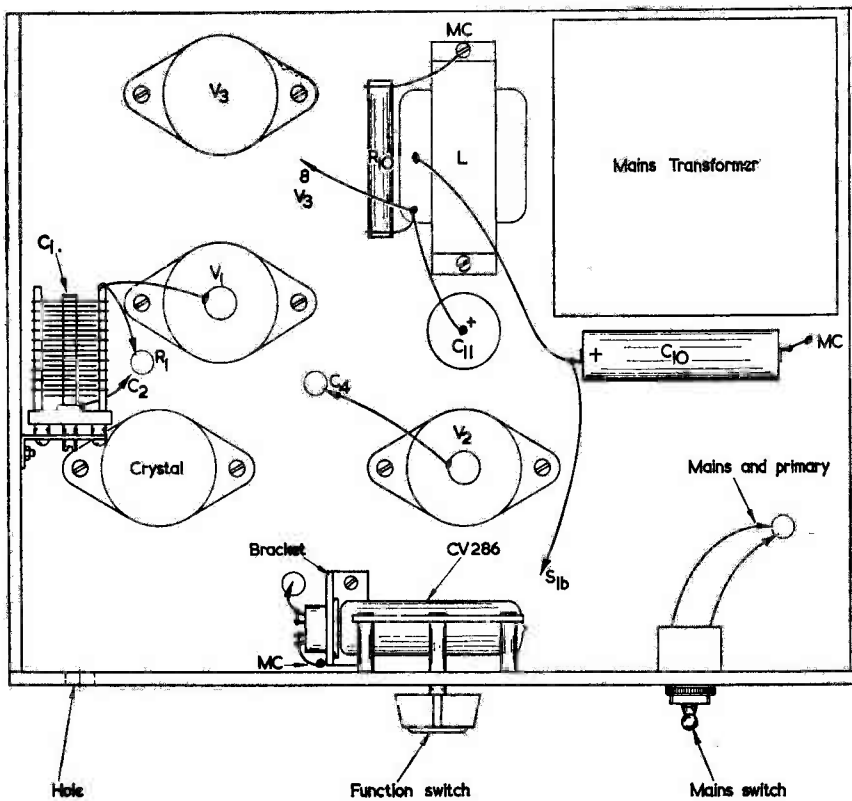


Fig. 2. Above-chassis layout of the prototype

and a “plop-plop” sound should accompany reception until the switch is returned to the no-modulation position, when the signal is again c.w.

Operation Method

It is felt that fairly complete details of ways of using the marker will be appreciated, so that it can be of maximum utility. Experienced constructors will probably be familiar with these points.

The marker is crystal controlled, and produces signals which may be heard at 100 kc/s, and multiples of 100 kc/s. Such multiples are termed harmonics. The 2nd harmonic is 200 kc/s, the 3rd is 300 kc/s, and so on.

If the marker output is fed into an all-wave receiver, the marker can be heard at 100 kc/s, 200 kc/s, 300 kc/s, 400 kc/s, and so on. With higher frequencies, the frequency is usually given in Mc/s. So the marker will be heard at 1 Mc/s (1000 kc/s), 1.1 Mc/s (1100 kc/s), 1.2 Mc/s (1200 kc/s), and so on. This continues throughout the bands tuned, each harmonic being 100 kc/s, or 0.1 Mc/s, from the previous harmonic.

Receivers are calibrated by tuning in harmonics, and marking the receiver scale accordingly.

If the output of a signal generator is fed into the receiver together with the marker signal, any difference between the generator frequency and

marker harmonic will produce an audible heterodyne. This tone drops in pitch as the signal generator is more accurately tuned, ceasing when generator and harmonic are at the same frequency. Signal generators may thus be calibrated with great accuracy.

A transmitter v.f.o. is calibrated, trimmed, or checked in the same way as a signal generator, except that only those harmonics embracing the amateur bands are required.

A grid dip oscillator is a type of signal generator, and can be calibrated against harmonics as for a signal generator.

An absorption wavemeter can be calibrated with the aid of a sensitive receiver with a tuning meter, coupling being made by a loop in the marker output lead.

Adjusting C₁

Initially, C₁ is adjusted to compensate for circuit differences, so that the crystal operates on the correct frequency.

The B.B.C. Light Programme frequency is maintained to an extremely high degree of accuracy, and thus furnishes a ready means of checking the marker frequency. The Light Programme is on 1500 metres, or 200 kc/s so the marker second harmonic is adjusted to agree with this.

The marker signal can easily be located at a similar frequency to the Light Programme, by switching on the neon modulator. However, for highly accurate adjustment the modulator is best switched off. The Light Programme and marker signals should be at similar strength, and a little adjustment of coupling may be required to achieve this. A foot or so of wire will probably cope for aerial and, as the marker signal will probably swamp the B.B.C. signal, this wire may be placed near the marker output terminal or may be looped round an insulated wire attached to this terminal.

The frequency error may only be some cycles per second, and will then be audible as a flutter on reception. C_1 is adjusted, with an insulated blade, to reduce the frequency of this flutter. When the adjustment is nearly correct (say within 1 c/s) the error will be heard as a rise and fall in the received signal, or in background noise. If the receiver has a tuning meter, the indication given by this will rise and fall. When C_1 has been adjusted, it can be left.

Receivers having short wave bands only may also be used, C_1 being adjusted against the standard frequency transmissions on 2.5 Mc/s. This course may also be followed in areas where the 1500 metre transmission is not received.

Receiver Calibration

It is only necessary to take a short lead from the receiver aerial terminal to C_9 . Very few 100 kc/s harmonics fall in the long wave band. A fair number are found in the medium wave band.

On higher frequency bands, many harmonics are found, and it is in the range 1.8 Mc/s to 30 Mc/s that the marker is most useful.

Amateur band limits can be found by the appropriate harmonics; e.g., 1.8-2 Mc/s, 3.5-3.8 Mc/s, etc. Calibration within these bands can be at 100 kc/s intervals: 1.8, 1.9 and 2 Mc/s; 2.5, 3.6, 3.7 and 3.8 Mc/s, etc.

The unmodulated output will not be audible unless the receiver has a b.f.o. If the receiver has a tuning meter, this will help to give an indication of tuning.

V.F.O. and Generator Calibration

Here, the v.f.o. or generator output is made to beat against the marker harmonic, so it is necessary to avoid too much difference in signal strength. That is, a little adjustment of coupling may be needed as was required for setting of C_1 . If one signal is very many times more powerful than the other, this tends to swamp out the weaker signal, and the heterodynes may be less readily heard.

When beating a v.f.o. or signal generator output against the marker harmonic, the receiver tuning will have no influence on results, other than allowing signals to be tuned in in the normal way. That is, accuracy of v.f.o. or generator calibration does not depend on the exact tuning of the receiver.

The b.f.o., if available, should not be used. If the signal generator or v.f.o. is tuned correctly, no audible beat will be obtained. If the generator is tuned slowly away from the correct frequency, a note will be heard, rising in pitch as tuning proceeds.

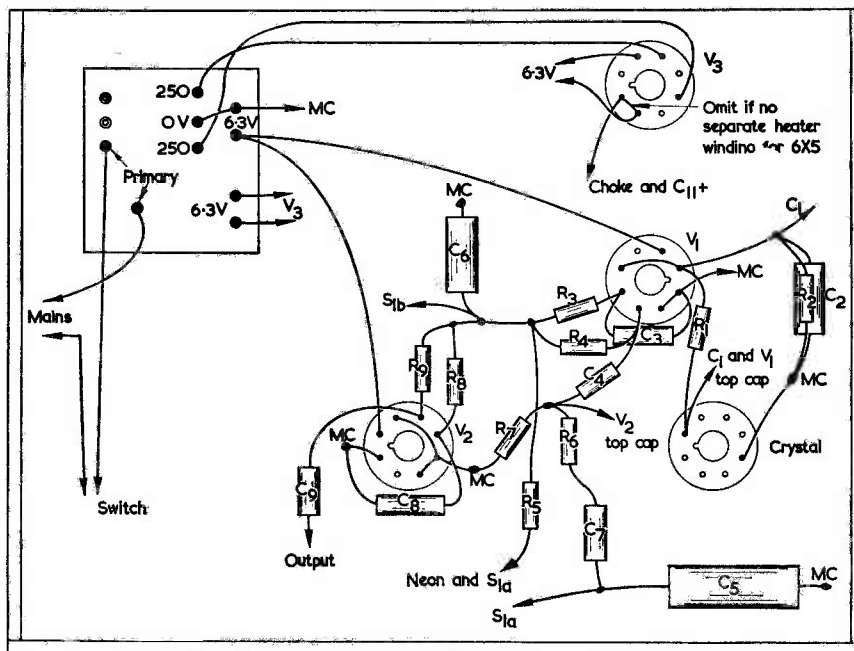


Fig. 3. The wiring below the chassis. Valveholder connections are for the valve types specified in Fig. 1

Drift in the v.f.o. or generator will be shown by the signal slowly moving off frequency, so that a low, audible tone begins, slowly rising in pitch. Equipment should be switched on at least 20 minutes in advance.

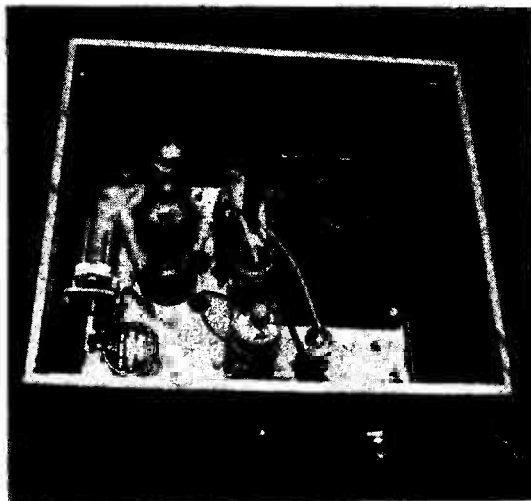
A g.d.o. is treated as for a signal generator, except that very accurate tuning is frequently impossible and calibration may be at quite well separated points, such as 1 Mc/s intervals, on h.f. ranges.

For calibration of an absorption wavemeter, a receiver with tuning meter is necessary. Enough coupling is required between wavemeter and receiver aerial lead for the tuning meter reading to drop when the wavemeter is tuned to the receiver frequency. Usually, some 4 or 5 turns of insulated wire, near the wavemeter coil, will suffice. However, this depends on the actual equipment used. Very tight coupling should be avoided, as it will modify the wavemeter tuning. The receiver is tuned to various harmonics, the wavemeter adjusted to resonance, and the wavemeter dial marked.

Harmonic Identification

The particular harmonics are readily identified when the receiver has a calibrated dial. If no calibration is present (as in a home-built receiver) then only one harmonic need be identified in each band, as others can be counted off from this. For example, 2.5 Mc/s could be identified from MSF, then 0.1 Mc/s points counted off from this to calibrate the whole band. An amateur band, or any known station, will similarly allow identification of one or more harmonics, and thus permit calibration of the whole receiver waveband.

With superhets of simple type, image frequency reception will begin to become more apparent



Internal cabinet view of the Crystal Marker Unit

as frequency is increased. Such reception is at twice the intermediate frequency from the signal frequency and can thus be identified. Also, it is weaker.

Calibration of t.r.f. sets can be as described for superhets, regeneration being advanced until the detector is just oscillating. Good harmonic strength is obtainable at frequencies higher than 30 Mc/s. If wished, very high frequency harmonics can be increased several times in strength by temporarily connecting a simple tuned circuit from C_9 to chassis. A 25pF or 50pF capacitor is then added in the lead to the receiver.

CAN ANYONE HELP?

Requests for information are inserted in this feature free of charge, subject to space being available. Users of this service undertake to acknowledge all letters, etc., received and to reimburse all reasonable expenses incurred by correspondents. Circuits, manuals, service sheets, etc., lent by readers must be returned in good condition within a reasonable period of time.

Verdik 10W Quality Amplifier.—T. Patefield, 3 Monk Street, Blackburn, Lancs, wishes to purchase the service sheet.

* * *

"The Radio Constructor", October 1958.—T. Green, 19 Blakehall Road, Wanstead, London, E.11, wishes to purchase a copy of this issue.

* * *

Z3/ZC 33183.—G. B. Finney, 103 Cross Lane, Royston, Barnsley, Yorks., has obtained this unit, serial No. APT 1348, valve line-up—CV850, CV417 and CV408. Believed to be pre-amplifier for 70 Mc/s. Has any reader any information?

R1174A VHF Receiver.—H. A. Tarry, 126 Upney Lane, Barking, Essex, requires the circuit or any information on this ex-R.A.F. unit.

* * *

H45843 Receiver.—P. Gaynor, 82 Leamington Street, Bradford 9, Yorks., would like to receive information on the valve layout and speaker connections, etc.

* * *

"Demobbed Valves".—J. Fitzgerald, 1,100 Harrow Road, London, N.W.10, wishes to purchase a copy of this publication (published by V.E.S. Ruislip and now out of print).

(Continued on page 262)

NEWS AND COMMENT . .

Outlook

As we have mentioned on a previous occasion, much interesting information on radio and television matters may be gleaned from the financial pages of the daily papers. A feature which often gives interesting news about developments in the not too far distant future is the chairmen's annual statements of public companies. Any such statement by Mr. Jules Thorn, chairman and managing director of Thorn Electrical Industries can be relied upon to give a sound practical exposition of the present situation and future trends in the radio industry. (Although your junk box may seem far removed from the activities of the major radio companies, their present actions may eventually largely decide what you build and what components you use.)

Last year Mr. Thorn referred to the declining sales of the television industry but, apparently, this trend has now been reversed, "With the imminence of the new 625 line B.B.C.2 programmes". As Mr. Thorn states "... as it seems that the new services will, for the first time, provide a real alternative programme, we expect an increasing demand for our dual standard receivers".

We feel that this question of a genuine alternative programme is the great need of television today. We have all experienced the frustration of tuning to the other channel only to see a similar programme and, of course, on some occasions, seeing the identical event, speech, etc.

Mr. Thorn made reference to the continuing high level of transistor radio sales. In this connection an interesting graph was recently published in the London *Evening Standard* entitled, "The Switch to Transistors". The chart showed very clearly the rise in sales from approximately 500,000 transistor radios in 1959 to approaching 3,000,000 in 1962. In the same period valve models dropped from 1,000,000 to less than half a million. The chart also enabled one to visualise the enormous increase in portable sets because of the use of transistors.

Professional Merger Development

A U.K. and Eire Section of the Institute of Electrical and Electronics

Engineers has been established to serve the interests of the 1,100 I.E.E.E. members in Great Britain and Ireland resulting from the merger of the Institute of Radio Engineers (I.R.E.) and the American Institute of Electrical Engineers (A.I.E.E.) to form the I.E.E.E. This is a "non-national" professional society of some 160,000 members, organised in nine Regions and with learned society activities designed to serve the expanding field of electrical and electronic engineering.

Membership of the Section is made up of I.E.E.E. members of all grades with mailing addresses within Great Britain and Ireland and represents about half the present membership of the European Region of the I.E.E.E.

It is not customary to use I.E.E.E. grade abbreviations following a member's name to indicate a professional qualification; moreover the I.E.E.E. structure includes non-professional grades which enjoy all the benefits of the I.E.E.E. publications and other learned society activities.

The aim of the Section will be to achieve close co-operation with the I.E.E., Brit. I.R.E. and other professional societies, which between them already hold several hundred meetings, colloquia and conferences a year all over Great Britain and Ireland covering all aspects of the electrical and electronic field. In these circumstances the role of the Section is seen primarily as seeking to join in or initiate joint meetings or conferences, and as performing the special function of providing a two-way link with professional activities in the United States and elsewhere. In this way more opportunities will be created for lectures and papers by American engineers over here and by our engineers in the United States.

Transfers

The neat professional appearance of the communications receiver shown on the cover of this issue has not only been achieved by the stylish placement of controls consequent upon a logical placing of components, but has been enhanced by the use of Panel Sign Transfers. Some constructors affect not to be interested in style but, as in other

pursuits, a good style is often indicative of a job well done.

We have, of course, for many years supplied these transfers and their popularity seems always to be on the increase. We have now reorganised the sets for the convenience of constructors and taken the opportunity to enlarge their scope.

We have now increased the number of sheets in each set to 6, revised and added to the contents and are issuing them as follows: PS3 Wording—white (more than 1,000 words and symbols); PS4 the same wording but in black; PS5 Dials—containing scales, frequencies, control panels, etc., the latter having white markings on a black background; PS6 is the same as PS5 except that the control panels are white markings on a clear background. The cost is 4s. 6d. per set.

Circular Aerials

A new concept in radio aerial design permits reduction in the height of a 60ft tower aerial to a 2ft circular aerial without loss of performance.

Developed by the Northrup Corporation in California, the aerials range in size from a mere 6in in diameter to nearly a mile across, and in heights from 2in to 300ft.

The aerials, 100 to 300ft high, are capable of accomplishing the same tasks as tower aerials more than 1,000ft high. But in contrast to vertical aerials, the circular ones are much easier and less costly to maintain and are less vulnerable to strong winds and low-flying aircraft.

For less demanding applications, circular aerials 3ft in diameter and less than 4in high have been developed for mounting on cars, trains and other vehicles for mobile communications. Because of their low height these aerials are sturdy and can be installed rigidly, reducing vibration and making the aerials less vulnerable to damage.

In another application, a ring aerial only 5ft high will be installed on a ship, now under construction, which will be used to recover astronauts after they land in the ocean following space flights. This aerial consists of five circular tubes ranging in size from 3ft to 35ft in diameter. When completed, it will be capable of performing with an efficiency close to that of a 120ft aerial.

The twenty-seventh in a series of articles which, starting from first principles, describes the basic theory and practice of radio

part 27

understanding radio

By W. G. MORLEY

IN LAST MONTH'S ISSUE WE COMPLETED OUR discussion on r.f. transformers having single tuned windings. We shall now carry on to assemblies having two tuned windings.

R.F. Transformers With Two Tuned Windings

Fig. 165 illustrates two tuned circuits, both of which are resonant at the same frequency. A signal, from a source having a high impedance, is applied to the lower tuned circuit, whilst the upper tuned circuit couples into a load which similarly presents a high impedance.

Let us assume that a very loose inductive coupling exists between the two coils. As a result of this loose coupling a voltage will appear across the output load. Since both tuned circuits are resonant at the same frequency, the amplitude of this voltage will be greatest at the resonant frequency, whereupon we will have the response curve shown in Fig. 166 (a). This response curve is given by *two* tuned circuits and, as is to be expected, it exhibits sharper selec-

tivity than would occur if a single tuned circuit were employed on its own.

Let us next bring the two coils closer together, so that the coupling between them becomes tighter. As would be anticipated, the amplitude of the output voltage increases, whereupon we get a response curve having a higher peak, as in Fig. 166 (b).

If we continue to bring the coils closer together we will find that, after a certain point, the output amplitude at the resonant frequency *diminishes*. We will also find that the single peak of the response curve is replaced by two peaks, each of these being spaced by an equal amount on either side of the resonant frequency. The response curve now takes up the appearance shown in Fig. 166 (c). If we continue to bring the coils closer together, the peaks separate further, giving a response curve such as that of Fig. 166 (d).

The point at which output amplitude commences to decrease, as the coils are brought together, corresponds to the *critical coupling* for the two tuned circuits. It is at this point that the single peak of the response curve commences to change into the two separate peaks.¹

To illustrate the effect further, Fig. 167 shows a group of response curves for the two tuned circuits of Fig. 165. Curve A represents the response which is offered before critical coupling is reached, whilst curve B is that given by critical coupling. As the coupling exceeds critical coupling the single peak of curve B breaks up into the two peaks of curve C. It will be seen that the two peaks of curve C have

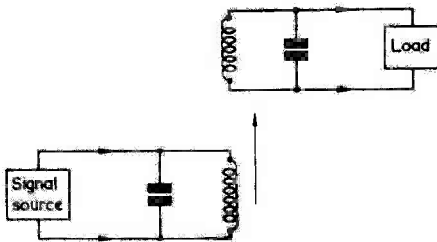


Fig. 165. In this diagram two tuned circuits are resonant at the same frequency. The inductive coupling between the two coils may be altered by varying the distance between them

¹ If the tuned circuits have widely differing values of Q, the two separate peaks may not appear immediately after critical coupling is achieved. In most practical applications likely to be encountered in radio work, however, it will be found that the Q of the tuned circuits will be roughly equal, whereupon the appearance of two peaks immediately after critical coupling can be assumed.

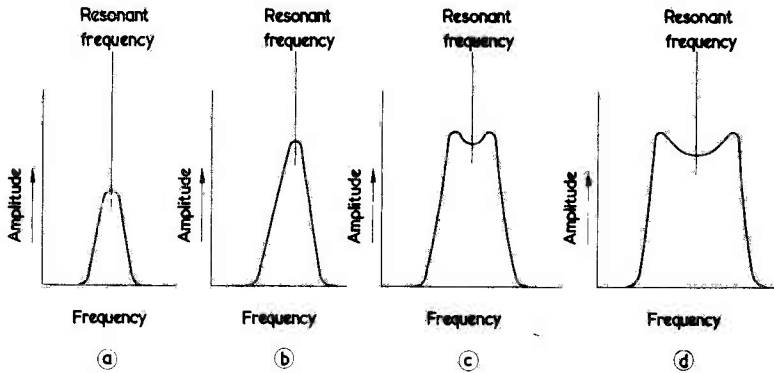


Fig. 166. When the coupling between the two coils of Fig. 165 is loose, the response curve will appear as shown in (a). When the coils are brought closer together, the amplitude of the peak response increases, as in (b). Further tightening of the coupling causes the single peak to break up into two (c), the peak separation increasing, as in (d), when the coupling is further tightened

the same amplitude as the single peak given at critical coupling. It should be noted also that the selectivity at critical coupling, as indicated by curve B, is lower than that for curve A, this being mainly due to the broadening of the peak.

The response curve offered after critical coupling has been reached is of considerable use in radio work because, instead of providing maximum amplitude at a single frequency, it offers maximum (or near-maximum) amplitude over a band of frequencies. As shown in Fig. 168, all frequencies which appear between the points where the line XY cuts the curve correspond to amplitudes which are higher than XY. If the small difference in amplitude between the peaks and the "trough" of the curve is ignored, it can be assumed that all these frequencies pass through the two tuned circuits at maximum amplitude. Actually, the peak-to-trough amplitude difference increases with peak separation, and it can become excessively high for high values of separation. Such conditions are not, however, encountered in conventional radio circuits or components.

It is possible for the two tuned circuits of Fig. 165 to be made up into an r.f. transformer assembly, whereupon they may provide coupling between, say, one valve in a radio receiver and another. Transformers of this nature are very commonly employed, and their function is to allow a band of frequencies to be fed from one valve to the next. If the band of frequencies is to be relatively narrow, the transformer is so made that the coupling between the two tuned circuits is less than critical, with the result that the response curve exhibits high selectivity. Such an r.f. transformer is described as being *under-coupled*. If a wider band of frequencies is to be passed the transformer may be constructed such that the two tuned circuits are at critical coupling. The transformer then offers the response curve with a broader top, as shown by curve B in Fig. 167. When a still wider band of frequencies is to be passed, the coupling is made tighter than critical, whereupon the transformer is described as

being *over-coupled*. In a particular class of receiver (the superhet), one section provides amplification at a single fixed frequency (or at a band of frequencies around a fixed centre frequency) and this is referred to as the receiver's "intermediate frequency amplifier". The fixed frequency (or fixed centre frequency) is then known as the "intermediate frequency". The intermediate frequency is within the radio frequency spectrum and is treated in the same way as any other radio frequency. Coupling within the intermediate frequency section of the receiver may be carried out very conveniently by r.f. transformers having two tuned circuits, and these then become known as *intermediate frequency transformers* or *i.f. transformers*.² According to the design of the receiver, i.f. transformers may be under-coupled or over-coupled, or may employ critical coupling. In valve radio receivers intended

² As we shall see later, i.f. transformers may also have single tuned windings instead of the two tuned windings in the assemblies described here.

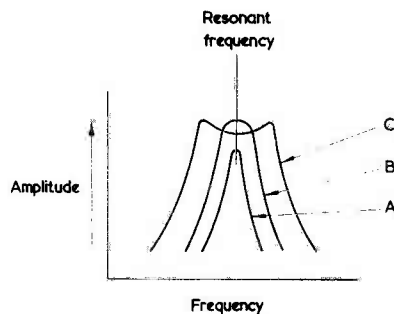


Fig. 167. A group of response curves for the tuned circuits of Fig. 165. Curve A is given before critical coupling is reached, curve B occurs at critical coupling, whilst curve C appears after critical coupling

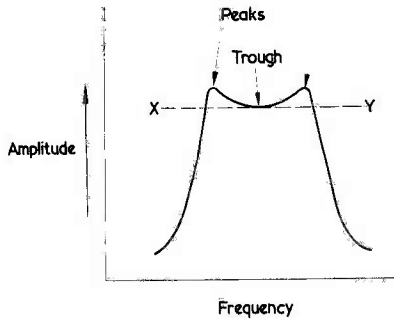


Fig. 168. In this diagram, line XY meets the response curve at the lowest point of the trough. If the small difference in peak-to-trough amplitude is ignored, the response offers virtually maximum amplitude over the range of frequencies between the points where line XY cuts the curve

for domestic entertainment it is rather more usual to employ critically coupled or very slightly under-coupled i.f. transformers.

Before passing on to consider practical i.f. transformers, it should be mentioned that a number of factors may qualify the point at which critical coupling is achieved as the coils of the two tuned circuits approach each other. The most important of these is that, if the Q of either tuned circuit is reduced, a tighter coupling is required to obtain critical coupling. Since the Q of a tuned circuit may be effectively reduced by connecting a resistor (or resistive impedance) across it, it follows that an i.f. transformer having critical coupling will function as an under-coupled transformer if either of its tuned circuits connects to an external circuit which causes it to be loaded by too low a resistive impedance. In practice, i.f. transformers are designed to operate in specific circuits, the impedances of which may be approximately gauged beforehand.

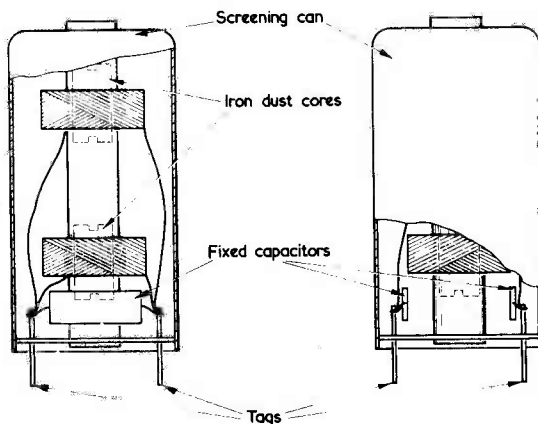


Fig. 169. The construction of a typical i.f. transformer for operation in the frequency range 455 to 480 kc/s. The transformer has four tags at its base

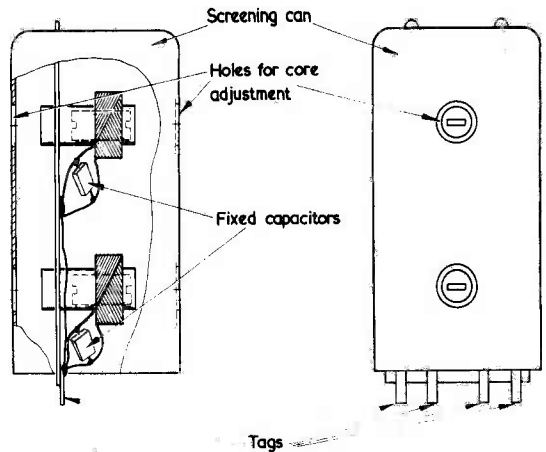


Fig. 171. An alternative method of i.f. transformer construction. The coil formers are mounted on a sheet of insulating material

I.F. Transformers

In a domestic superhet receiver operating on the medium and long wavebands, it is usual to employ an intermediate frequency which is in the range 455 to 480 kc/s. The actual intermediate frequency employed within this range depends mainly upon the design of the receiver, and is not of importance in the present discussion. The receiver will normally employ i.f. transformers which comprise two tuned circuits, both being resonant at a frequency within the range.

The frequencies 455 to 480 kc/s lie between the medium waveband (about 1,500 to 500 kc/s) and the long waveband (about 300 to 150 kc/s) and we may, in consequence, expect the tuned windings in the corresponding i.f. transformers to be somewhat similar in design to those we have already considered for medium and long wave operation. This is, indeed, the case, as may be gathered from examining a typical transformer, as shown in Fig. 169. The i.f. transformer illustrated in this diagram has two windings fitted to a common former, each of these consisting of a single wave-wound pie. Occasionally, two-pie windings are employed. Both coils are wound with litz or bunched wire. Two fixed capacitors are mounted at the base of the transformer, and each of these is in parallel with one of the windings. The capacitances of the fixed capacitors will, normally, lie between some 50pF and 150pF according to transformer design. In general, silvered mica capacitors are employed because of their low temperature coefficient. Iron dust cores are fitted to both windings to enable



Fig. 170. The circuit symbol for the i.f. transformer of Fig. 169

them to be adjusted to the designed inductance, and the whole assembly is mounted in a metal screening can.³ The corresponding circuit symbol is shown in Fig. 170.

We saw in Fig. 156⁴ that it is possible to change the degree of coupling in a single tuned winding r.f. transformer by adjusting the iron dust core so that it protrudes (for the correct inductance setting) on either side of the tuned winding. This effect may also occur with the i.f. transformer of Fig. 169, and it assumes considerable importance in this instance since the degree of coupling in the transformer has to be very accurately maintained for correct operation. In conventional transformers, iron dust cores should protrude outwards when they are correctly set up, as in Fig. 169. If either of the cores is adjusted so that it protrudes from the winding on the inside, the increase in coupling (due to the relatively high permeability core material which now appears between the windings) may be so great that the transformer becomes grossly over-coupled. In some instances, the physical design of the i.f. transformer is made such that it is impossible to adjust either core to the incorrect setting. Even when the two cores protrude on the correct side of the windings it is still possible to obtain quite significant changes in coupling if external circuit conditions cause the cores to be set up at markedly different positions to those intended for the design. Thus, it is possible for an i.f. transformer to be designed such that correct alignment⁵ occurs when

³ The screening can prevents magnetic and capacitive couplings between the transformer and other components in the receiver, and the manner in which it carries out this function will be described later.

⁴ Published in "Understanding Radio" part 25, September 1963 issue.

⁵ "Alignment" refers, here, to the setting up of a tuned circuit to the desired frequency.

both dust cores protrude slightly outwards from the windings. If excessive capacitance is applied to the transformer by the external circuit, it may be necessary to have the cores protrude by a considerably greater amount in order that each winding may resonate at the desired frequency. The coupling between the two windings may now become significantly reduced, and a transformer which was designed for critical coupling could become noticeably under-coupled. The same effect will also occur if the transformer is aligned at a frequency which is higher than that for which it is designed.

Despite its dependence on core setting for correct coupling, the i.f. transformer construction of Fig. 169 is used very widely, since it employs the minimum of component parts and is simple to assemble. It is perfectly suitable for use in receivers where external circuit conditions can be kept reasonably constant (as occurs in most conventional valve receivers including, in particular, those manufactured on mass-production lines) and where it is aligned at, or very near to, the design frequency.

An alternative construction which overcomes the dependence on core positioning is illustrated in Fig. 171. In this instance the winding axes are parallel to each other instead of being in line. Provided that both cores protrude from the windings on the same side, the coupling is relatively independent of core position and may be very closely maintained at the desired level. Transformers of this type are more expensive to manufacture than those of Fig. 169 because assembly is less simple and there are more piece-parts, and they are usually encountered in higher-grade receivers.

Next Month

In next month's article we shall continue to discuss the i.f. transformer.

BBC Places Building Contract for new TV & VHF Relay Station at Forfar

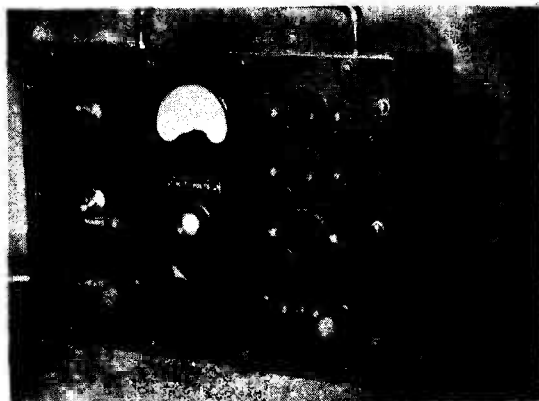
The B.B.C. has awarded a contract to Messrs. Laird Brothers (Forfar) Ltd. for the construction of the building for the television and v.h.f. sound relay station which is to be built at Harecairn, near Forfar, Angus.

The new station is one of a number being built by the B.B.C. to extend and improve the coverage of its Band I television and v.h.f. sound services. It is expected that the Forfar station will be brought into service in the late summer of 1964; it will serve the southern half of the county of Angus and parts of the adjoining counties of Kincardine, Perth and Fife. Because of the need to avoid interference to other transmitters, the power used on the television service will have to be restricted and the Forfar station will not serve the City of Dundee, where, however, a separate television relay station is to be built. The interference problem will be less acute on v.h.f. and it will be possible to use higher power, thus serving Dundee with the three v.h.f. sound programmes.

Bench Power Supply

A Versatile Instrument for Temporary Set-ups

By D. Noble G3MAW
and
D. M. Pratt G3KEP



External appearance of the power supply unit. The variable control is positioned below the pilot lamp with the insulated terminals on either side

IT IS OFTEN NECESSARY TO OBTAIN a specific h.t. voltage when either testing a piece of equipment under construction or while using apparatus without its own power supply. One method of obtaining the required voltage is to take it from a piece of existing equipment by soldering wires directly to the appropriate points. Alternatively, each piece of equipment with its own power supply could be fitted with an octal socket so that ancillary equipment can be run from it.

A disadvantage with such a procedure, however, is that the supplies might occasionally be grossly over-run, and damage to the transformer and rectifier may occur. Also, of course, it may not always be possible to obtain exactly the correct voltage required. The writers have, there-

fore, designed a power supply unit specifically for the applications outlined above.

Specification

One requirement of the unit was that a variable supply should be available from 0 to 300 volts at up to 80mA. Secondly, an optional 150 volt stabilised supply was desirable and, if needed, should be available at the same time as a higher voltage unstabilised output. These requirements were met by the unit, which also provides a 6.3 volt output for heaters at a current depending upon the capabilities of the mains transformer used.

Circuit

The circuit is shown in the accompanying diagram. This is very

simple and needs little explanation. The choice of regulator valves is not critical provided they will pass the full rated value of h.t. current.

The output voltage is adjusted by the potentiometer VR_1 . This varies the control grid voltage on V_2 and V_3 , and the voltage appearing at the cathodes attains a value related to this in accordance with the current passed. The use of valves in the regulation circuit obviates the use of a potentiometer with a very high wattage rating. The potentiometer used in the circuit given here dissipates less than half a watt.

Parasitic stopper resistors, R_1 and R_2 , are provided to prevent the regulator valves from acting as a push-pull oscillator at v.h.f. frequencies.*

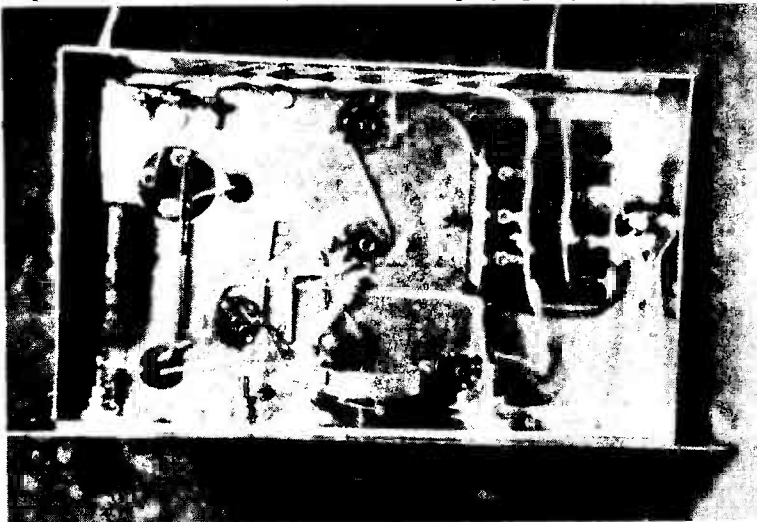
Construction

The unit was built on a chassis $4\frac{1}{2} \times 8 \times 2$ in, with a front panel measuring 9×7 in, in a cabinet of corresponding dimensions.

Mounted on the front panel are three international octal valveholders and four insulated terminals for the output connections. The pin connections for the octal sockets are given on the circuit diagram, and these correspond to a standard adopted by many constructors.

The panel also carries a meter which indicates the output voltage appearing across the terminals. Almost any low current moving-coil meter may be employed, with the correct value of series resistor, to

* The mains transformer shown in the circuit diagram has three 6.3 volt heater windings. If difficulty is experienced in obtaining a transformer with three heater secondaries, it would be possible to employ an auxiliary heater transformer to provide one of the three 6.3 volt supplies.



Below-chassis view of the regulated power supply

Components List

Resistors

- R₁ 100Ω ½ watt
- R₂ 100Ω ½ watt
- R₃ 5kΩ 5 watts wirewound
- R₄ 1.2mΩ ½ watt (for 500μA meter—see text)
- VR₁ 500kΩ potentiometer linear track

Capacitors

- C₁, C₂ 16+32μF, 500V wkg., electrolytic
- C₃ 16μF, 500V wkg., electrolytic

Valves

- V₁ EZ80
- V₂ EL84
- V₃ EL84
- V₄ 150C2

Inductors

- L₁ Smoothing choke, 10H, 80mA
- T₁ Mains transformer. Secondaries: 300-0-300V at 80mA, 6.3V at 1A, 6.3V at 4A, 6.3V at 2A. (See text)

Switches

- S₁ s.p.s.t. toggle switch (mains on-off)
- S₂ d.p.d.t. toggle switch (stabiliser switch)

Meter

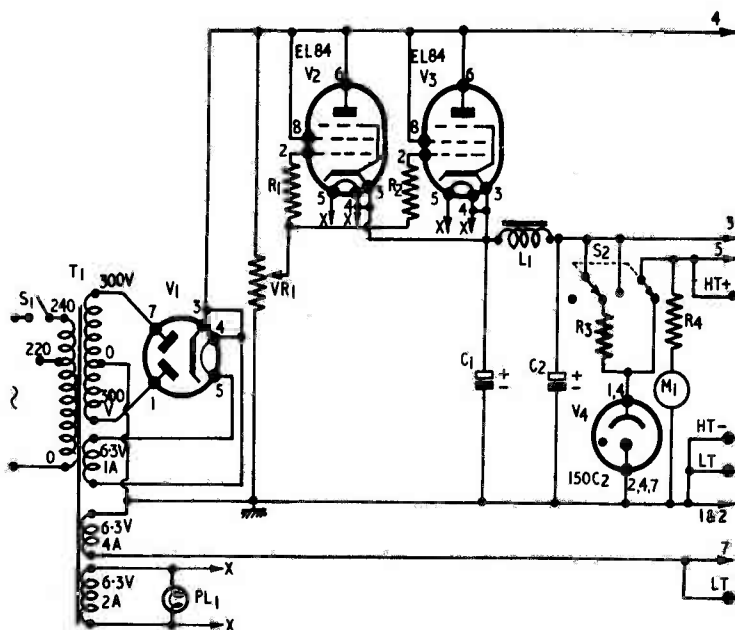
- M₁ 500μA meter (see text)

Pilot Lamp

- PL₁ 6.5V, 0.3A pilot lamp

Sockets

- 3 B9A valveholders
- 1 B7G valveholder
- 3 International octal valveholders
- 1 Pilot lamp holder



Circuit diagram of the regulated power supply

enable voltages up to 600 volts to be measured. The meter employed in the prototype is as used in the well known 19 Set, and is already calibrated 0-600 volts. This particular meter should be used with a 1.2MΩ resistor in series.

Outputs

Output is provided for 6.3 volts and three h.t. voltages on the octal sockets. For "lash-ups" and test purposes, 6.3 volts and the h.t. voltage connected to pin 5 of the octal sockets are available from the terminals.

Pin 5 is the usual connection when using the unit. It provides either a smoothed regulated supply, or a

stabilised voltage of 150 volts selected by switch S₂. When using the stabilised supply, the potentiometer, VR₁, should be increased until the meter gives a slight downward kick thus indicating that the stabiliser valve has struck.

Pin 3 of the octal socket will provide a higher voltage simultaneously with a stabilised voltage from pin 5, while at pin 4 there appears the full unsmoothed h.t. output direct from the rectifier cathode.

This power supply has many times over saved the time spent in its construction, and can be considered an addition to the constructor's den which is well worthwhile.

ELECTRICAL ENGINEERS EXHIBITION

18th — 25th March 1964

The organisers of the Electrical Engineers Exhibition are faced with a problem.

It is that having taken and allocated all available floor space at Earls Court to exhibitors, the demand is such that the layout had to be partially replanned to accommodate more stands than was originally envisaged.

In 1964 it will be the world's only exhibition of its kind, but the admission of overseas exhibitors now promises a high standard of representation of the world's electrical industry which will, for the first time, be gathered under one roof.

More British exhibitors will be there than ever before, but in addition many European and other overseas countries are represented, including 12 from Germany.

All overseas exhibits will be on the first floor, some of them on the largest sites available.

SATIN-FINISH

For Small Parts

By C. Morgan

This article describes an experimental method of applying a satin-finish to small aluminium parts. It must be emphasised that all chemicals employed should be handled with care and that they must be stored where children cannot reach them. All containers should be thoroughly washed after use. It would be wise to commence with dilute solutions and to experiment with small pieces of aluminium before attempting work with parts actually required for equipment

IT IS OFTEN THE ENVY OF THE CONSTRUCTOR THAT, when a kit of parts is purchased from a supplier, the smaller parts of the kit contain such items as aluminium brackets and supports, etc., which are beautifully finished with a satin appearance. When the kit is assembled it is placed with other home-built gear on the rack or shelf, whereupon it immediately stands out and makes the constructor wish he had all his small parts finished in the same way.

The secret of the satin-finish is not very complicated. Indeed, a suitable process is quite simple.

In addition, the finish will not only last the life of the metal but, unlike a black crackle finish, will not collect dust. The latter effect is one of the major faults of a black or grey crackle finish.

Several items are required to carry out the process and include two photographic, or similarly flat, trays. These should be large enough to take the panel or small parts to be finished, and Pyrex dishes are ideal. A word of warning: *never* use metal trays or containers for this process, as the chemicals can stain or even destroy them. Also needed are a few ounces of sodium hydroxide in solution and a few ounces of sodium dichromate in solution, both of which should be well stoppered until required.

The aluminium panel or part to be finished is first given a good wash in turps or any other cleaner that will remove grease from the metal. It is next dried thoroughly in a warm oven and, with a pair of photographic tongs or clean pliers, placed into the dish. A warm solution of sodium hydroxide is then poured on to it, whereupon the metal will start to bubble.

Leave for about five minutes, then take the metal out of the solution with the assistance of the tongs, at the same time ensuring that the liquid is not allowed to drip over the hands or floor. Wash the metal under a running tap for a few seconds, and then place it in a tray of sodium dichromate solution. This last dip will ensure that any black stains which are on the metal will disappear. When satisfied that the last of the stains has been cleared, remove the metal with the tongs and wash again under running water. Remember to have the windows well open throughout the operation and ensure that there are no naked flames nearby, as the gases given off by the process include hydrogen.

When completed, the chemicals should be replaced in well stoppered and labelled bottles, and placed in a safe place out of reach of children's hands. It should be noted that these chemicals do burn.

Mullard Announce Full Range of All-Glass Crystal Units

A range of miniature and sub-miniature glass-encapsulated quartz crystal units has been announced by Mullard. The new types are identical mechanically but superior electrically to standard metal-encapsulated crystals.

Compared with metal types, the all-glass crystals are less liable to ageing effects, have a closer initial tolerance and a higher activity.

Results of life-tests have enabled Mullard to guarantee that the nominal frequency of an all-glass crystal will remain within 3 to 3.5 parts per million over a period of one year. Standard production units are supplied with an initial tolerance in nominal frequency of ± 12 parts in a million. Closer tolerances are available to special order. Frequency drift over a temperature range of -20°C to $+70^{\circ}\text{C}$ is only ± 15 parts in a million.

By mounting the crystal plate in an evacuated, all-glass envelope the mechanical loading on the crystal plate is reduced. This decreases the equivalent series resistance and thus increases the Q-factor by about 100%. Q-factors of 30,000 can readily be achieved.

Production crystals in HC-26/U holders can be supplied covering the range 3.5 to 87 Mc/s.

TRANSISTORISED TELEVISION CIRCUITS

PART 1 By Gordon J. King,
Assoc.Brit.I.R.E., M.T.S., M.I.P.R.E.

Transistors, which are already ousting valves in most sound radio and audio applications, are similarly replacing valves in television receivers. In this article, which is the first of a series of six, our author introduces the subject of television transistor circuits and deals, in particular, with the tuner unit

AS TRANSISTORS HAVE REPLACED VALVES IN THE majority of radio receivers during the last several years, so are they expected to replace valves in television sets during the coming years. At the time of writing there are at least four British television receivers which are almost fully transistorised, plus several models originating from other parts of the world. In valve television sets, some of the circuits are being transistorised. For example, there are now transistorised tuners and the Pye group, at least, is using a transistorised sync separator stage in some of their models.

It would seem, therefore, that two things are likely to happen. One, the progressive build-up of the "all transistor" television receiver and two, the introduction of more transistorised circuits and sub-assemblies into valve models. It is high time, then, that we got to know something about the use of transistors in television circuits.

This series of articles will not only discuss and examine the various stages in a transistorised model right from the aerial input to the picture tube and loudspeaker, but it will also highlight specific circuit techniques as they apply collectively to transistorised television in general and individually to specific receivers and circuits.

Before continuing, the term "almost fully transistorised", given above, should be explained. So far, there are two applications which cannot be transistorised: (i) the e.h.t. rectifier and (ii) the picture tube. Thus, although the term "fully transistorised" is often used in transistor TV literature, both the picture tube and e.h.t. rectifier have thermionic characteristics.

The e.h.t. rectifier heater is energised from pulse current in the line output stage in the usual manner while the tube heater is powered direct from the battery or mains power supply. Tubes specifically for transistor portable receivers are being made, and one 8½in example by Mullard has a 11.5 volt, 0.7 watt heater, thereby making it suitable for connection across a 12 volt car battery with the

minimum of current. This is Type AW21-11 which has a 90° deflection angle; but more about tubes later.

Economic Advantages

The main reason for a change from valves to transistors in TV sets is not so much one of weight reduction for, including batteries, the weight of a transistor TV receiver is possibly about the same as, or a little greater than, a comparable valve set. However, transistors can have economic advantages and then, of course, transistors do give portability in terms of function if not of weight.

It is estimated that within a few years most transistor types will settle down to a price level about 30% below that of mass-produced valves. The basic content of transistors is low, mainly because of their minute requirements. As an example, about 100 power transistors can be made from one gram of hyper-pure mono-crystalline silicon, but one ton of this material costs about a million pounds.

Reliability and Noise

Generally speaking, transistors are more reliable than valves, and the reliability factor is always on the increase. New techniques are speedily lifting transistors from v.h.f. into the u.h.f. sphere, and already a u.h.f. transistorised tuner is available in this country. Owing to their low thermal noise, transistors have the edge on noise performance over valves at v.h.f. and u.h.f., and this brings us to the first stage of a transistorised TV set, where noise performance is probably the biggest factor of all.

Low-Noise R.F. Amplifier

All transistor sets so far available in this country employ a tele-tuner which, circuit-wise, has several things in common with its valve counterpart. It is well known that a triode valve in the earthed-grid mode has the best possible noise performance. Indeed, such a stage forms one part of the well-known cascade r.f. amplifier used in many tuners.

The transistorised teletuner uses the transistor equivalent, which is the earthed-base r.f. amplifier, where the signal is applied to the emitter circuit and developed in amplified form in the collector circuit, as shown in Fig. 1.

Using a Mullard AF102, AFZ12, the Philco 2N1742 or a v.h.f. equivalent transistor, a gain of around 18dB on Band I and 12dB on Band III is possible with a noise factor of about 4dB power ratio, which is some several times better noise-wise than a valve. The stage takes a little over 1mA at 9 volts.

While the earthed-base circuit (sometimes called the "common base" circuit) does not provide quite so much gain as, for example, the common emitter circuit, it has two distinct advantages as a TV r.f. amplifier. One is the low noise feature, and the other is the ability to match the aerial to the mixer or frequency changer.

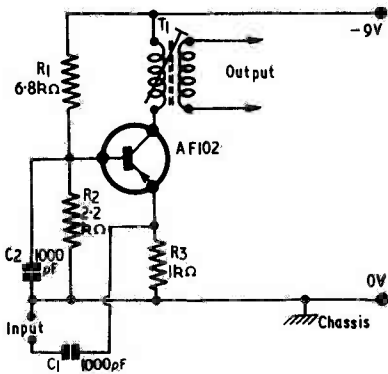


Fig. 1. Earthed-base or "common base" r.f. amplifier as usually found in the first stage of transistorised TV sets. While this circuit does not give quite as much gain as an earthed-emitter ("common emitter") amplifier it has the advantages of low noise and low to high impedance matching. The nominal gain is about 15dB and the noise factor expressed as a power ratio about 4dB

The circuit will match from about 25 to 300Ω to a 100kΩ or higher load. Thus, it is possible to apply the signal from a 75 ohm coaxial or 300Ω ribbon feeder direct to the emitter without the use of a matching transformer. This arrangement is used in Fig. 1, with C₁ serving simply for isolation.

The base is earthed from the signal point of view through C₂, while R₁ and R₂ provide forward bias in the base-emitter junction and, together with R₃, across which the input signal is developed, also provide d.c. stabilisation. T₁ is, of course, tuned to the required channel, and the inherent damping of the circuit automatically provides sufficient bandwidth for the sound and vision signal without, usually, the need for a damping resistor.

The latest idea is to employ two additional transistors for the frequency changer stage, one as the mixer and the other as the local oscillator with both

arranged in the common base configuration. This, then, usually means that the transistor tuner features three transistors, including that in the r.f. amplifier stage.

Tuner Circuit

At this juncture it will be best to consider the tuner as a whole and investigate a typical circuit. In Fig. 2 is given the complete tuner circuit of the Perdio Portarama Mark II Transistorised Television Receiver. Here TR₁ is the r.f. amplifier. TR₂ the mixer and TR₃ the local oscillator. It will be seen that the r.f. stage is basically similar to that in Fig. 1.

Inductors L₅, L₆ and L₈ are concerned essentially with the rejection of the vision i.f., the sound i.f. and medium-wave signals respectively, while L₁ is the aerial coil, which is very flatly tuned due to the heavy damping of the transistor emitter circuit.

The collector of TR₁ is loaded by the primary of the bandpass coupling transformer, L₂ L₃.

The oscillator TR₃ has very much in common with the r.f. amplifier. The base is earthed through C₁₅ and the collector is loaded with an inductor, which is really the oscillator coil. The circuit oscillates instead of amplifies because of the positive feedback from the collector to the emitter, this taking place partly through the internal impedance of the transistor and partly through the feedback capacitor C₁₆.

The oscillator frequency is governed by L_{4(a)} in parallel with L₄, plus the stray capacitances in parallel with these inductors. Actually, L_{4(a)} serves rather like the fine tuning capacitor of valve type tuners, and the inductance is adjustable, giving permeability tuning, instead of having a capacitance varying the tuned frequency.

The oscillator coil proper, L₄, is switched across L_{4(a)} according to the channel selected, using the basic turret principle. This applies also to coils L₁, L₂ and L₃.

A study of the mixer stage will show that this is also almost the same basically as the r.f. amplifier and the oscillator, with small deviations between the values of the base and emitter resistors. The base bias of TR₂ is adjusted to provide optimum mixing action. The emitter of TR₂ thus receives the amplified sound and vision signals across L₃ and the local oscillator signal through C₁₄. Across the i.f. coil, L₇, are developed the sound and vision i.f.'s, these usually being the 405 line "standard" frequencies of 34.65 Mc/s vision and 38.15 Mc/s sound.

A.G.C. Systems

There are three basic techniques for applying a.g.c. to transistorised tuners. One is to decrease the forward current in the base-emitter junction, thereby decreasing the effective alpha of the stage with increase in signal input, the second is to increase the forward current in the base-emitter junction with increase in signal input, and the third is to adopt a method of variable damping.

The first is fairly obvious and is akin to the

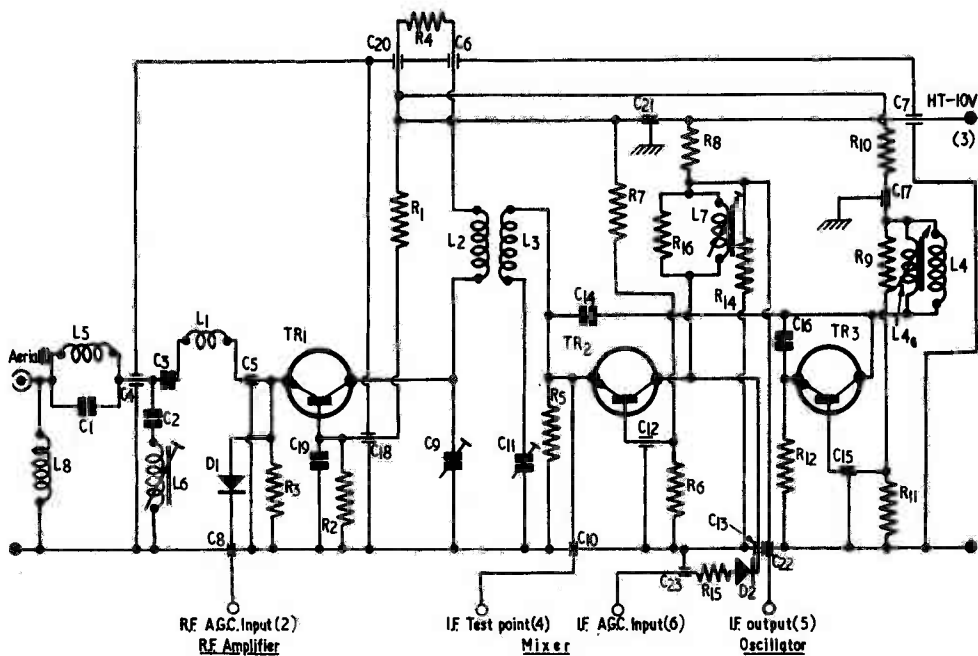


Fig. 2. Transistorised teletuner as used in some versions of the Perdio "Portarama" Transistorised Television Receiver, Mark II. This is manufactured by R. and E. Hopt and is described in the text

Components List (For the teletuner of Fig. 2)

Resistors

R ₁	6.8kΩ ±10%
R ₂	2.2kΩ ±10%
R ₃	1kΩ ±10%
R ₄	470Ω ±10%
R ₅	1kΩ ±10%
R ₆	1.8kΩ ±10%
R ₇	10kΩ ±10%
R ₈	680Ω ±5%
R ₉	10kΩ ±10%
R ₁₀	680Ω ±10%
R ₁₁	1.8kΩ ±10%
R ₁₂	680Ω ±10%
R ₁₄	1.8kΩ ±5%
R ₁₅	220Ω ±10%
R ₁₆	8.2kΩ ±10%

Capacitors

C ₁	120pF
C ₂	18pF
C ₃	30pF

C ₄	30pF
C ₅	47pF
C ₆	1,000pF
C ₇	1,000pF
C ₈	1,000pF
C ₉	2·8pF
C ₁₀	60pF
C ₁₁	2·8pF
C ₁₂	1,000pF
C ₁₃	9pF
C ₁₄	1pF
C ₁₅	1,000pF
C ₁₆	2pF
C ₁₇	1,000pF
C ₁₈	1,000pF
C ₁₉	1,000pF
C ₂₀	1,000pF
C ₂₁	1,000pF
C ₂₂	30pF
C ₂₃	1,000pF

Diodes

D ₁	OA70
D ₂	OA79

Coils

L ₁	Aerial coils
L ₂	Band pass (r.f.)
L ₃	Band pass (mixer)
L ₄	Osc. coils
L _{4(a)}	Fine tuning
L ₅	Vision i.f. rej.
L ₆	Sound i.f. rej.
C ₇	i.f. output
L ₈	M.W. rejector

Transistors

TR ₁	AF102
TR ₂	AF102
TR ₃	AF102

technique of reducing the mutual conductance (gm) of a valve stage, and hence the gain, by increasing the negative grid bias, and it needs no further explanation. The damping arrangement is employed in the Perdio tuner and will be considered shortly, but the second arrangement, whereby the forward base-emitter current is actually increased to decrease the stage gain, needs a little studying in detail.

Consider the circuit in Fig. 3. Here we have the basic common base amplifier (or any other kind of configuration, for that matter) with the potentiometer P₁ arranged to vary the forward current in the base-emitter junction. The normal transistor effect, of course, is that as the base forward current is increased, so does the collector current increase and, within limits, also the gain of the stage.

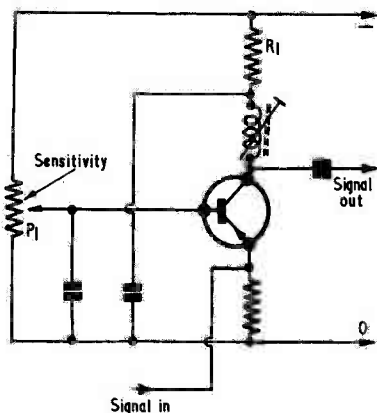


Fig. 3. This circuit is used to demonstrate forward a.g.c. (see text)

However, Fig. 3 features collector resistor R_1 , which was not considered in the circuit of Fig. 1. Now, as the collector current is increased by increasing the forward base-emitter current, so the volts drop across R_1 increases. This lowers the voltage at the collector and, with careful design and choice of component values, has the effect of reducing the stage gain despite the increase in forward base-emitter current. The result is, of course, the opposite to what would happen without R_1 .

One might question the good of such a roundabout way of gain control. The reason is one of input impedance change with change of bias. With a valve r.f. amplifier it will be recalled that, when the bias is increased, not only is the gm reduced but the input capacitance varies as well. At TV frequencies this is important as it can affect the tuned frequency

and response characteristics of the amplifier. Several artifices have been adopted to counteract the effect, one being the use of a low value unbypassed resistor in the cathode circuit. The resulting negative current feedback stabilises the input capacitance over a fairly wide range of gain control.

With a v.h.f. transistor amplifier it has been found that the change of input capacitance is less when the forward bias is increased than when it is decreased, and the scheme which has been evolved to give a fall in gain with an increase in collector current is called "forward a.g.c."

Variable Damping

In the tuner circuit of Fig. 2, diodes D_1 and D_2 are employed to control the effective gain without drastically changing the parameters of the r.f. stage and the mixer. Under low signal input conditions the diodes are virtually non-conducting and thus have little or zero effect on the normal operation of the stages.

However, with an increase in input signal the a.g.c. circuit (which will be fully dealt with in a later article) produces a bias which tends to increase the "conductivity" of the diodes. D_1 thus shunts the signal applied to TR_1 emitter while D_2 shunts the signal at the output of the mixer TR_2 .

To ensure that the noise performance is in no way impaired, diode D_1 does not start to conduct until diode D_2 is fully conducting. The diodes reduce the signal transfer because, when they are conducting, their impedance is reduced. The impedance, and hence the amount of damping, is governed directly by the amount that the diodes are conducting. They can, in fact, be considered as a variable resistor across the appropriate tuned circuits which decreases in value when the signal is strong and increases in value when the signal is low.

(To be continued)

New Astronaut Monitoring Device

For the first time, astronauts' physical and emotional conditions during flight can be monitored by a small radio device which is worn like a belt and allows the astronaut to move freely around in his space capsule without trailing wires behind him.

This unique miniaturised telemetry package, which weighs only fourteen ounces, can be worn by astronauts, test pilots and parachute jumpers to measure and transmit their heart action, respiration rate, skin temperatures and suit differential pressure. Twelve different measurements can be monitored. It can also be used in tests on athletes, motorists, ski-jumpers and other persons operating under stress.

Measuring $9 \times 3\frac{1}{2} \times \frac{3}{4}$ in, this device is only one-tenth the size of existing monitoring equipment. It contains a small radio transmitter with its own power supply, which, when used inside a space capsule or aircraft, broadcasts its information to a radio unit which in turn relays it to the ground or a recorder in the craft. It is also possible for the first time to measure reactions during a parachute jump, as the monitor can then transmit its information direct to a ground listening station.

The device was developed and manufactured by the Hughes Aircraft Company of America, for the U.S. Air Force, and can be manufactured in the United Kingdom by EMI Electronics, for sale by Emihus Ltd., the company jointly owned by EMI and Hughes.

A recent test on a motorist negotiating heavy traffic in Los Angeles registered a heartbeat of 115 per minute. Astronaut Scott Carpenter's heartbeat recorded only 104 during re-entry.



This month Smithy the Serviceman, aided as always by his able assistant Dick, inspects the contents of the Workshop loft. Dick discovers that many of the old principles of radio have modern applications, whilst Smithy allows himself to indulge in some poignant and nostalgic memories

BUT THERE'LL BE ALL SPIDERS and things up there!"

Smithy's protesting assistant diverted his gaze from the hatch in the ceiling back to the Serviceman.

"Goodness only *knows* what's up there," he continued, hotly. "Dash it all, that hatch hasn't been opened since I started working here!"

Smithy sighed.

"I will admit," he confessed, "that it has been quite some time since anybody had a look up there. But that is all the more reason for having a clear-out now."

"Why don't *you* go up then?" asked Dick. "It'll be all *your* old junk up there, not mine."

Smithy put a hand to the small of his back and winced violently.

"Now, you know," he said reprovingly, "how much my lumbago plays me up in this weather. At my venerable age I have to delegate the more interesting jobs to those who are younger and more active than I am."

Dick surveyed the Serviceman with disgust.

"Up until this moment," he remarked, "you've been nipping around the Workshop like a two-year-old. How is it that your lumbago always comes on when there's something heavy to shift or awkward to do?"

"My old Army doctor explained it to me years ago," replied Smithy. "He said I had a conditioned reflex."

A doubtful expression came over Dick's face as he considered this statement.

"Well, all right then," he said reluctantly, "but I'm still not going to get my clothes all mucked up in that loft."

Fall-out

With an alacrity which was praiseworthy in a person of his advancing years and declining physical condition, Smithy jumped to his feet and opened a cupboard. He extracted a roll of bright blue denim material, opened it out, and displayed to his outraged assistant a pair of elephantine overalls cut in the style favoured by the cotton-pickers of America.

"There you are," he remarked cheerfully. "I got these surplus just before the war, and I've kept them on one side ever since for jobs like this."

Dick surveyed the combination garment with abhorrence.

"You couldn't," he protested weakly, "*buy* surplus before the war."

"I", replied Smithy loftily, "have *always* been able to buy surplus."

The Serviceman helped his unwilling assistant into the all-enveloping garment, after which he helped to take in the slack at various places with the aid of judiciously applied accumulator bulldog clips. Eventually, Dick was ready. Standing precariously on a Workshop stool, he reached up and gingerly pushed the ceiling hatch several inches to one side.

Immediately, two heavy black objects with gold lettering on their sides dropped through the aperture, flashed past his upturned face and

hit the floor with a heavy metallic thud.

"Blimey," said Dick, startled. "What was that?"

Smithy picked up the objects and examined them with interest.

"These," he remarked, in a tone of affection, "are old Ferranti a.f. transformers. I've got a whole box of them up there somewhere."

Dick stepped down from the stool and picked up one of the transformers.

"They're a bit weighty, aren't they?"

"I'll say they are," replied Smithy enthusiastically. "There's a good few pounds of laminations in these. They were made in the days when an a.f. transformer *was* a transformer!"

But the instinct of the explorer had now become aroused in Dick, and he was already re-mounting the stool preparatory to climbing up into the loft.

"Cor," he yelled out after a moment, "there isn't half some rubbish up here. Stand by a minute, and I'll pass the bits down to you."

The next five minutes were devoted to the descent through the ceiling aperture of electronic devices of doubtful condition, dubious purpose and certain antiquity. Smithy took each item from his assistant and placed it reverently on his bench.

After this period Dick returned to ground level. His face now had an appearance reminiscent of the male performers in the Black and White Minstrel Show, but Smithy felt that this would not be an opportune

moment to remark on this fact. Besides, Dick was consumed with curiosity concerning the nature of some of the appliances he had discovered.

Early Speaker Units

"Talk about junk," said Dick enthusiastically, walking over to the motley collection on Smithy's bench. "I reckon I've seen everything now!"

He pounced on a small Bakelite unit having a slender metal reed protruding from its centre.

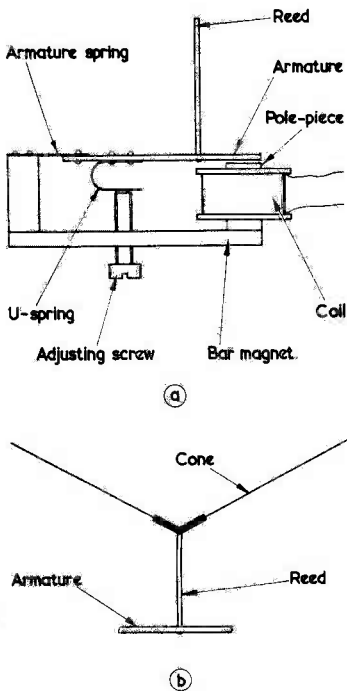


Fig. 1 (a). The simple mechanism of an early loudspeaker "unit". The bar magnet could appear at other positions around the magnetic circuit
(b). The armature of the loudspeaker "unit" was coupled by the reed to a cone

"What," asked Dick, "is this gadget?"

"That", replied Smithy, "is a loudspeaker unit of the type we used to use in the early '30s. It's hopelessly out of date now, but I suppose there's no harm in describing how it works because of the basic principles involved."

Smithy removed the Bakelite cover, and showed Dick the internal construction. (Fig. 1 (a).)

"You couldn't have anything

much simpler than this," continued Smithy. "It consists partly of a pole-piece, a bar magnet, and an armature on a spring. A second U-spring is fitted to the armature and its effect is controlled by a screw fitted to the base of the gadget. This screw adjusts sensitivity. What we used to do was to slowly turn the screw so that pressure on the U-spring slackened off. When we reached the correct point the armature would suddenly pull up against the pole-piece with a noticeable thump. We then turned the screw in the opposite direction until the increased pressure on the U-spring caused the armature to pull off again. The unit was then ready for use."

"I can follow that," remarked Dick, frowning, "but how did it work?"

"As you can see," replied Smithy, "there is, also, a coil on the pole-piece. We used to feed the a.f. output from a receiver or amplifier into this coil, whereupon the varying a.f. currents caused the armature to waggle backwards and forwards in sympathy. The armature was coupled to a core or diaphragm by way of the thin metal reed fixed to it (Fig. 1 (b)), with the result that we had a loudspeaker offering the utmost in fidelity and truth of reproduction!"

"What a ghastly idea!" commented Dick. "Did people *listen* to speakers like that?"

"Of course they did," chuckled Smithy. "We used to think they were marvellous! Every now and again you would get a really loud burst of music which caused the armature to bang up against the pole-piece. If the pressure applied to the armature U-spring wasn't sufficient it would then stick there, and you'd have to tighten the adjusting screw up a bit more."

"One of the coil terminals," remarked Dick, "has got a plus sign alongside it."

"That terminal," said Smithy, "would go to h.t. positive. The other would then go to the anode of the output valve."

"I don't get that," said Dick, puzzled. "What difference does it make which way round the coil was connected?"

"You have to remember that the coil is passing the standing anode current of the output valve," explained Smithy. "When this flowed through the coil in the correct way it assisted the magnetism offered by the bar magnet. It was considered that, if you connected it the wrong way round, the standing current would not only decrease the effect of the bar magnet but that it would,

eventually, also demagnetise it."

"Couldn't you use an output transformer to isolate the standing current?"

"Some people did," replied Smithy. "And there was a Ferranti model available with a 1:1 ratio

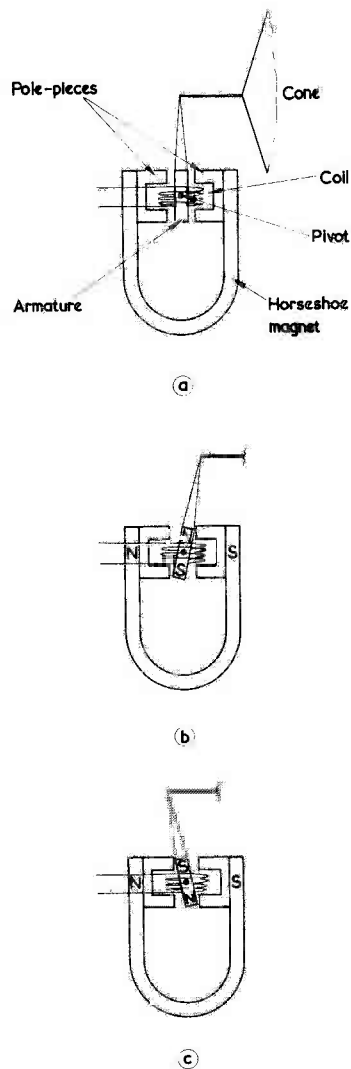


Fig. 2 (a). The essentials of a balanced armature loudspeaker. The coil consists, in practice, of a large number of turns and is secured between the pole-pieces
(b). When current flows through the coil in one direction the armature becomes magnetised and swings over on its pivot, as shown here
(c). If the direction of coil current is reversed, the armature swings over in the opposite direction

which was particularly intended for this purpose. Incidentally, you'll often find that old headphones are given polarity markings as well. This is for the same reason as with that little speaker unit: if a standing current flows in the wrong direction it might eventually demagnetise the headphone magnet."

Dick picked up a speaker which seemed to consist of little more than an inverted cone.

"Is this a complete speaker using one of those units?"

"Oh no," replied Smithy. "The one you've got there has a balanced armature unit."

"Balanced armature?" repeated Dick with interest. "They're selling balanced armature phones and reproducers in the surplus market at the time being."

"That's right," confirmed Smithy. "Although those, of course, are later military versions of the gubbins you have there. Inside a typical balanced armature drive unit you would have a horseshoe magnet and two sets of pole-pieces with a pivoted armature between them. (Fig. 2 (a).) There would also be a fixed coil which energises the armature. If a voltage is applied to the coil with a polarity which causes the outer end of the armature to become North and the inner end to become South, the armature swings over in one direction. (Fig. 2 (b).) If the polarity of the voltage is reversed, the outer end of the armature becomes South and the inner end North, whereupon the armature swings over in the other direction. (Fig. 2 (c).) Obviously, the armature swings back and forth in sympathy when a.f. is applied to the coil, whereupon you only have to couple a cone to the armature and you've got a loudspeaker! Crafty, isn't it?"

"I suppose so," agreed Dick dubiously. "But it's a wee bit old-fashioned, though, isn't it?"

"Not entirely," replied Smithy. "The balanced-armature principle keeps crossing up quite frequently in a.f. work. For instance, balanced armature movements have been used quite a bit for gramophone record cutters. The principle has been extensively used, also, in magnetic pick-ups. In this case the system works the other way round. The armature is waggled back and forth by the gramophone stylus, whereupon its ends alternate from North to South and back again according to the amount of movement and its frequency. The varying changes in flux in the armature cause corresponding voltages to appear across the coil, and these can then be applied to the input terminals of an

a.f. amplifier. Pick-ups of this type were very popular in the days of 78's, and in some cases the gramophone needle, itself, was the armature."

Short Wave Receivers

Dick nodded his head and allowed his attention to wander to an early and obviously home-constructed receiver. The components in this were mounted on a baseboard behind a metal control panel which measured some 16 inches long by 10 inches high. The receiver had one valve only.

for the amateur were very few and far between then, so that what most people who were interested in short wave reception used to do was to build receivers having superlative reaction performances. The circuit I used in that set of mine was as simple as it possibly could be (Fig. 3) and the secret of its success lay in the care with which I got the reaction to operate. You may note that the reaction capacitor has got a slow-motion drive on it, and I was able, with its aid, to bring reaction to the tiniest proportion imaginable below oscillation point. Reaction increases

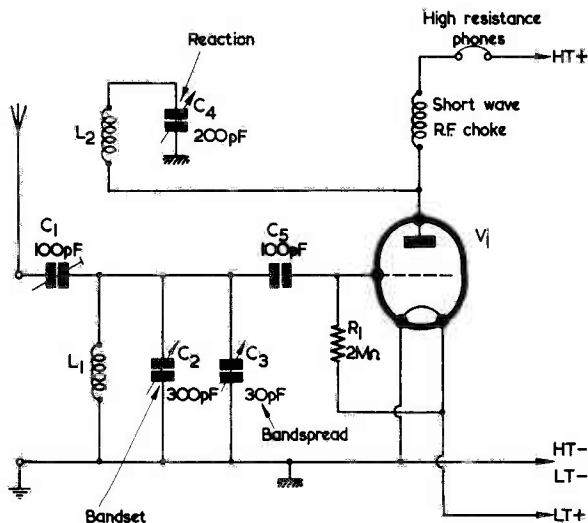


Fig. 3. The very simple circuit of Smithy's early short-wave receiver. The valve is a 2 volt battery type, but this could be replaced by a mains valve with R_1 returned to cathode. C_3 and C_4 have slow-motion drives, and the values shown for all variable capacitors are typical. To obtain smooth reaction, which is the whole secret of the receiver, it may be necessary to adjust the values of C_5 and R_1 . L_1 and L_2 are the grid and reaction windings of a plug-in coil

"Corluvaduck," remarked Dick indicating his specimen. "You certainly didn't believe in miniaturisation in those days!"

"That set," remarked Smithy with dignity, "was an early short wave receiver I knocked up for myself. I picked up all continents with it almost as soon as I'd finished it."

"With that?" said Dick incredulously. "Why, it's only got one valve!"

"I know," replied Smithy, "and it's a 2 volt battery triode at that."

"It sounds", commented Dick, "almost beyond belief."

"On the contrary," said Smithy. "A performance of that nature was pretty commonplace in those days. You must remember that superhets

the effective Q of a coil, and the Q of the grid coil must have been very high indeed when I had the reaction control at this level."

"What is the series aerial trimmer for?"

"That was to cure 'dead spots' caused by the aerial," said Smithy. "You would find that, at certain frequencies, reaction used to become almost non-existent. This could be cured by adjusting the series capacitor. Usually, it had to be reduced in value. Trouble with 'dead spots' was less evident, also, if you used a third winding on the coil for aerial coupling. With a coupling coil it was usually possible to dispense with the series aerial trimmer. The aerial connected, of course, to one

end of the coupling winding, whilst the other end connected to chassis."

"Could you get similar results with modern components?"

"Oh, definitely," replied Smithy. "But you may have to play around a bit with the values of the grid leak and grid capacitor until you get the correct reaction effect. What you have to aim for is a regeneration circuit which gives you a gentle rushing noise that is just audible when you go into oscillation. Valves are likely to be a bit troublesome, and if you were to use current mains types you might have to try quite a few before you found one that gave you really good results."

"What about the reaction circuit itself?"

"There are several circuits you can try out," replied Smithy, drawing up a piece of paper. "The feedback circuit I used to like most myself was the one I used in that old set of mine. (Fig. 4 (a).) The reaction capacitor is at the earthy end of the reaction winding, instead of being between the winding and the anode of the detector, and this means that you can mount it directly on to a metal panel. An interesting alternative, which was sometimes described as 'throttle reaction', consists of using a fixed capacitor or trimmer for feedback and of having the variable reaction capacitor between anode and chassis. (Fig. 4 (b).) This time the reaction capacitor works in the opposite direction. At maximum

capacitance it doesn't allow sufficient r.f. to flow in the feedback circuit for oscillation to occur. As the capacitance is reduced, more and more r.f. flows in the reaction circuit until you eventually go into oscillation."

Smithy paused for a moment and stroked his chin reflectively.

"Another good reaction circuit," he continued, after a moment's thought, "consists of using an r.f. pentode with, again, a fixed capacitor, or trimmer, in the reaction feedback circuit. (Fig. 4 (c).) The actual regeneration control is then given by a potentiometer which varies the voltage on the screen grid. A considerable advantage with this circuit is that it enables the reaction control to be mounted at any convenient point on the panel, since it only handles d.c. The circuit usually gives very smooth reaction, and it isn't a bad idea to put fixed resistors in series with either end of the pot so as to make it operate over a restricted range of voltages only. (Fig. 4 (d).) This causes the critical voltages near the oscillation point to be covered by a greater angle of rotation of the potentiometer, and is equivalent to adding a slow-motion drive to it."

Two-Valve Receiver

Dick looked thoughtfully at the dirty and unkempt receiver which he had salvaged from the loft.

"Do you know, Smithy," he remarked after a moment, "I think I'll knock up a little short wave set with reaction one of these days just for the fun of it. It will have to be a mains job, though."

"Yes, a mains receiver would be better these days," agreed Smithy, "and it mightn't be a bad idea to start off by using a 12AU7 and employ the second triode as an a.f. amplifier. A considerable advantage with using a 12AU7 is that you can swop it for a 12AX7 or 12AT7 without having to change the base connections. This gives you a wide choice of valves to play with till you find one which gives you the smoothest reaction. Since you will be using a triode detector you'll need a reaction circuit employing a variable capacitor, because there is, of course, no screen grid to apply a potentiometer control to. To obviate hum, it's desirable to keep heater voltages away from the grid of the detector triode, and you could achieve this by using pin 2 as the signal grid and having pins 4 and 5 at chassis potential. The 6.3 volt heater supply can then go to pin 9 (Fig. 5). This method of connection keeps the signal grid well away from

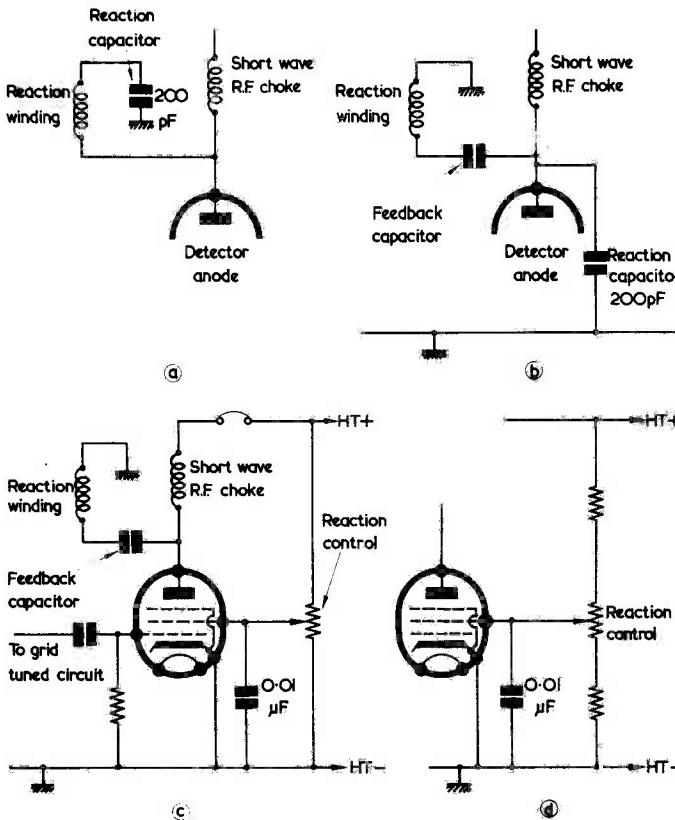


Fig. 4. It is possible to employ a number of feedback circuit configurations to obtain smooth reaction. In (a) the reaction feedback circuit is the same as in Fig. 3. An arrangement, sometimes referred to as a "throttle reaction" circuit, is shown in (b). The value of the feedback capacitor between the anode and the reaction winding is experimental and lies between some 20pF and 200pF. It should be adjusted for best results. Alternatively, a trimmer could be employed. In (c) a potentiometer provides reaction control. The same remarks as in (b) apply to the feedback capacitor. Reaction adjustment with a potentiometer control may be eased by inserting fixed resistors in series with the potentiometer, as in (d). In both (c) and (d) the total potentiometer resistance may be of the order of 100kΩ

the heater supply. Also, you should use a low-loss ceramic valveholder. Another tip is to keep h.t. potential down to about 100 volts or so. You don't need any more than this, and a low h.t. voltage will very probably assist in making reaction nice and smooth. Heater current will be a mere 0.3 amps, and h.t. current will be a few milliamps only, so a small mains transformer with a half-wave h.t. secondary of 125 volts or thereabouts will be quite adequate. And, of course, the chassis *must* be isolated from the mains because, apart from any other reason, you're using headphones and the safety question has to be considered."

"What about coils?"

"Plug-in coils are pretty essential," said Smythy. "Because coil switching tends to introduce too many losses. A good choice would be given by Denco Maxi-Q coils, which plug into an octal valveholder. The 'yellow' range of these coils has a grid winding and a reaction winding, whereupon you can apply the aerial via a series pre-set capacitor, as I did in that old set of mine. And the 'green' range of Maxi-Q coils has a grid winding, a reaction winding and a coupling winding, which means that you can apply your aerial to the coupling winding instead. Neither type of coil needs to be screened for this application, incidentally."

"Is the short wave r.f. choke important?"

"Very much so," said Smythy. "If you don't use a good choke you won't get good reaction. You want a choke with at least three sections, or pies. A good component is the Denco RFC5, which has four sections, together with an inductance of 2.6mH."

"It looks," commented Dick eagerly, "as though I'm going to have quite a bit of fun knocking up this set!"

"You will have," confirmed Smythy. "And you'll get a lot of pleasure out of listening to it too. Nowadays, what with TV, hi-fi, f.m. and transistors, many radio enthusiasts have forgotten all about the short wave bands. They have forgotten, also, that you can get almost incredibly good results from simple and inexpensive regenerative detector circuits provided that care is taken in their design and construction. The secret is to use a layout which keeps all signal frequency wiring as short as possible and to play around with valves and component values in the detector circuit until reaction is really smooth and silky. Get a set into that condition, connect it up to a reasonably good

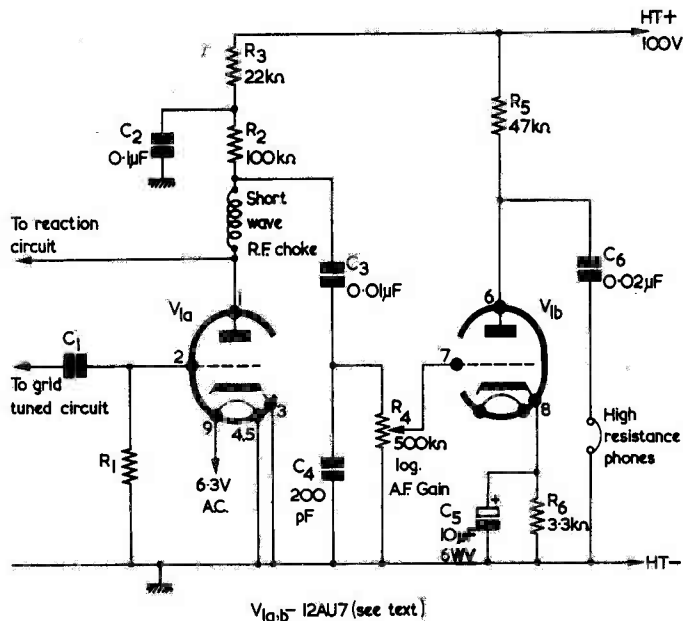


Fig. 5. A suggested two valve receiver employing a 12AU7 or similar valve. C₂ and R₃ provide decoupling, whilst C₄ offers an r.f. bypass which, with a one valve circuit, would have been given by self-capacitance in the phone leads. The valve pins indicated should give optimum protection against hum, and the 6.3 volt heater wiring should be kept well clear of pin 2

aerial and earth, and the stations simply roll in!"

Up Aloft Once More

"Well, we certainly seem to have found *something* amongst this old stuff," said Dick, "which is applicable to the present day."

Smythy gazed at the collection on his bench.

"It's funny," he remarked with a tone of nostalgia in his voice, "how these old bits and pieces bring back the memories. Even nowadays, when we've got satellites whirling about us and when such things as colour television are taken for granted, there is still a certain indefinable romance about radio. I suppose that part of the fascination lies in the fact that it is impossible to *see* what happens when we operate a piece of radio equipment. We know that electric currents flow, and we know that some circuits are resonant, that some circuits pass a.c. and that others pass d.c., but we have no sense with which we can perceive the existence of the currents. Instead we employ meters and other devices, such as loudspeakers, to convert the currents into forms which become perceptible to us."

The Serviceman gestured towards the bench.

"The peculiar thing," he carried on, "is that every item of this old junk brings back a memory which is as fresh as though it happened only yesterday. That old horn loud-speaker, for instance, was one of the first models I could lay my hands on, and I can always remember the time I connected it up. At that exact instant someone was bashing out the 'Ride of the Valkyrie', and the sound came tumbling out of that old tin horn as though the whole orchestra was crowded into the overgrown headphone at its base. The same applies to that old crystal set over there with the variometer tuning and the ebonite panel. I drilled my first hole into ebonite on that panel and I'll always remember the stink it made!"

Smythy turned away from the bench.

"The trouble with radio," he said, almost sadly, "is that, sometimes, a little bit too much of you sticks to the things you've made and to the jobs you've done."

"Come off it," interrupted Dick impatiently. "You'll have us all in tears soon! Anyway, I'm going to see what else there is up in the loft."

"As you like," said Smythy, momentarily shaking off his mood. "I'll get ready to take the bits and

pieces from you.”

Dick clambered once more through the ceiling.

“I’ll have to look further afield this time,” he called out, “I’ve cleared all the stuff that was stored around the hatch.”

Final Discovery

There was silence for a moment, broken only by occasional grunts as Dick manoeuvred himself about the loft.

“I’ve made a find!” he called out suddenly. “This must be the box of transformers you talked about. Phew, it’s heavy!”

The sound of energetic man-handling reached Smithy’s ears, to be followed by his assistant’s voice.

“I’ve got it moving now,” shouted Dick. “All I’ve got to do is to pull it off this joist—oh, cor blimey!”

Dick’s wail of dismay was succeeded by an ominous creaking noise from the ceiling. Suddenly, in a shower of plaster and broken laths a large wooden box came hurtling down, dissipating some 1,000 foot-pounds of potential energy as it struck the floor. The whole structure

of the Workshop shuddered and a cloud of dust rose in the air.

A neat rectangular hole had now appeared in the ceiling and it was through this that Dick thrust a woe-begone and perspiration-streaked countenance.

Dick’s face cleared momentarily when, as the dust cleared, he saw that both Smithy and the more valuable Workshop equipment had been unharmed by the descent of the transformers. But his expression reverted to its previous state when he surveyed the floor, which was now strewn with a diverse pattern of transformers. Dick decided to go into the attack.

“Well,” he remarked brightly. “I got them down, didn’t I?”

“That,” snorted Smithy, “shall go down as the understatement of the year.”

Desperately, Dick sought for a new angle to the conversation. His eye, roving across the floor, noticed a transformer that was different from its black-enamelled and gold-lettered fellows.

“There’s a stranger over there,” said Dick, pointing to the component. “I wonder how that got into the box?”

Smithy glanced in the direction indicated by his assistant, and his expression of fury gradually disappeared.

“Well, I’m dashed,” he remarked as he picked up the transformer. “Do you know, Dick, this is the mains transformer I employed in my very first mains receiver back in the late ’20s. Dear me, this does bring back the memories! In those days, of course, mains sets were an extremely new development and it was quite an achievement to get them to ackle without a fantastic hum level. I remember that what I did with this transformer was to . . .”

Now that he had diverted Smithy’s thoughts along more comfortable channels, Dick quietly withdrew his head, made his way to the hatchway and gently lowered himself to the floor. Smithy was now so engrossed in his memories that he evinced no surprise whatsoever when he found his assistant’s face alongside him, whereas previously it had been inverted and peering through the ceiling.

Besides, he had just spotted a further transformer which had functioned as a phase-splitter in his first push-pull a.f. amplifier. . . .

HEAT SINKS FOR TRANSISTORS

By R. J. Barrett, GW3DFF

In this article the author discusses the importance and advisability of providing adequate heat sinks for transistors, and explains the experiments he has carried out and the technique used to make the necessary temperature measurements. He concludes with a number of practical designs of heat sinks for power transistors

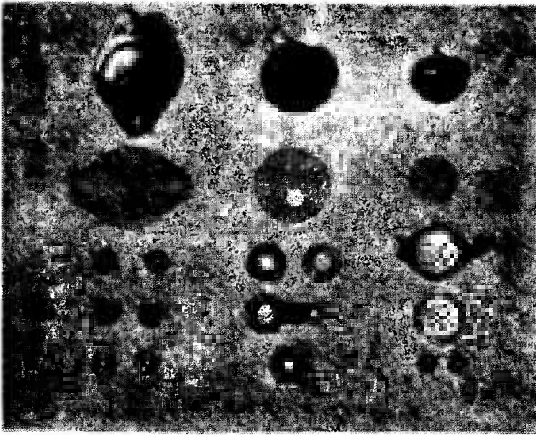
THE POWER TRANSISTOR HAS ARRIVED. THE magazines and handbooks are full of designs for amplifiers using power transistors for output stages, and for d.c. convertors with high performance figures. The power transistor lends itself also to regulated power supplies and to many other experimental circuits. It is a most useful device, but it suffers from the disadvantage that the harder it is worked the hotter it becomes, and that, unless something is done about its temperature rise, it will eventually destroy itself.

The writer has been engaged recently in building various items of equipment using power transistors, and it was noticed that the information given regarding the mounting of the transistor and details of the heat sink to be used were not really sufficient.

Many published designs quoted as follows: “The transistor should be mounted on a heat sink of 50 square inches.” No information on the shape or colour of the heat sink was given, and in many designs the heat sink seemed to be so large that any miniaturisation gained by using transistors was lost by having two enormous heat sinks bolted alongside.

Experiments

The following experiments were carried out firstly to determine if the method of mounting the transistor on the heat sink had much effect, secondly to find out if a heat sink painted matt black was better than one of bright aluminium, and thirdly to ascertain if the heat sink could be reduced in size without adversely affecting its performance. The



A group of typical power transistors, together with their mica washers and mounting hardware

illustration shows a number of typical power transistors together with their insulated mica washers and mounting hardware. The latter can be supplied with the transistor, and are used to electrically insulate its body from the heat sink. The mica washers are also quite useful as templates for drilling transistor mounting holes. The power transistor used throughout the experiments was a Newmarket NKT 402. This is of a type and size which could be used in a 15 watt transistor amplifier.

The first problem was to devise a method of measuring the temperature of the transistor when power was being supplied to it, and the technique chosen consisted of using a thermistor (a thermistor exhibits a change in resistance with a change in temperature) which was attached to the body of the transistor. The thermistor chosen was a Stantel type M.52* and it was calibrated to indicate temperature in the following manner. It was connected by very thin wires (to avoid any heat transfer along the wires) to an accurate and sensitive resistance bridge, after which it was immersed, together with a thermometer, in a large beaker of paraffin oil. The thermistor was placed very close to the bulb of the thermometer and the beaker was heated by means of an electric hotplate. In this way the temperature of the oil could be measured with the thermometer and directly related to the resistance of the thermistor. A graph was plotted showing temperature versus resistance for the thermistor over the range 25°C to 80°C. The thermistor was removed from the oil and cleaned, after which it was fitted to the top of the NKT 402 transistor case with Araldite adhesive. Fig. 1 shows the temperature/resistance curve obtained for the particular thermistor employed.

The first experimental heat sink was a 7in square of 16 s.w.g. aluminium. This material was chosen as being of a type that may well be used by a home constructor. Copper was purposely avoided, owing

to its cost. The aluminium was found to be brightly polished on one side and to have a slightly lesser polish on the other. It was thoroughly cleaned and the mounting holes for the transistor, together with a very small hole on the top edge with which to hang the plate up, were drilled. Both the transistor and the centre of the plate were smeared with silicon grease to provide good thermal contact, and the NKT 402, complete with its thermistor attached, was bolted to the centre of the heat sink. Thin stranded wires were connected to the collector, base and emitter, and the plate was supported by a thin cord to allow good thermal ventilation. (See illustration.) A 10 volt stabilised power supply was used to supply power to the transistor; an ammeter was placed in series with the collector, and the current flowing in the transistor was controlled by adjusting the base current by means of a 5kΩ variable resistor. In this way, controlled amounts of power could be passed through the transistor, and the thermistor mounted on it would indicate, by its change in resistance, the temperature of the transistor. Fig. 2 shows the circuit as set up, and the whole experiment was conducted in a room in which the temperature was controlled at 18°C ± 1°C.

Loss of Heat

There are, of course, three methods by which heat may leave the heat sink:

- (1) *By conduction.* For the purpose of this experiment it was necessary to minimise this effect. Any connecting wires from the thermistor or transistor provided a possible

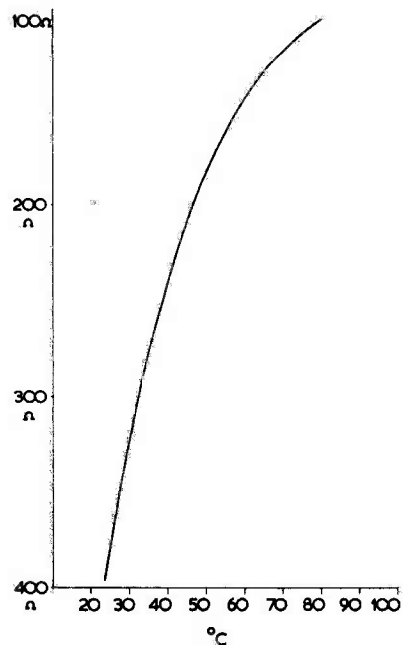
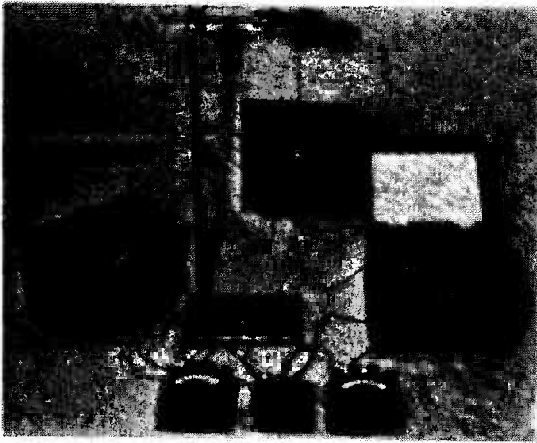


Fig. 1. The thermistor resistance/temperature curve

* Stantel thermistors are manufactured by Standard Telephones & Cables Ltd.—EDITOR.



The experimental set-up in which heat sink performance was evaluated

heat conduction path, and for this reason the thinnest possible wires were used.

- (2) *By convection.* The plate was mounted vertically to ensure uniform convection, and care was taken to avoid any draught, as it was found that any movement within the room produced enough draught to make measurements impossible.
- (3) *By radiation.* The heat sink was later to be painted black in order to assist and measure this effect.

All was now ready for the first set of measurements to be taken. Ten volts were applied to the collector and the $5k\Omega$ base resistor was adjusted until the current flowing into the collector was 0.3 amps. After half an hour, by which time it was considered that the assembly would have settled to a steady temperature, the resistance of the thermistor was measured on the resistance bridge, and checked against the calibration graph, giving the temperature in degrees Centigrade. Measurements were taken at various input powers, but it was not considered advisable to run the input up too high when the graph showed the temperature rise to be excessive.

Results

Fig. 3 shows measured temperatures of the

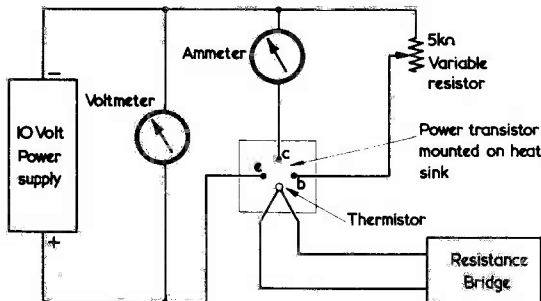


Fig. 2. The circuit employed for evaluating the performance of the heat sinks

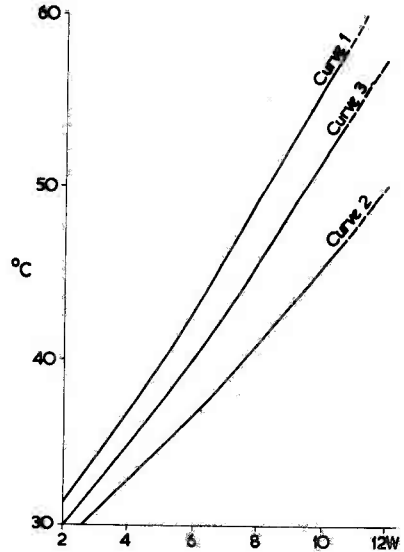
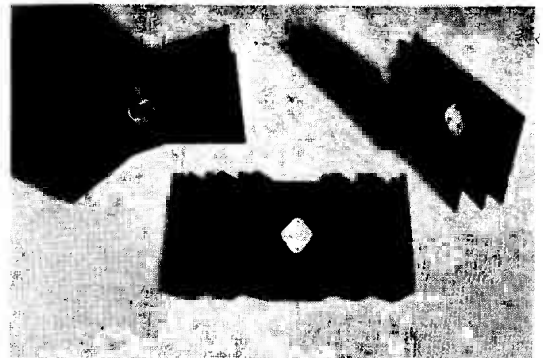


Fig. 3. Results obtained with an aluminium heat sink 7in square. Curve 1 is for bright aluminium, and Curve 2 is for the same area painted matt black. Curve 3 shows the effect of introducing a mica washer between the transistor and the heat sink

transistor. Curve 1 gives the temperature of the transistor when mounted on its 7in square of bright aluminium, and Curve 2 shows the considerable advantage gained by giving the heat sink one coat of matt black paint. The paint was applied to both sides of the plate, without removing the transistor, and the curves show that it is certainly well worth taking the trouble to paint a heat sink black. Reference to the 50°C point will show that with a bright aluminium heat sink the transistor has less than 8.5 watts flowing through it, whereas with the matt surface it can be run at the full 12 watts input with no increase in temperature. Curve 3 shows the effect of inserting a mica washer between the transistor and the heat sink. It will be noted that much of the advantage gained by painting the heat sink black has been lost, because of the poorer thermal contact which now existed between the transistor and the heat sink. In practice this can be improved



The physical appearance of the heat sinks of Fig. 5

somewhat by the application of silicon grease to the plate, the mica washer and the transistor before fixing, but in the writer's opinion the improvement will be slight.

Conclusions drawn from the experiments and information regarding fixing transistors to heat sinks

1. Always aim for as efficient a heat sink as possible. (Transistors should be run well within the manufacturers' temperature ratings.)
2. Paint the heat sink black on both sides, leaving the area where the transistor is to be mounted bright and clean.
3. Ensure that fixing holes, etc., are free from burrs, and that the area on which the transistor is to be mounted is as smooth as possible.
4. Fix the transistor very firmly to the heat sink.
5. Mount the heat sink vertically to assist cooling, and provide as much ventilation as possible.
6. When possible avoid the use of mica insulating washers. Try to insulate the whole heat sink instead.
7. Smear silicon grease on all surfaces, if available, for better thermal contact.

Smaller Heat Sinks

A number of heat sinks of smaller dimensions but of similar area were constructed, and three of these are shown in some detail in case the reader may wish to fabricate similar types. All the sinks have an area equivalent to a 7in square but, as can be seen, either have folds or additional plates to reduce the overall size.

The first, shown in Fig. 4 (a), is of a corrugated type, and was made from a piece of aluminium 10 by 5in, which has been bent in a vice to form the angles shown. The four small holes in the corrugated section are to assist in mounting the sink, and these can be placed wherever desired. Note that the area where the transistor is to be fixed must be left clean and not painted, so that good thermal contact is assured. If it is desired to reduce the size of this type of heat sink still further, the angles of the corrugations can be decreased considerably, bring down the length from 7in to approximately 5in. It is important not to alter the height/length ratio too much when modifying this type of heat sink, and the transistor should always be mounted somewhere near the centre.

The types shown in Fig. 4 (b) and (c) are of similar construction, both being made up of more than one plate. The plates can be bent to any angle to suit the constructor's wishes, but the angles should be great enough to allow good air circulation between the plates. It is most important that the surfaces of the plates, where they are fixed together, should be as flat as possible and quite clean. They

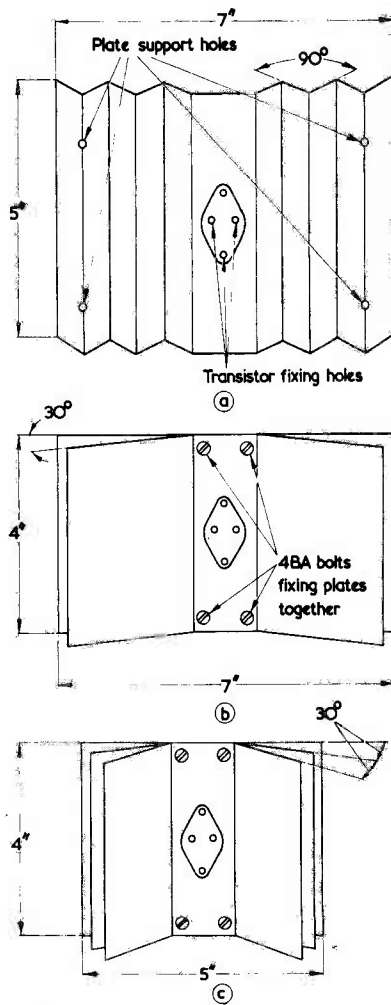


Fig. 4. Alternative patterns of heat sink which have similar efficiencies to a flat plate 7in square. In (a) the heat sink is corrugated, whilst in (b) and (c) additional angled plates are fitted

should be tightly bolted together with at least four bolts and, in common with all heat sinks, should be mounted vertically so that air may circulate up through the fins.

These three heat sinks have produced efficiencies almost identical to that of the full 7in square plate, and were all tested under the conditions described for the original experiment.

It is hoped that these simple designs will encourage the amateur to produce his own heat sinks to a pattern convenient to the job in hand, and to assist his power transistors to live to a ripe old age.

AMERICAN REGISTRATION FOR NEW MAGNETRON

The JEDEC type number 5586A has now been reserved for the English Electric Valve Co. Ltd tunable Magnetron type M542A. This new tube will in future be marketed bearing this code and it is expected that the recognition now given by the U.S.A. will be an added boost to world sales. The 5586A operates over the frequency range 2700-2900 Mc/s with a peak output power of 1 Megawatt and a guaranteed capability of 5,000 complete tuning cycles.

ANNULAR TRANSISTORS

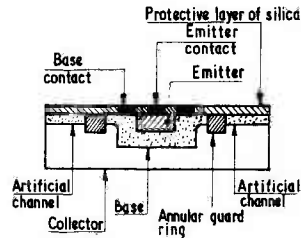


BY J. B. DANCE, M.Sc.

IF ONE LOOKS THROUGH CATALOGUES OF SILICON transistors, one finds many n.p.n. high voltage transistors, but until recently it has not been possible to manufacture high voltage silicon p.n.p. transistors with good characteristics. If one attempts to increase the voltage rating of p.n.p. silicon transistors by increasing the resistivity of the collector material, the leakage current of the device is vastly increased owing to a phenomenon known as channelling.

Channelling occurs when the surface of a transistor collector effectively changes its type and becomes part of the base. For example, in a p.n.p. transistor part of the p type collector can change to n type material. The surface of a planar silicon transistor is protected by a layer of silicon dioxide (silica), but when channelling takes place beneath the surface of the silica, a part of the base-collector junction may be present at the edges of the crystal where it is subject to contamination, etc., resulting in a high leakage current.

A new breakthrough in transistor design has recently been reported by Motorola Semiconductor Products of America in which these difficulties are eliminated. An artificial channel is deliberately introduced in the collector region beneath the protecting layer of silica and the controlled characteristics of this channel completely obscure any other stray channelling effects. The artificial channel is broken close to the base as shown in the diagram by an annular band of the same type of semi-



Cross section of an annular transistor

conductor material as the collector (p type in p.n.p. transistors) which has an impurity doping level which makes channelling through it impossible. Thus the collector-base junction is confined by this ring and is fully protected against contamination by the silica coating. The leakage currents are therefore small.

This new production process is also expected to be useful for other types of semiconductor devices, including n.p.n. transistors. It is expected that it will enable transistors to be produced which are less susceptible to radiation damage than the present types and which may therefore be invaluable for instrumentation in the upper atmosphere in the Van Allen radiation belts, etc.

Further details of these devices may be obtained from the manufacturers, Motorola Semiconductor Products Inc., Technical Information Centre, Box 955, Phoenix 1, Arizona, U.S.A.

CAN ANYONE HELP?

(Continued from page 240)

Indicator CRT Type 103.—H. Bradbury, 36 Hassop Street, Beswick, Manchester 11, requires the service manual or information, also details of power pack (type unknown).

* * *

Loan of Magazine.—W. Hartshorne, 186 Jewell Road, Castle Lane West, Bournemouth, Hants, wishes to obtain copy of *The Radio Constructor*, May 1958, for limited period.

Loan of Magazine.—D. E. Taylor, 72 Boscombe Crescent, Downend, Bristol, would like to obtain a copy of *The Radio Constructor*, August 1956.

* * *

Transceivers Type B44, Mk II and Mk III.—J. Ayres, G3DQT, 7 Berrylands Road, Surbiton Hill, Surrey, is in urgent need of the service manuals, or circuit diagrams, of these equipments.

* * *

Mullard GM3156-15 Oscilloscope.—P. Sladen, c/o St. Lawrence Hospital, Chepstow, Mon., would like to obtain any information relating to this unit.

Cover Feature

General Coverage Communications

DOUBLE SUPERHET Receiver

By Frank A. Baldwin, A.M.I.P.R.E.

The communications receiver design described herewith is of advanced design and as such it is not recommended for the beginner, although the author discusses how the whole project may be concluded in easy stages. Apart from completing the design in its entirety, many readers will no doubt be interested in inserting some parts of the circuit into their own receivers, thereby bringing them more up to date and in line with current trends

MANY READERS OF THE MAGAZINE WILL, NO doubt, already be equipped with a communications receiver of some kind or another, whilst others may be satisfied with a t.r.f. which has given sterling service over the years. Others again may have toyed with the idea of constructing such a communications receiver but have never, for one reason or another, "got around to it". The design offered here should appeal to all these readers in that it is capable of being constructed in easy stages if desired or, where preferred, as a complete design in itself. Alternatively, where required, certain stages may be omitted altogether and this fact will probably be of interest to those who are "near beginners" or those who do not have the proverbial (and I often think mythical) long pocket.

In the present instalment the circuit will be discussed and the Components List featured so that those who are interested may be able to assess the design and obtain the required components. Part 2, to be featured in the next issue, will discuss the components used and will give general constructional notes.

Circuit—General Considerations

The circuit is shown in Fig. 1 and from this it will be seen that it is an 11-valve double superhet design having a first i.f. of 465 kc/s and a second i.f. of 85 kc/s. The various stages are as follows: V_1 r.f. amplifier (EF183); V_2 frequency changer 465 kc/s (ECH81); V_3 frequency changer 85 kc/s (ECH81); V_4 Q multiplier (ECC83); V_5 i.f. amplifier (EF183); V_6 a.m. detector/a.g.c. (ECC82); V_7 product detector/b.f.o. (ECH81); V_8 first a.f. amplifier/output (ECL83); V_9 rectifier (EZ81); V_{10} voltage stabiliser (150C2) and V_{11} 100 kc/s crystal oscillator (EF80).

From the foregoing, it will be noted that the valve line-up of this receiver has been, for the most part, confined to the Mullard B9A range, these being the latest types available to the home constructor and excellent for the purpose for which they have been included in this receiver. An additional factor here is that the writer preferred to maintain a mostly B9A-based design in that the use of bases having various sizes was obviated and that the great advantage of including the new frame grid type valves was possible. The only exceptions to the foregoing are the 100 kc/s crystal itself and the voltage stabiliser, these being B7G based.

Looking at the circuit as a whole, it will be noted that the r.f. stage (V_1) is a high gain tuned arrangement into the grid of which, when required, is injected the output from the 100 kc/s crystal standard, this providing marker points up to, and including, 30 Mc/s.

An external aerial switching arrangement (not shown) allows the aerial input to be disconnected when the 100 kc/s oscillator is in use and this has been found to be of considerable assistance in that the audible calibration points are not then masked by the reception of strong signals at one and the same time.

With the type of chassis employed (to be described in Part 2) variations of the design are fairly easily achieved and consequently certain stages may be omitted at the outset and added at a later time, although it would be a good plan to include all the required valveholders at the commencement of construction.

The r.f. amplifier, crystal oscillator and product detector are those that come to mind by a study of Fig. 1 as capable of being omitted. Also, the voltage stabiliser could be dispensed with in the first instance. In this manner, the initial cash outlay

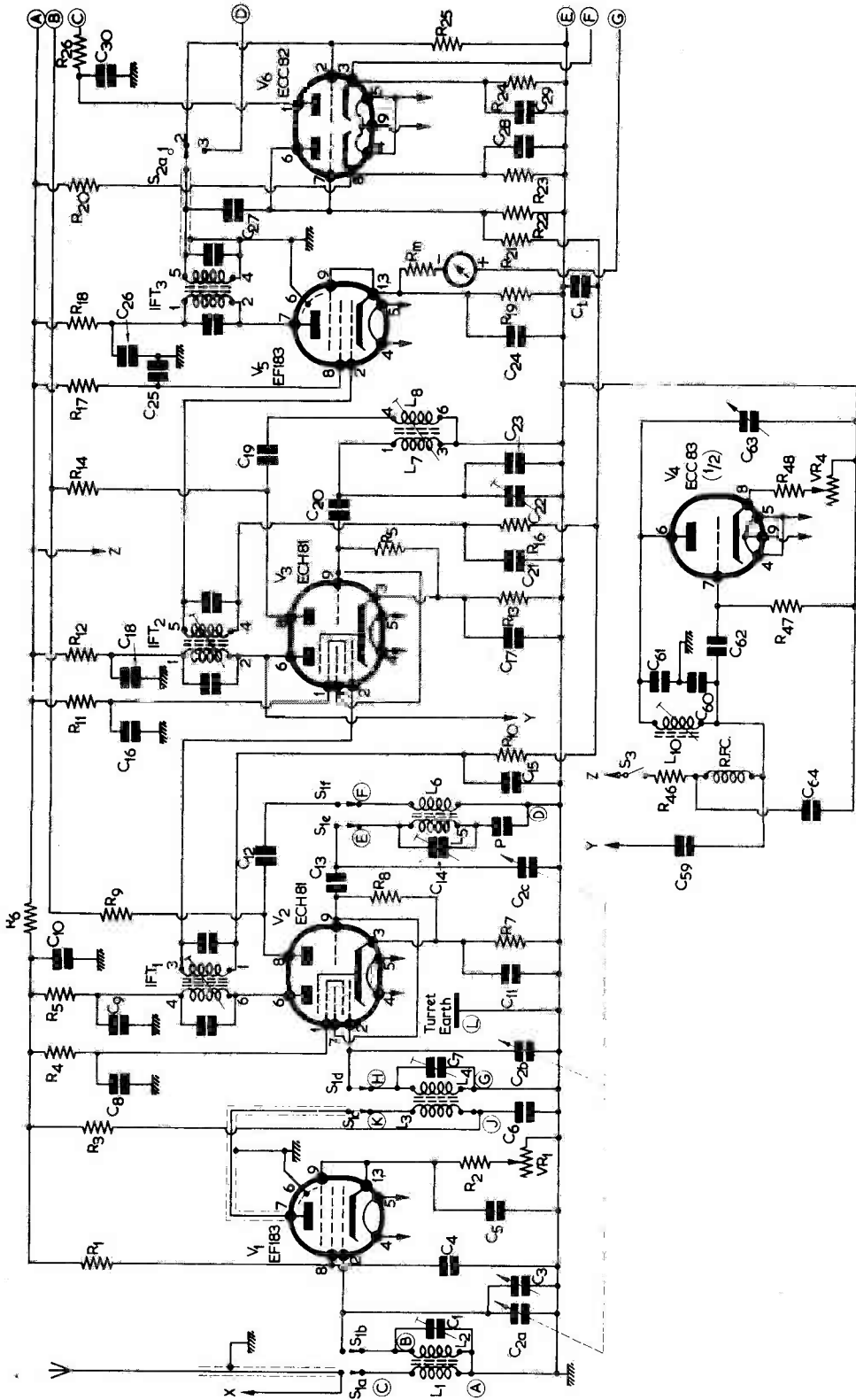


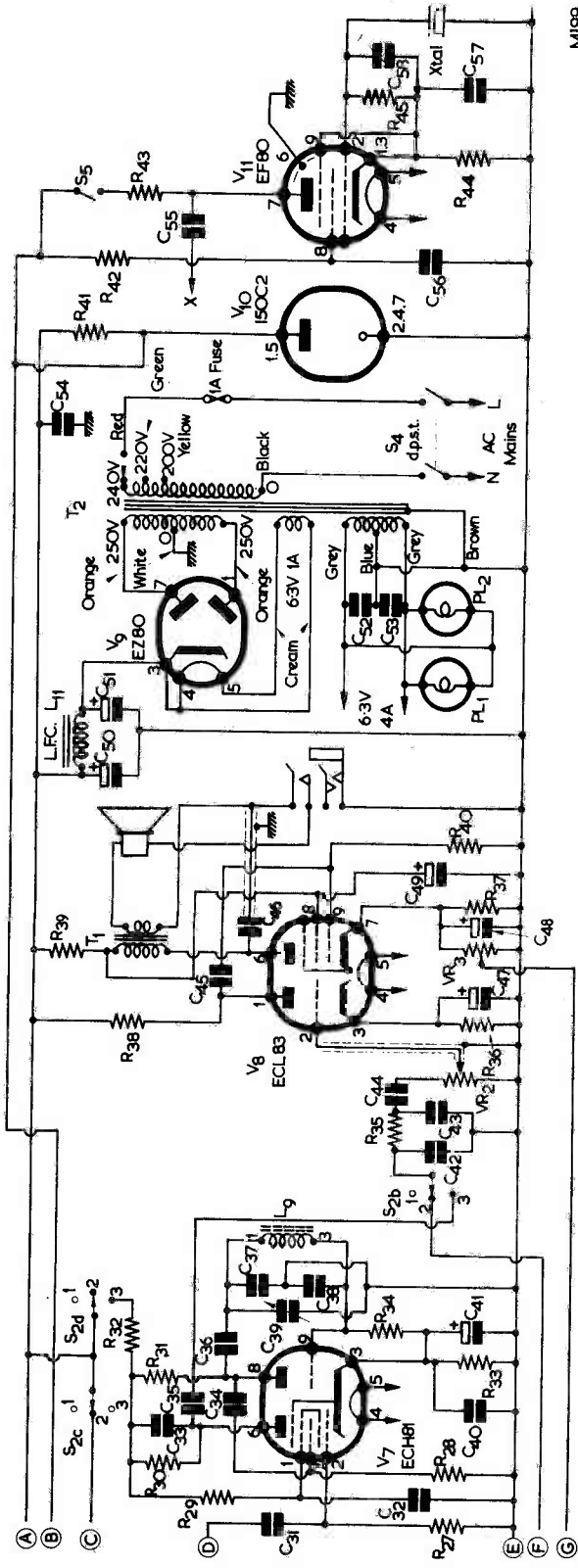
Fig. 1. Circuit of the general coverage communications receiver. The letters within the circles refer to the turret contacts

Components List

Resistors

(All fixed resistors 1/2 watt
5% unless otherwise specified)

- R₁ 33kΩ 10%
- R₂ 200Ω
- R₃ 10kΩ 1 watt 10%
- R₄ 22kΩ 1 watt 10%
- R₅ 10kΩ 10%
- R₆ 4.7kΩ 2 watt 10%
- R₇ 220Ω
- R₈ 47kΩ
- R₉ 22kΩ 10%
- R₁₀ 47kΩ 10%
- R₁₁ 33kΩ 2 watt 10%
- R₁₂ 33kΩ 10%
- R₁₃ 120Ω
- R₁₄ 22kΩ 10%
- R₁₅ 47kΩ
- R₁₆ 47kΩ 10%
- R₁₇ 33kΩ 10%
- R₁₈ 10kΩ 1 watt 10%
- R₁₉ 100Ω
- R₂₀ 390kΩ
- R₂₁ 1MΩ 10%
- R₂₂ 1MΩ 10%
- R₂₃ 3.3kΩ
- R₂₄ 82kΩ
- R₂₅ 1MΩ 10%
- R₂₆ 33kΩ 10%
- R₂₇ 220kΩ
- R₂₈ 470kΩ
- R₂₉ 22kΩ
- R₃₀ 12kΩ
- R₃₁ 47kΩ
- R₃₂ 33kΩ 1 watt
- R₃₃ 270Ω
- R₃₄ 47kΩ
- R₃₅ 56kΩ 10%
- R₃₆ 1kΩ 10%
- R₃₇ 470Ω
- R₃₈ 100kΩ 10%
- R₃₉ 1.5kΩ 2 watt
- R₄₀ 220kΩ 10%
- R₄₁ 4.7kΩ 5 watts
- R₄₂ 100kΩ
- R₄₃ 10kΩ 10%
- R₄₄ 10kΩ
- R₄₅ 470kΩ
- R₄₆ 47kΩ 10%
- R₄₇ 2MΩ
- R₄₈ 1.5kΩ
- R_m 47Ω (see text)
- VR₁ 5kΩ
- VR₂ 1MΩ log track
- VR₃ 500Ω (pre-set)
- VR₄ 5kΩ



Capacitors

- C₁ 3–30pF con. trimmer (Philips)
- C_{2(a), (b), (c)} 315pF variable, 3-gang (Denco Ltd.)
- C₃ 25pF variable, (Jackson Bros., type C804)
- C₄ 0.01μF tubular (Mullard)
- C₅ 0.01μF tubular (Mullard)
- C₆ 0.1μF tubular (Mullard)
- C₇ 3–30pF con. trimmer (Philips)
- C₈ 0.01μF tubular (Mullard)
- C₉ 0.1μF tubular (Mullard)
- C₁₀ 0.1μF tubular (Mullard)
- C₁₁ 0.01μF tubular (Mullard)
- C₁₂ 100pF silver mica
- C₁₃ 100pF silver mica
- C₁₄ 3–30pF con. trimmer (Philips)
- C₁₅ 0.01μF tubular (Mullard)
- C₁₆ 0.01μF tubular (Mullard)
- C₁₇ 0.1μF tubular (Mullard)
- C₁₈ 0.1μF tubular (Mullard)
- C₁₉ 100pF silver mica
- C₂₀ 100pF silver mica
- C₂₁ 0.01μF tubular (Mullard)
- C₂₂ 3–30pF con. trimmer (Philips)
- C₂₃ 75pF silver mica
- C₂₄ 0.1μF tubular (Mullard)
- C₂₅ 0.1μF tubular (Mullard)
- C₂₆ 0.1μF tubular (Mullard)
- C₂₇ 120pF silver mica
- C₂₈ 0.01μF tubular (Mullard)
- C₂₉ 33pF silver mica
- C₃₀ 0.5μF tubular (Mullard)
- C₃₁ 20pF silver mica
- C₃₂ 0.01μF tubular (Mullard)
- C₃₃ 0.001μF ceramic
- C₃₄ 100pF silver mica
- C₃₅ 0.05μF tubular (Mullard)
- C₃₆ 100pF silver mica
- C₃₇ 520pF silver mica
- C₃₈ 4,700pF silver mica
- C₃₉ 50pF variable (Jackson Bros., type C804)
- C₄₀ 0.01μF tubular (Mullard)
- C₄₁ 25μF, electrolytic, 12V wkg.
- C₄₂ 270pF silver mica
- C₄₃ 270pF silver mica
- C₄₄ 0.005μF (see text)
- C₄₅ 0.01μF tubular (Mullard)
- C₄₆ 0.1μF tubular 500V wkg.
- C₄₇ 10μF, electrolytic, 12V wkg.
- C₄₈ 25μF, electrolytic, 25V wkg.
- C₄₉ 8μF, electrolytic, 350V wkg.
- C₅₀ 32μF, electrolytic, 450V wkg. } In single
- C₅₁ 16μF, electrolytic, 450V wkg. } can
- C₅₂ 5,000pF ceramic
- C₅₃ 5,000pF ceramic
- C₅₄ 0.01μF tubular (Mullard)
- C₅₅ 2pF silver mica
- C₅₆ 0.1μF tubular (Mullard)
- C₅₇ 0.001μF silver mica
- C₅₈ 3–30pF con. trimmer (Philips)
- C₅₉ 0.001μF ceramic
- C₆₀ 7,500pF silver mica
- C₆₁ 2,500pF silver mica
- C₆₂ 0.001μF ceramic

- C₆₃ 100pF variable (Jackson Bros., type C804)
 - C₆₄ 0.001μF ceramic
 - C_t 0.5μF tubular (Mullard)
- (Also required are additional 3–30pF concentric trimmers for the coil turret. See Part 2)

RF Choke
2.5mH

S-Meter

- Type SR-2P (1mA f.s.d.) (Henry's Radio Ltd.)
- L₁₀ 85 kc/s (Electroniques Ltd.)

Valves

- V₁ EF183 (Mullard)
- V₂ ECH81 (Mullard)
- V₃ ECH81 (Mullard)
- V₄ ECC83 (Mullard)
- V₅ EF183 (Mullard)
- V₆ ECC82 (Mullard)
- V₇ ECH81 (Mullard)
- V₈ ECL83 (Mullard)
- V₉ EZ81 (Mullard)
- V₁₀ 15OC2 (Mullard)
- V₁₁ EF80 (Mullard)

Valveholders

- McMurdo B9A (10)
- McMurdo B7G (2)

Phone Jack and Socket

- Igranic (H. L. Smith & Co. Ltd.)

Dial Lamp and Mountings

- 6.3V, 0.3A (H. L. Smith & Co. Ltd.)

Fuse and Holder

- Cartridge type with 1A fuse (H. L. Smith & Co. Ltd.)

Speaker

- 7 x 4in elliptical, 3Ω

Leadthroughs

- As required (see Part 2) (H. L. Smith & Co. Ltd.)

Flexible Coupler

- Miniature ceramic type (H. L. Smith & Co. Ltd.)

Chassis, Panel, Cabinet

- (H. L. Smith & Co. Ltd.)—undrilled only

Coil Turret

- Type CT7/B (Denco Ltd.)

IFT's

- IFT₁ 465 kc/s (Denco Ltd. type IFT11/465)
- IFT_{2, 3} 85 kc/s (Denco Ltd. type IFT12/85)

Switches

- S_{2(a), (b), (c), (d)} 4-bank, 4-pole, 3-way type S15 (Denco Ltd.)
- S_{3, 5} s.p.s.t. type S263 (A. F. Bulgin Ltd.)
- S₄ d.p.s.t. type S300 (A. F. Bulgin Ltd.)

BFO Coil

L₉ 85 kc/s (Denco Ltd. type 2/85)

Output Transformer

T₁ Type 117E (H. L. Smith & Co. Ltd.)

LF Choke

L₁₁ 10H, 120mA, 200Ω, type M101 (H. L. Smith & Co. Ltd.)

Mains Transformer

T₂ Pri: 0-200-220-240; Secs: 250-0-250V, 120mA; 6.3V (centre-tapped) 4A; 6.3V, 1A. Type 7023 (H. L. Smith & Co. Ltd.)

Knobs

(H. L. Smith & Co. Ltd.)

Dial, Drive Mechanism, etc.

Eddystone Cat. No. 898 (Home Radio Ltd.)

Crystal

100 kc/s vacuum mounted (Brookes Crystals Ltd.)

could be somewhat reduced, the remaining stages being added as the opportunity occurs.

R.F. Stage (V₁)

When used as an r.f. amplifier, the EF183, in addition to providing the required high gain factor, also has the further advantage that the stage output signal-to-noise ratio is very much greater than that available, however good the design, at the output of a similar stage using a hitherto conventional valve. The r.f. stage in any receiver is of great importance in that it immediately precedes the frequency changer stage and therefore the noise voltage developed in the r.f. stage must of necessity be very much less than that of the frequency changer if an appreciable improvement in the signal-to-noise ratio is to be obtained. The primary requirement here therefore is a valve having a high mutual conductance (g_m).

It can be shown theoretically that the gain of any r.f. (or for that matter i.f.) amplifier is approximately proportional to the mutual conductance of the valve used in such an amplifier.¹

In this manner it is interesting to note that the more conventional type of valve used today in many receivers is the octal based 6K7, this valve having a mutual conductance of some 2mA/V. The more modern 6BA6 exhibits a somewhat higher gain with a mutual conductance of 4.4mA/V. In contrast to the foregoing, the EF183 variable- μ r.f. pentode has a maximum mutual conductance of some

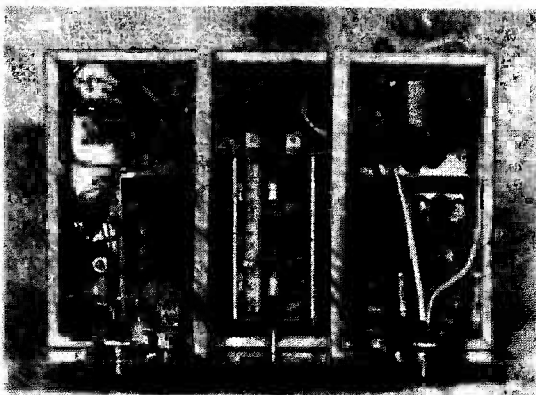
¹ It is approximately correct to state that stage gain = $\frac{\mu R}{r_a}$ but

as the mutual conductance (g_m) is arrived at by dividing r_a into μ , g_m usually replaces both μ and r_a in the formulae. Therefore, for approximate purposes, the stage gain will equal $g_m \times R$ when the former is stated in mA/V and the latter in kΩ; R being the effective dynamic resistance of the anode load. Mutual conductance (g_m) is nearly always quoted by valve manufacturers when dealing with r.f. pentodes, whereas values for r_a and μ are not always stated.

13mA/V, which is three times that provided by the 6BA6 and seven times that of the 6K7.

The high gain tuned r.f. amplifier of V₁ selects and amplifies the weak signals received from the aerial and passes them to the first frequency changer stage. The r.f. stage, being tuned, confers the advantage that the strength of the required signal is very much greater than that of any interfering, and therefore unwanted, signal on the image frequency, with the result that image and i.f. breakthrough, with their consequent heterodynes, are eliminated.

Operating as a high gain stage, the grid of V₁ is tuned by C_{2(a)}—one section of a 3-ganged variable capacitor—together with the additional parallel capacitance of C₁ (3-30pF concentric trimmer) and the r.f. trim control C₃—this latter component being mounted on the front panel. C₃ considerably assists by peaking the signal exactly into resonance and, together with the gain control (VR₁) inserted into the cathode circuit, enables the stage to be under the complete control of the operator at all times.



Below-chassis view showing, at left, the l.f. choke; centre, the coil turret and output transformer and right, the r.f., i.f., Q multiplier, crystal oscillator and voltage stabiliser stages. Range 3 of the turret is shown with only two 3-30pF trimmers, an additional trimmer having been added subsequently

With the r.f. stage shown, high gain is easy to achieve but stability must be borne in mind. Instability will arise due to energy being fed back from the anode circuit to that of the grid due to stray capacitance coupling between the two circuits, accidental inductive coupling or the grid/anode capacitance of the valve itself. Although the grid/anode capacitance of an r.f. pentode is of a low order, it is the determining factor of the maximum stage gain that can be achieved. Careful screening and due attention to layout is all important if a high gain with stability is to be obtained. To this end, it will be noted from the illustrations included in this series of articles that the below-chassis screening is liberal. Moreover, each valveholder in the circuit has a small metal screen soldered across it, effectively screening the anodes from the grids

and their respective associated wiring, etc. (See Fig. 2.)

Should instability occur in the r.f. stage, it will be necessary to reduce the r.f. voltage at the anode. This will then have the effect of proportionally decreasing the energy being fed back via the grid/anode capacitance of the valve.

In the circuit under discussion, the aerial signal is fed via a length of coaxial cable, the outer braiding of which is earthed, to connection C of the turret. The signal induced across L_1 , L_2 is tuned by the variable capacitors previously mentioned. R_2 and C_5 , together with the r.f. gain control VR_1 , provide cathode bias for this stage, variation of VR_1 taking the stage up to, but just short of, oscillation point. R_1 and C_4 are the screen decoupling components, whilst the anode is connected, via a short length of coaxial cable, to tag K of the turret. C_6 decouples L_3 to chassis, the required h.t. potential being applied to tag J via R_3 .

For purposes of clarity it should be noted that only one set of coils is shown in the circuit diagram. The bandswitch $S_1(a), (b), (c), (d), (e), (f)$ associated with V_1 and V_2 are all contained as an integral part of the turret itself.

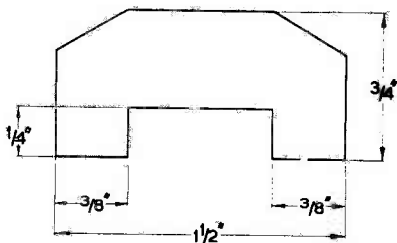


Fig. 2. Measurements of the valveholder screens

The amplified and tuned r.f. signal is now applied, via the tuned inductor L_4 , to the grid of the mixer section of V_2 (ECH81), L_4 being tuned by a further section of the 3-ganged variable capacitor $C_2(b)$ and the associated concentric trimmer C_7 .

1st Frequency Changer

The values of the various components in this circuit have been chosen in order that the stage will be operating under conditions which lead to excellent conversion without squegging.

The signal is applied to the grid of the ECH81 triode heptode and controls the electron stream. The stream is also restricted by the oscillator output injected into grid 3 (pin 7), this increasing and decreasing the overall g_m of the heptode in sympathy with the frequency of oscillation.

R_4 and C_8 isolate the screen grid (pin 1), the low r.f. impedance of C_8 retaining the grid virtually at earth potential.

The triode oscillator employs an inductively coupled tuned grid circuit, and is self biased by

R_8 , C_{13} . The cathode components R_7 and C_{11} do not, as is sometimes thought, provide fixed bias for the oscillator. The oscillator grid is returned to the upper end of R_7 and is not in any way affected by the potential difference existing across this resistor. The p.d. across R_7 provides bias for the heptode signal grid (pin 2), this being connected via L_4 to the h.t. negative line (chassis) and, therefore, to the lower end of R_7 .

The efficiency of a frequency changer cannot be conveyed by mutual conductance but is expressed in terms of conversion conductance (g_c) stated in mA/V (milliamps change of i.f. current per volt change of signal). The figure stated for the ECH81 is $775\mu A/V$, on the assumption that the oscillator input is at optimum level. Conversion conductance is partly dependent on the control ability of both oscillator and signal grids, therefore the oscillator input must be controlled if maximum g_c is to be obtained. This has been achieved here by careful selection of component values and component quality. Further, a regulated h.t. supply for the oscillator anode is provided from the voltage stabiliser (150C2) via R_9 .

The frequency stability of both the first frequency changer stage and that following (V_3) is due in considerable measure to the inclusion of a constant h.t. supply for both oscillator anodes. Variations in h.t. voltage can result in variations of the oscillator frequency which, in turn, vary the signal frequency which appears at i.f.

The oscillator grid is tuned by $C_{2(c)}$ and the trimmer C_{14} . A padder capacitor is shown (P) and this is an integral part of the turret.

The resultant 465 kc/s i.f. signal at the heptode anode of V_2 is fed from the secondary of IFT_1 into the grid of the following stage.

2nd Frequency Changer

The second frequency changer has a.g.c. applied to the signal grid via R_{10} decoupled by C_{15} . In this stage, the incoming 465 kc/s i.f. signal is converted to 85 kc/s, the oscillator grid being tuned by the fixed capacitor C_{23} and the concentric trimmer C_{22} . The inductances L_7 and L_8 are those of a normal 465 kc/s b.f.o., the capacitor values, together with the variation in frequency obtained by adjustment of the dust core, allowing oscillations to be maintained at a frequency of 380 kc/s (f_s , incoming signal, minus f_o , oscillator frequency = $465 - 380$ kc/s = 85 kc/s).

Provided a good layout and mechanical stability is achieved, the circuit will be found to be quite stable after the usual initial period of warming up. In practice, the writer has found the oscillator circuits to be extremely reliable. Although it is more normal in current practice to include a crystal controlled oscillator at the V_3 position, quality crystals are somewhat expensive items and the writer preferred to use the available cash in the purchase of a 100 kc/s crystal as a frequency standard.

L_8 is the feedback winding to the anode of the oscillator, this being supplied with a supply potential

from the stabilised h.t. line via R₁₄.

The 85 kc/s i.f. signal is now applied to the grid of the following stage by way of the 85 kc/s i.f. transformer IFT₂.

I.F. Stage

The i.f. stage is constructed around a further EF183 pentode and, with the high gain available, only one such stage is included. Although more than adequate gain is available from this design, there is no doubt that a further stage would provide still further selectivity, in which case the writer would prefer—in view of the gain then given—to attenuate this somewhat by mounting two i.f. transformers “back to back”, these being top coupled with a 5pF capacitor. Such an addition would be made between V₃ and V₄, the added stage being fitted with an i.f. gain control. In view of the physical layout employed, such an inclusion should be incorporated at the outset.

Since an S-meter is included, an i.f. gain control has not been employed, as this would unduly affect the operation of this tuning device. The writer has not found this omission to be a great disadvantage, gain being adequately controlled by both the r.f. and a.f. controls as required.

A.G.C. is not applied to either the r.f. or first frequency changer stages, as the writer preferred these to be uncontrolled in the interests of stability. It is applied to V₅ via R₁₆ and C₂₁.

Detector/A.G.C.

C₂₇ is connected to both the anode and the grid of the first half of V₆ (ECC82 double triode). This half of the valve is diode connected (i.e. the grid is strapped to the anode and these two electrodes then provide a diode anode) At all positions of S_{2(a)}, C₂₇ is connected to V_{6(a)} this diode providing a rectified negative delayed a.g.c. voltage to the main a.g.c. line via R₂₁.

The time constant of the a.g.c. system is arranged for a slow decay thus enabling satisfactory reception of both s.s.b. and c.w. signals without the necessity of including an a.g.c. on/off switch.

The circuit provides for both carrier and product detection dependent upon the position of S_{2(a)}, (b), (c), (d). This switch has been so wired that it acts, in position 1, as a standby switch. In this position, no output from the last i.f. transformer is provided for V_{6(b)} (the a.m. detector) and no h.t. voltage is applied either to this stage or to the product detector V₇. Additionally, no input is provided from the detector to the grid of the output stage. In this position, then, switch S₂ as a whole effectively cuts the h.t. potential to the a.m. detector, the product detector, and the signal inputs to the respective grids of both V_{6(b)} and V_{8(a)}. The receiver is, in consequence, effectively muted with respect to signals, whilst the valve heaters are still supplied with an a.c. voltage in order that these stages shall be ready for immediate operation when required.²

² When used with an amateur transmitter, it may be preferable for S_{2(c)} to break the main h.t. supply to V₁-V₅ inclusive.

In position 3, S_{2(a)} takes the output from IFT₃ and applies this to the grid of the product detector V₇ via a 20pF capacitor C₃₁, the grid being returned to chassis via R₂₇.

At S_{2(b)} the output from the product detector, via C₃₅, is taken to the grid of the first audio stage (V_{8(a)}). At S_{2(c)} h.t. is disconnected from the a.m. detector (V_{6(b)}) and, at S_{2(d)} h.t. is applied to the product detector and its associated oscillator. In this manner, it will be noted that the a.g.c. voltage from V_{6(a)} is still operative whilst the detector portion of this valve is inoperative.

The resistor R₂₂ of V_{6(a)} is the a.g.c. diode load and the capacitor C_t the time constant component, this controlling the rate at which a change of a.g.c. bias can become effective. The delay is controlled by the fixed potential divider R₂₀ and R₂₃, the voltage drop across R₂₃ appearing as a positive voltage on the diode cathode. The diode will not then pass current until the signal input to V_{6(a)} exceeds the positive bias. This prevents the operation of a.g.c. when receiving weak signals. The slow decay of the a.g.c. system allows satisfactory reception of both c.w. and s.s.b. signals and makes S-meter readings of these rapidly varying signals an easy matter.

The a.g.c. take-off is via R₂₁, the controlled stages being V₃ and V₄, the resistor/capacitor filters R₁₀, C₁₅ and R₁₆, C₂₁ providing decoupling.

In position 2, the switch at S_{2(a)} applies the output from IFT₃ to the grid of V_{6(b)}, whereupon the latter stage operates as an infinite impedance detector. The great advantage of this type of detector is that it has very little damping effect on the secondary winding of the last i.f. transformer. S_{2(c)} applies h.t. to the anode of V_{6(b)} in position 2.

At S_{2(b)} the a.f. output from the detector cathode is fed through the r.f. filter components C₄₂, R₃₅ and C₄₃ and, via C₄₄, to the volume control VR₂ and thence to the grid of V_{8(a)}.

Product Detector and B.F.O.

The combined product detector and b.f.o. are contained within a single envelope (V₇) and this is an advantage over the more normal method of utilising a separate b.f.o. valve plus a double-triode as the product detector.

The values of the capacitors C₃₇, C₃₈ have been so calculated that the effective tap in L₉ is roughly 10% from one end. The total tuning capacitance across the winding (C₃₇, C₃₈, C₃₉) is such that the specified coil will oscillate at 85 kc/s, plus or minus the required variation given by the iron dust core and the variable capacitor C₃₉ (b.f.o. pitch control).

When in use, oscillations derived from the b.f.o. circuit (triode portion of the valve) are fed, via C₃₄, to the product detector section of the valve, thus enabling s.s.b. (single side band) signals to become intelligible at the correct setting of the pitch control C₃₉. The b.f.o. also, of course, enables c.w. signals to be read.

It will be seen from the circuit that both the outputs from V_{6(b)} (a.m. detector) and V_{7(a)} (product detector) are fed through the r.f. filter network

(after $S_{2(b)}$) to the volume control, VR_2 .

In order to prevent instability and induced hum, the connection from the slider of VR_2 to the grid of the first audio stage ($V_{8(a)}$) is screened.

1st Audio and Output Stage

The a.m. detector ($V_{6(b)}$) provides no a.f. amplification. The task of the first audio stage ($V_{8(a)}$) is, therefore, that of a voltage amplifier to provide an adequate signal for the power output stage, $V_{8(b)}$. The basic requirements of an audio stage (as distinct from a power output stage) are freedom from amplitude and frequency distortion and the provision of adequate gain. The former is commonly caused by valve overload originating from the input voltage running into grid current or non-linear conditions, whilst the latter distortion emanates from shortcomings in the coupling circuit. Adequate gain usually presents no problems. In the circuit shown, component values have been chosen which provide the required audio gain free from distortion. $V_{8(a)}$ is RC coupled to the output stage, $V_{8(b)}$.

The requirement of $V_{8(b)}$ is that it should deliver power to actuate the speaker (or phones) as distinct from a voltage output—as is the case with $V_{8(a)}$.

The audio output from the pentode section appears across the output transformer T_1 and is then applied to the speaker. Output to the headphones socket is via C_{46} , insertion of the plug into this socket automatically muting the speaker. The output transformer T_1 is correctly matched to the pentode section. The headphone output could alternatively, of course, be coupled into the anode circuit of $V_{8(a)}$, in which case a speaker muting switch arrangement would be required. When using the headphones, the audio gain control (VR_2) should, of course, be used with due care. Some 2.5 watts of power output is available at full gain from $V_{8(b)}$, and this is more than adequate for the average shack or workshop.

The a.f. coupling capacitor C_{44} has a value (0.005 μ F) which provides a measure of bass cut. This counteracts to some extent the accentuated low frequency response resulting from the high i.f. selectivity. The value of C_{44} may be changed, if desired, to suit individual preferences.

Power Stage

The power supply stage is conventional and conforms to standard practice with reference to present-day receiver design. Isolation from the a.c. mains supply is given by the mains transformer T_2 .

The a.c. is converted to pulsating d.c. by the full-wave rectifier V_9 (EZ80). This pulsating potential is then smoothed by the capacitor input filter given by C_{50} , C_{51} and the l.f. choke L_{11} .

It will be noted that the rectifier has its own heater winding and that the remainder of the valves in the circuit are fed from a further winding which is adequately rated to supply the required current. All heater leads are composed of a twisted pair of wires and an earthed heater return (i.e. by way of chassis) must not be used. The two ceramic capacitors C_{52} , C_{53} prevent the appearance of r.f. voltages on the heater wiring.

The double-pole-single-throw switch S_4 (on/off) ensures that the mains supply is completely disconnected when the receiver is switched off. A 1A fuse is inserted in the live mains lead as an overload protection device.

Voltage Stabiliser

The voltage stabiliser V_{10} (15OC2) maintains the h.t. voltage supplied to both the oscillators of V_2 , V_3 and, also, the crystal calibrator stage, V_{11} , at a near constant value regardless of variations in mains supply or load current. The voltage drop across the 15OC2 is nearly constant over a fairly wide current range, the tube being connected in series with the limiting resistor R_{41} , and the load being connected in parallel with the regulator tube. The value of R_{41} is that which causes slightly less than the maximum allowable tube current to be passed when there is no load current.

Crystal Calibrator

The crystal calibrator stage V_{11} is constructed around an EF80 r.f. pentode. An on/off switch S_5 is included in the stabilised h.t. supply to this stage and the switch is panel mounted. The concentric trimmer C_{58} allows some adjustment of the 100 kc/s fundamental in order that alignment may be made against WWV, MSF, etc. The output is connected to the aeri. input via C_{55} . Oscillations will be apparent up to, and exceeding, 30 Mc/s.

Q Multiplier

Here, one half of an ECC83 is used as the 85 kc/s Q multiplier, and high selectivity is obtained due to Q multiplication derived from the positive feedback employed. A tuned circuit having a multiplication factor of some 20 to 40 applied will result in a Q factor as high as a good crystal filter and this has been achieved in the circuit shown.

Off resonance, the impedance of the tuned circuit shown (C_{60} , C_{61} , C_{63} , L_{10}) is low and therefore attenuates i.f. signals. The opposite effect, however, takes place when the circuit is at resonance. By virtue of the very high impedance achieved when resonant, a highly peaked i.f. response results.

The actual resonant frequency of the tuned circuit effectively determines the position of the peak within the i.f. passband and, after initial adjustments to the circuit, this position is controlled by the operation of C_{63} , which is brought out to the front panel as, also, is the on/off switch S_3 .

The oscillator circuit of V_4 has its positive feedback controlled by the variable resistor VR_4 in the cathode line. The pot cored inductor L_{10} is connected in a Colpitts circuit between grid and anode with an earthed tap at the junction of the two capacitors C_{60} , C_{61} , the coupling capacitor C_{59} being connected to the anode of V_3 .

The additional components required in providing the more usual notch or reject positions have not been included here, for in practice the writer has found that by the time the correct reject position has been found, the offending signal has usually vanished. Those who require this latter facility,

however, could quite easily incorporate S_3 with VR_4 and, in the position formerly occupied by S_3 on the panel, fit the necessary yaxley switch providing the peak and reject positions. A suitable circuit for this is provided, by the manufacturer, with the inductor L_{10} .

The cathode, grid and anode of the unused half of V_4 are strapped together and connected to chassis.

S-Meter

A positive reference voltage for the S-meter circuit is taken from the cathode resistor of the output valve $V_{6(b)}$ via the potentiometer VR_3 . This voltage should be approximately 2, this being equal

to the cathode voltage of V_5 under no-signal conditions. VR_3 should therefore be suitably adjusted and, once set, no further alteration should be required. The S-meter should now read zero. Signals of sufficient amplitude to overcome the fixed a.g.c. voltage on $V_{6(a)}$ will cause a reduction in the voltage on the cathode of V_5 and thereby cause the S-meter to give an indication of signal strength. It was not found necessary to place a balancing potentiometer across the meter. The resistor R_m (47Ω with the meter employed in the prototype) is of correct value to give full-scale deflection with S_9 signals. Meters having differing internal resistances may require alternative values in R_m .

(To be continued)

An introduction to . . .

COLOUR TELEVISION

By J. R. DAVIES

PART 6

IN THE LAST ARTICLE IN THIS SERIES WE DEALT with the X and Z demodulator system employed in the R.C.A. CTC11 receiver, examining also the reference frequency oscillator and its synchronising circuits, and the colour killer. We shall now carry on to the cathode ray tube which provides the colour picture at the receiver.

Colour Presentation Devices

A number of presentation devices for reproducing the colour television picture at the receiver have been proposed, and some of these have been the subject of considerable development work. So far as domestic colour receivers are concerned, however, only one device has stood the test of successful commercial production. This is the three-gun shadow-mask cathode ray tube introduced by R.C.A. The three-gun shadow-mask tube has been employed in all American domestic colour receivers since the inception of the N.T.S.C. system, and is similarly employed in domestic colour receivers manufactured in Japan. We shall here, therefore, devote our attention to this presentation device only.

A current shadow-mask tube (at the time of writing) is the R.C.A. 21 inch colour picture tube type 21FJP22, and we shall refer to this type

whenever it is necessary to quote a particular example of construction or operation.¹

Shadow-Mask Operating Principle

It is the function of a colour picture tube to reproduce, as a coloured image, the luminance and chrominance information which is available from the associated receiver. The shadow-mask tube has three electron guns instead of the single gun which is used in a conventional monochrome tube; and these guns are identified by the colours to which they correspond, whereupon we refer to the red gun, the green gun and the blue gun. The three guns are aimed down the neck of the colour picture tube in the manner shown in Fig. 27. The beams from the guns do not, however, travel unimpeded to the phosphors on the screen. They have, first, to pass through the perforated shadow-mask.

In Fig. 28 we see what occurs at a single aperture in the shadow-mask. Because of the spacing between the guns, the three beams arrive at the aperture from different directions. In consequence, after they have passed through the aperture the

¹ Acknowledgments are due to R.C.A. Great Britain Ltd., who have made available to the author technical information on the 21FJP22 colour picture tube, as well as circuit details for receivers in the CTC11 series.

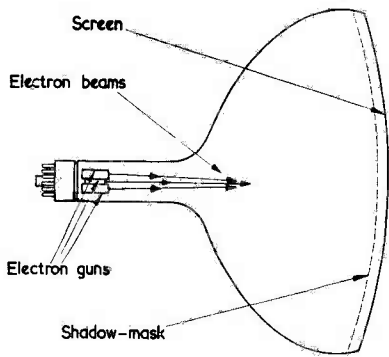


Fig. 27. In the three-gun shadow-mask tube, three electron guns are fitted at the base end of the neck

beams diverge again, whereupon they carry on to strike the screen at three different points. At each of these points is a phosphor "dot", i.e. a small circular area of phosphor, and each phosphor dot provides one of the three primary colours of the system. The result is that the electron beam from the red gun falls on to a red phosphor dot, the electron beam from the green gun falls on to a green phosphor dot, and the electron beam from the blue gun falls on to a blue phosphor dot.

In a 21in colour picture tube the shadow-mask has more than 300,000 apertures, and each of these corresponds to a trio of three phosphor dots on the screen, as in Fig. 28. In consequence, whatever the position of the electron beams inside the tube (whilst they are deflected to produce a picture) the shadow-mask perforations always cause the red beam to fall on red phosphor dots, the blue beam to fall on blue phosphor dots, and the green beam to fall on green phosphor dots.² If the blue and green guns of the tube were cut off and the red gun was allowed to emit an electron beam on its own, only the red phosphors would be activated and the reproduced raster would be wholly red. Similarly, only the blue phosphors would be activated if the blue gun emitted an electron beam on its own, and only the green phosphors would be activated if the green gun emitted an electron beam on its own. If both the red and blue guns emitted a beam there would be a magenta raster on the screen. This is because

² This assumes correct operating conditions, as we shall see shortly.

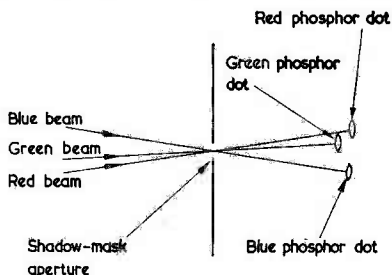


Fig. 28. When the three beams pass through an aperture in the shadow-mask, they carry on to strike different colour phosphor dots

additive mixing of red and blue produces magenta. If the green gun were then allowed to emit an electron beam, there would be an overall white raster, because white is produced by additive mixing of the three primary colours.

It should be noted that the additive mixing effect given by the phosphor dots is not exactly the same as occurs when light beams of different colours are projected on to a common area on a screen. In the colour picture tube, the primary colours appear as separate discrete circles in each trio of phosphor dots. However, the phosphor dots are so small and close together that—so far as the eye is concerned—they merge together, offering the same impression of additive mixing as is given when coloured lights are projected on to a screen. Fig. 29 shows a small group of phosphor dots, and illustrates their close spacing. An idea of the small size of the dots may be gathered from the fact that, in the 21FJP22 tube, the spacing between centres of adjacent trios is only some 0.029in.

We have just noted that, in the three-gun tube, we may obtain an overall magenta raster by mixing red and blue, and an overall white raster by mixing

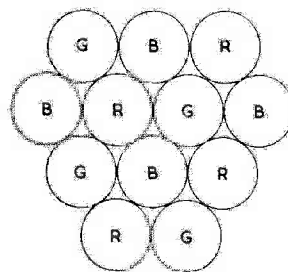


Fig. 29. A small group of colour phosphor dots

red, blue and green. It follows that we may obtain any other colour capable of being resolved by the N.T.S.C. primary colours by simply regulating the beam intensity of each gun as required. When a detailed colour picture is being reproduced the beam from each gun will be modulated by the luminance and chrominance signals fed to it, and each part of the scene will, in consequence, be depicted with the colour such signals ascribe to it.

Although the principle of operation of the three-gun shadow-mask tube is, basically, that which has just been described, a number of additional components and setting up operations are necessary if successful functioning is to be achieved in practice. We shall return to these after we have examined the construction of the tube.

Three-Gun Tube Construction

The external appearance of a modern three-gun shadow-mask colour tube is largely similar to that of a normal monochrome tube with a 70° deflection angle and a circular screen. Fig. 30 illustrates the more important dimensions of the 21FJP22, and it will be seen that this is capable of reproducing a picture measuring 15½in high by 19¼in wide with

rounded sides. The tube must be oriented in the receiver such that the pad with the V-groove is uppermost. This orientation causes the blue gun to be uppermost, with the red and green guns displaced by 120° .³ An integral protective window is fitted to the front of the tube, and is secured in place with a transparent plastics resin. As with monochrome tubes, an outside conductive coating is applied to the bulb. When this coating is connected to chassis, the resultant capacitance to the *ultor* provides a reservoir capacitor for the e.h.t. supply. (The "*ultor*" corresponds to the "final anode" in British terminology.) In the 21FJP22, the capacitance between external coating and *ultor* is 2,000pF to 2,500pF.

The neck of the three-gun tube has an outside diameter of 2in, this being a considerably larger dimension than occurs with monochrome cathode ray tubes. Because of the wide diameter, greater power is required in the deflector coils to provide the requisite magnetic field strength inside the neck.⁴ The relatively wide neck is needed to accommodate the three guns. Because of the wide neck, there is much less risk of corner shadow,⁵ and there is no necessity for the deflector coils to be mounted close up against the flare, as is common with monochrome tubes. The associated deflector coils are, in fact, so mounted that their position along the tube neck may be varied, and this provides one of the adjustments employed in setting up the tube in its receiver.

Fig. 30 also shows the positions of the *radial-converging pole pieces* and the *lateral-converging pole pieces* inside the neck. The function of these pole pieces will be discussed shortly.

The 21FJP22 differs from earlier three-gun shadow-mask tubes in that the *ultor* consists, electrically, of a single element. In earlier tubes the *ultor* was divided into two sections coupled together by a $56k\Omega$ resistor. One section of the *ultor* appeared at the screen end, and provided the e.h.t. reservoir capacitance with the external conductive coating. This section was coupled directly to the e.h.t. supply of the receiver. The section of the *ultor* isolated by the $56k\Omega$ resistor appeared at the end remote from the screen. The result of this arrangement was that the $56k\Omega$ resistor prevented excessive current flow and damage in the event of a momentary internal arc between the *ultor* and any other electrodes. With the 21FJP22 it is recommended that the *ultor* supply (and the focusing electrode supply) be of a limited-energy type in order to prevent damage due to momentary internal arcs.

In common with earlier tubes, the 21FJP22 is aluminised, and no ion trap is employed.

The construction of a single gun is shown, in simplified form to illustrate the order in which the

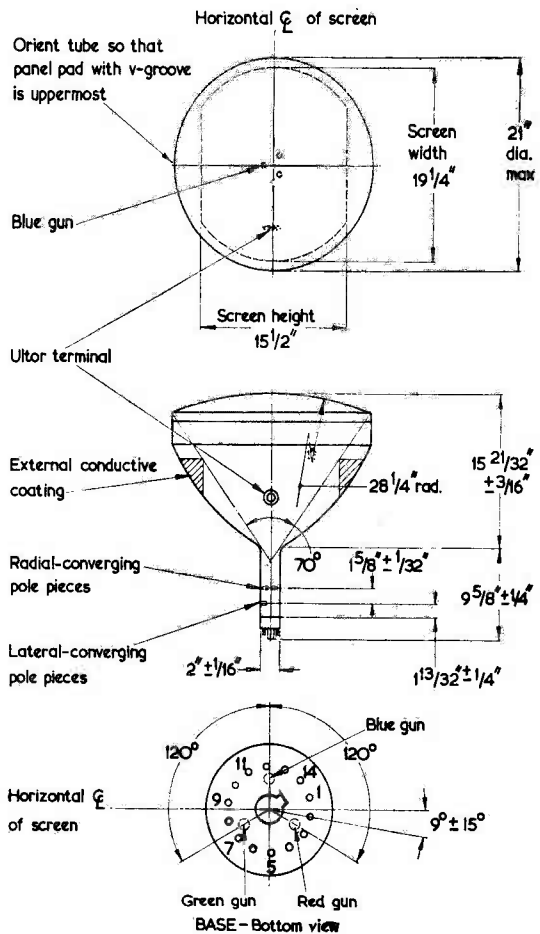


Fig. 30. Some of the more important dimensions of the 21FJP22 colour tube. (Courtesy R.C.A. Great Britain Ltd.)

electrodes appear, in Fig. 31. In this diagram we have the cathode and G_1 . The cathode and G_1 are employed for beam modulation in the same manner as in a monochrome tube. The next electrode is G_2 , and this functions as an accelerating electrode. G_3 is an electrostatic focus electrode. No magnetic focusing is employed with a colour tube, all focusing being controlled by the potential on G_3 . G_4 is the *ultor*, and this receives the full e.h.t. voltage. These electrodes are connected into circuit in the typical manner illustrated in Fig. 32, which corresponds to the circuit arrangement employed in the R.C.A. CTC11 receiver. The cathodes receive the luminance signal and, in the CTC11 receiver, have a potential above chassis of 310 to 315 volts. The first grids are coupled to the R-Y, B-Y and G-Y outputs (see Fig. 19 (b), published last month) and have a potential of 200 volts above chassis. The second grids are connected to three potentiometers coupled between a 386 volt h.t. supply point and the boosted h.t. line. In the CTC11 receiver these potentiometers

³ This orientation also takes advantage of the correction built into the tube for the vertical component of the earth's magnetic field in the northern hemisphere.

⁴ The high e.h.t. voltage applied to the three-gun tube also necessitates a greater power in the deflector coils than would be needed by a monochrome tube.

⁵ Caused by electrons striking the glass of the tube whilst passing through or immediately after leaving the deflecting field.

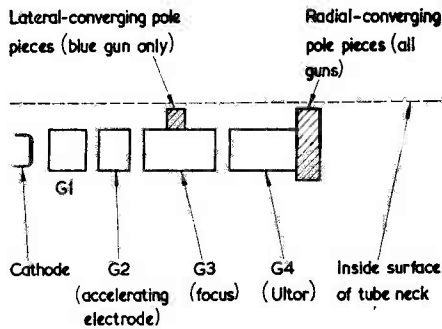


Fig. 31. A simplified diagram, illustrating the order in which the electrodes in each gun appear

meters may offer a potential of 720 volts for the red G_2 , a potential of 680 volts for the green G_2 , and a potential of 630 volts for the blue G_2 . The varying potentials on the second grids of the tube are necessary in order to compensate for differing G_1 cut-off voltages, drive requirements, and other factors. The focusing electrodes, G_3 , are all connected together and are applied to a common focus control which varies their potential above chassis. With the 21FJP22, the focusing potential may range, typically, from 3,360 to 4,000 volts for an ultor voltage of 20kV, and from 1,200 to 5,000 volts for an ultor voltage of 25kV. The fourth grid in each gun is the ultor and, as we have seen, this connects to the e.h.t. supply.

Fig. 32 does not illustrate the arrangements employed for brightness control. In the CTC11 receiver, brightness is controlled by varying the grid bias applied to the second video amplifier valve. The anode of this valve is d.c. coupled to the cathodes of the tube, with the result that varying bias voltages on its grid alter the d.c. potential on

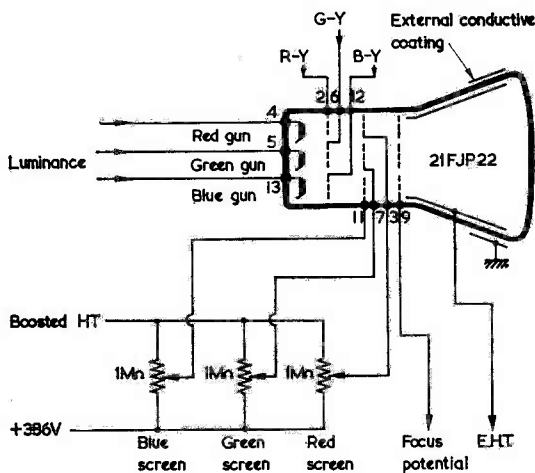


Fig. 32. The manner in which the 21FJP22 tube is connected up in the R.C.A. CTC11 receiver. The tube heaters are brought out at pins 1 and 14, and heater requirements are 6.3V at 1.8A. (Courtesy R.C.A. Great Britain Ltd.)

the tube cathodes and, hence, provide a control of brightness.

Convergence

In Fig. 28 we saw that, by reason of the shadow-mask principle, it is possible for the beam from the red gun to strike the red phosphors, the beam from the blue gun to strike the blue phosphors, and the beam from the green gun to strike the green phosphors. The guns are, of course, mounted near the base of the tube, whereupon the beams they emit travel down the tube neck and pass through the field provided by the deflector coils. The latter then deflect the beams in order that they may follow the scanning pattern needed for the reproduction of a television picture. Since the sources of the three beams are spaced apart from each other they will not, unless some means of external influence is applied, arrive at the screen at the same point.

The ideal condition for colour reproduction is provided when, throughout the raster, all three beams *converge* at a single point on the shadow-mask, as illustrated in Fig. 33. The three beams will

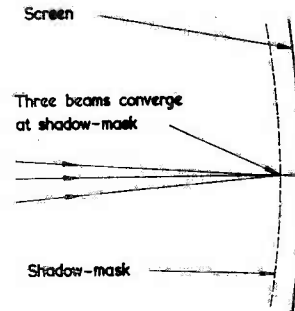


Fig. 33. An example of correct convergence

then pass through identical shadow-mask apertures to excite the appropriately coloured phosphor dots on the screen itself.

In order to provide acceptable *convergence* the three beams are subjected to an adjustable amount of magnetic deflection within the guns themselves. This deflection is provided by way of the radial-converging pole pieces and the lateral-converging pole pieces which, as we saw in Figs. 30 and 31, are mounted inside the neck on the gun assemblies. The magnetic field is provided by fitting magnets outside the tube neck which couple, through the glass of the tube, to the pole pieces inside.

Fig. 34 (a) illustrates, in simplified form, the elements of a *radial-convergence yoke* mounted on the neck of the tube so that it couples to the internal radial-converging pole pieces. The yoke employs three adjustable permanent magnets which may vary both the intensity and direction of the magnetic field given between the internal pole pieces which straddle the beams. In consequence, they may shift the corresponding beams in the manner illustrated in Fig. 34 (b), the direction of shift (as with all magnetic deflecting systems) being at right angles to the lines of magnetic force.

The red and green beams may be shifted diagonally but, because the blue gun is uppermost, the blue beam may only be shifted up or down. This amount of control is inadequate and a further deflecting control is applied to the lateral-converging pole pieces on the blue gun by way of a second magnet assembly. This second assembly is fitted to the tube neck in the same manner as an ion trap magnet, and its purpose is to primarily apply a magnetic field to the blue electron beam in the manner shown in Fig. 34 (c). Because the lines of force about the blue beam are vertical, the magnet assembly causes this beam to be deflected from side to side, or *laterally*. However, some of the lines of force from the magnet assembly pass through the green and red guns as well, whereupon adjustment of the permanent magnet causes lateral (or nearly lateral) deflection here also. The design of the magnet assembly is such that the green and red beams suffer lateral deflection in the opposite direction to the blue beam. Also, the amount of deflection they suffer is smaller. The overall beam shift directions which are now given are shown in Fig. 34 (d).

It is possible, by adjusting the three radial-convergence magnets and the lateral-convergence magnet, to cause the red, green and blue beams to converge at the centre of the screen. This process is known as *static convergence*, because the deflecting forces which provide the convergence remain static throughout the line and field cycles.

Static convergence adjustments do not enable satisfactory convergence to occur other than at the centre of the screen. The reason for this is that the radius of the shadow-mask is longer than the distance from the centre of the shadow-mask to the deflection centres for the beams.⁶ Fig. 35 shows that, after static convergence adjustments have been made, the three beams converge correctly at the

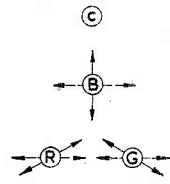
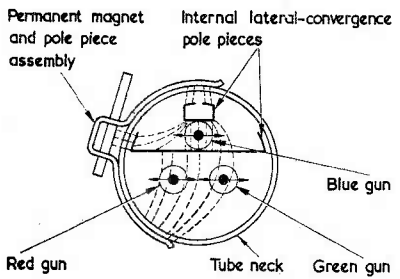
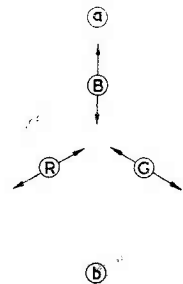
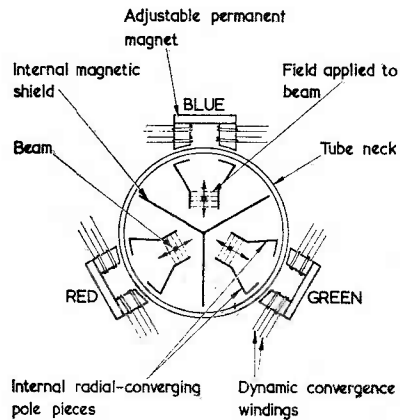


Fig. 34 (a). To obtain static convergence, external magnets are coupled to the internal radial-convergence pole pieces mounted on each gun. The "adjustable permanent magnets" shown here would, in a practical assembly, be capable of rotation, whereupon they could change the intensity and direction of the field in each internal set of pole pieces. Dynamic convergence correcting currents are applied to the windings on the magnet assemblies
 (b). The directions in which the three beams may be shifted by the radial-convergence magnets
 (c). The lateral-convergence assembly causes the blue beam to be shifted to right or left.
 (d). The directions in which the beams may be shifted whilst employing both radial-convergence and lateral-convergence magnets. Lateral-convergence adjustments shift the red and green beams in the opposite direction, and to a lesser extent, than the blue beam

⁶ The deflection centre for an electron beam inside a cathode ray tube is the point at which it apparently changes direction after leaving the gun. It is situated roughly at the centre of the field given by the line and vertical deflector coils.

⁷ This assumption, whilst demonstrating the main reason for lack of convergence away from the centre of the screen, does not take into account the fact that the sources of the three beams are spaced apart from each other. Because of this, the convergence errors away from the centre of the screen are more complex in character than is shown in Fig. 35.

centre of the screen. Assuming that each suffers an equal degree of deflection, the beams will then converge *behind* the shadow-mask if they are deflected to either side of the central position. By the time they reach the shadow-mask, they will have become divergent again. In Fig. 35 it is assumed that the point of convergence maintains a constant distance from the deflection centres for all levels of horizontal and vertical deflection.⁷

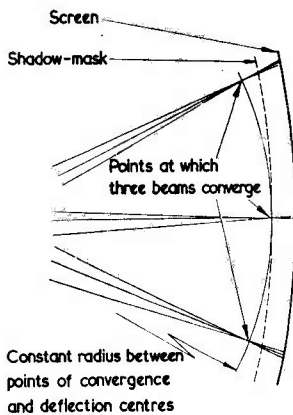


Fig. 35. Illustrating, in simplified form, the reason why convergence errors increase as the beam leaves the centre of the screen unless dynamic convergence circuits are employed

To overcome the lack of convergence which occurs when the beams are deflected away from the centre of the screen, a second set of convergence adjustments are required. These provide *dynamic convergence*, and they function by passing varying currents through windings fitted to the external radial-converging magnet pole pieces shown in Fig. 34 (a). The dynamic convergence correcting currents are obtained from the line and vertical timebases and they have a waveform similar to that shown in Fig. 36 (a). Each cycle of the convergence correcting current corresponds to one line cycle or one field cycle (according to whether it is derived from the line or vertical timebase), and the correcting current has a low value near the centre of the scan, where dynamic convergence is not needed. The correcting current then increases for beam deflections away from the centre of the screen, being at a maximum when the beams scan the edges of the picture. Thus, the dynamic convergence currents

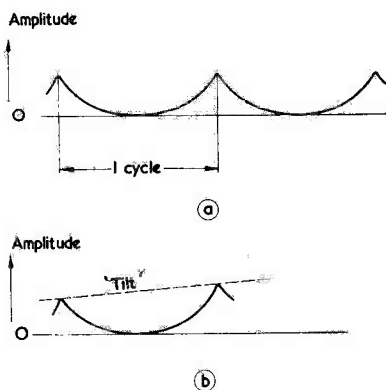


Fig. 36 (a). An example of a dynamic convergence correcting current
(b). To obtain an increased convergence current at one side of the picture, the correcting current may be "tilted", as shown here

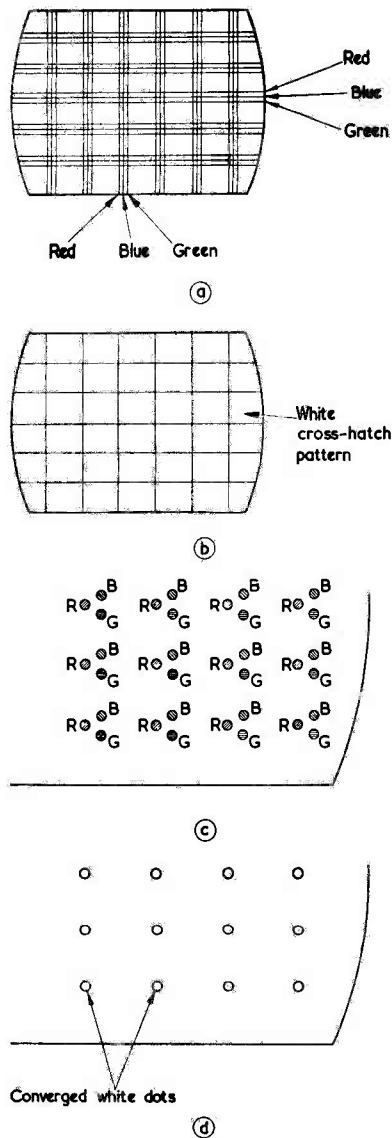


Fig. 37 (a). Cross-hatch display, illustrating a complete lack of convergence between the red, green and blue beams
(b). After convergence adjustments have been carried out, the three separate images become superimposed on each other, giving a white cross-hatch pattern. (In practice, convergence errors would more probably vary over different parts of the picture, and not as shown in the simple example of (a))
(c). A section of the screen, showing convergence errors when a white dot pattern generator is applied to the tube
(d). When convergence adjustments have been made, the three sets of dots become superimposed on each other, giving a white dot pattern

provide increasing correction as the beams move away from the centre of the screen and, from an examination of Fig. 35, this is the desired condition.

In some cases, more convergence correction is required on one side of the picture than on the other. Such correction may be provided by "tilting" the convergence waveform, as in Fig. 36 (b).

Normally, both vertical and horizontal convergence correcting currents are applied separately to the radial-convergence magnet pole pieces of Fig. 34 (a). These pole pieces then have two sets of coils for the separate currents. In some receivers, a dynamic convergence correcting current may also be applied to a coil on the lateral-convergence magnet assembly, although this technique does not appear to be common. The convergence currents are controlled in amplitude and tilt by a number of pre-set controls fitted to the receiver.

Convergence adjustments in a colour television receiver are normally carried out with the aid of a cross-hatch generator or a white dot generator. A cross-hatch generator causes a series of vertical and horizontal lines to appear on the screen, and a receiver with heavy convergence error could produce a picture like that shown in Fig. 37 (a). After convergence has been correctly carried out, the vertical and horizontal lines for each colour become superimposed on each other, giving an overall white cross-hatch pattern, as shown in Fig. 37 (b). A dot generator can cause a receiver with heavy convergence error to give a display like that of Fig. 37 (c). After convergence has been carried out, the red, blue and green dots become superimposed on each other, giving a pattern of white dots, as in Fig. 37 (d). It should be emphasised that these examples are only intended to show simple instances of lack of convergence. In practice, lack of convergence will more frequently appear over certain parts of the screen only.

Purity

In Fig. 38 we see a shadow-mask colour picture tube with all the external components fitted on its neck. These comprise the deflector coil assembly, the radial-convergence yoke, the lateral-convergence magnet, and the *purity magnet*, or *purifying magnet*. Up to now, we have discussed all these components with the exception of the purity magnet, and we shall now carry on to consider this magnet. In passing, it may be noted that the colour picture tube has no magnetic centring device, as is common with monochrome cathode ray tubes. Picture centring with colour receivers is carried out by passing direct currents of the requisite polarity and amplitude through the horizontal and vertical deflector coils.

When we discussed the basic operation of the colour television tube we showed (in Fig. 28) that the presence of the shadow-mask causes the electron beam from the red gun to excite the red phosphors, the electron beam from the green gun to strike the green phosphors and the electron beam from the blue gun to strike the blue phosphors. This process becomes feasible because the three electron beams reach the shadow-mask apertures from different directions.

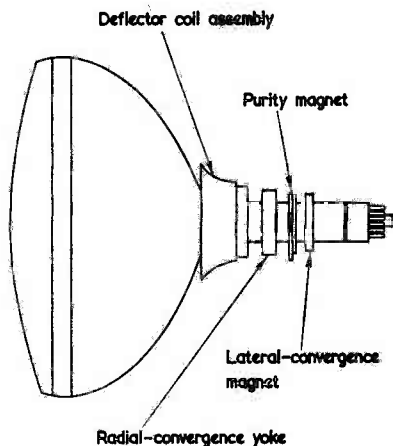


Fig. 38. The components which are fitted to the neck of the shadow-mask tube

Such a state of affairs represents operation under ideal conditions, however, and cannot exist in practice, because the three electron beams do not follow the exact paths dictated by the geometry of the tube. They become deflected due to local magnetic fields and, also, by the magnetic field of the earth. Further, component parts in individual tubes may have slight dimensional differences which cannot be taken up within acceptable tolerances.

All these factors can be corrected by the purity magnet. This offers a magnetic field across the tube neck of adjustable strength and direction, and it varies the effective positioning of the electron beam sources so that the beams arrive at the shadow-mask from the correct directions. The magnet consists normally of two flat rings, each of which is magnetised across a diameter. Both rings have a tab for adjustment, and it is possible to rotate one ring relative to the other, or both together. (See Fig. 39.) When the two tabs are alongside each other, the magnetic field of one ring is in opposition to that offered by the other, and the external magnetic field is at a minimum. If one ring only is rotated, the external magnetic field increases as the spacing between the tabs increases. As may be gathered, the assembly is capable of providing a magnetic field of any intensity within its limits, and in any direction.

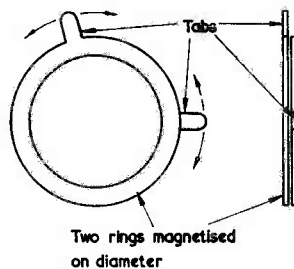


Fig. 39. The essentials of a purity magnet assembly. Either ring may be rotated relative to the other, or both rings may be rotated together

In order to adjust a colour picture tube for optimum purity⁸ it is usual to commence by disabling the green and blue guns by means of controls fitted to the receiver, or by cutting off the guns by applying a negative voltage (relative to the cathodes) to the G₁ electrodes. Purity adjustments are then carried out with the red electron beam only. Red beam current is normally higher than blue or green beam current, with the result that purity magnet adjustments for the red beam usually hold good for the green and blue beams as well.

With the red beam established, and with no signal input to the receiver, the purity magnet is adjusted for optimum red purity at and around the centre of the raster. The deflector coil assembly is then moved backward and forward along the neck of the tube until optimum red purity is offered over the whole of the screen. Adjusting the position of the deflector coil assembly causes the deflection centres for the three beams to be correspondingly shifted along the tube neck and it thereby alters the angle at which they strike the shadow-mask.

When optimum red purity has been achieved, the purity of the blue and green guns may be checked. If desired, all three guns can then be finally brought into operation, whereupon it should be possible to obtain a uniformly white raster. Shortcomings in purity for any colour should then become evident as *contamination* (the result of lack of purity) in sections of the white raster. If necessary, compromise purity settings may have to be employed in order to approach, as nearly as possible, optimum purity in each colour.

It has been common practice, especially in earlier receivers, to fit additional purity magnets around the cone of the shadow-mask tube. After the purity magnet on the tube neck and the deflector coil assembly has been set up, the magnets around the cone are then adjusted for optimum purity at the edges of the raster.

Degaussing

Because of the presence of strong magnetic fields, together with the magnetic field of the earth, it is possible for the metalwork in a shadow-mask tube and the receiver in which it is fitted to become magnetised. Such magnetisation may prevent adequate purity from being obtained.

This unwanted magnetisation may be removed by *degaussing*, or *demagnetising*, the tube and its surrounding metalwork, a process which is carried out with the aid of a *degaussing coil* connected to the a.c. mains supply. The coil is slowly moved about the tube and the receiver, with the result that the metalwork in and around the tube is subjected

⁸ "Purity" here defines the freedom from contamination, on the tube screen, of a colour by other colours. If, at all points on the raster, each electron beam excites only phosphor dots of its own colour, then purity is 100%.

to the alternating magnetic field it produces. After a short period the coil is slowly moved away from the receiver and tube so that the effect of its magnetic field becomes gradually reduced. When the coil is six feet or more away from the tube, the a.c. supply is switched off.

The requirements for a degaussing coil are not critical, and R.C.A. suggest, for connection to the American 117 volt a.c. mains, a coil consisting of 425 turns of No. 20 (21 s.w.g.) enamelled wire on a 12in diameter former about ½in wide. A coil of the same dimensions with approximately the same amp-turns should be suitable for use with British a.c. mains voltages.

A shadow-mask tube should be degaussed after its associated receiver has been moved from one location to another. The process may be carried out whilst the tube is in the receiver.

Setting Up Procedure

As may be imagined, the various purity and convergence adjustments on a shadow-mask tube tend to be interdependent. In consequence, it may be helpful to give a typical example of the various steps which may be required to set up a tube and receiver which are badly out of adjustment.

- (1) If the receiver has been moved, or as a precautionary measure, degauss the tube and chassis.
- (2) Set up focus.
- (3) Set up vertical and horizontal deflection controls.
- (4) Apply a cross-hatch or dot generator to the tube guns, adjusting this so that each colour is of approximately the same intensity. Adjust the static convergence magnets for convergence at the centre of the screen.
- (5) Adjust the purity magnet and deflector coil position for optimum red purity.
- (6) Check green and blue purity. If necessary, reach a compromise for best red, green and blue purity. Note: centre convergence should be checked before and after each purity adjustment.
- (7) Centre the raster.
- (8) Re-check static convergence and readjust if necessary.
- (9) Carry out dynamic convergence as detailed in receiver service manual.
- (10) Re-check red, green and blue purity, re-adjusting, if necessary, the purity magnet and the deflector coil position.

It should be pointed out that the above setting up procedure is typical only, and may vary for different conditions or different receivers. When setting up is required it may, in many instances, be necessary to make small adjustments for purity only.

(To be continued)

NEXT MONTH . . .

MODERN 3 + 1 T.R.F. RECEIVER



By RECORDER

IN THE PAST WE HAVE DEFINED ranges of time as "ages", where-upon we refer to the Stone Age, the Bronze Age, the Iron Age, and so forth. This being so, what age label, bearing in mind the fantastic onrush of invention and development which has marked the past five decades, can we tie to our present times? The difficulty of finding a suitable term is illustrated by the fact that, during the latter half of the nineteenth century, most people would have plumped quite happily for the Steam Age; but this does not, obviously, apply any more.

What is required is an epithet which implies causation, in that it defines the major qualifying influence on man's progress within the period covered. I would tentatively suggest that the most suitable description is the Computer Age. At the moment we are just entering the Computer Age, and the computing machines which we employ are large, complex and expensive. Even so, we have already seen a transition from valve to transistor operation, with a consequent lowering of bulk and power requirements. Also, computer development continues unabated, with the result that computers are capable of doing more and more with less supervision, simpler programming, and at higher speeds.

Analogue and Digital Computers

In 1920, Karel Capek invented the term "robot" in his play "R.U.R.", and the vision his work presented of mankind subject to the rule of the machine has captured the imagination of writers ever since. The fear of subordination to the machine is also reflected in the reaction, by some factory workers, to the word "automation". There is the fear that

jobs may be lost as positions on the production line are taken over by mechanical devices which are controlled by computers. In this respect, it would be foolish to deny that replacement of man by the machine has not already been in course for many years. Again, computers enter the field of executive decision, and can provide an answer to a problem having many variables much more quickly and with greater accuracy than a human being. As an example of this application, computers are currently employed for the training of military personnel by the use of "war games", wherein different sets of battle situations are presented to the participant for action. It is possible, indeed, for a whole factory to be run by a computer, with virtually no human intervention at all.

Nevertheless, the computer is a docile machine, and it only does what it has been told to do. Also, it has to be set up, or programmed, which means that it has no greater acumen than is imparted to it by its designer and by the programme. (It should be added, though, that some modern computers are capable of "learning", in that the experience gained from handling earlier work can be applied to the solution of later problems.)

There are two basic types of computer: the analogue computer and the digital computer. The analogue computer does not deal with figures as such but with quantities, and it can provide a solution to complex equations by replacing each function by an analogous electrical circuit. Serviceman Smithy's simple little multiplying device which appeared recently¹ is, actually, an elementary analogue computer. It consisted of three potentiometers, a battery and a null-indicating meter, and it was capable of solving the equation $A \times B = C$. Analogue computers are very valuable in the design of high-speed aircraft and missiles, wherein certain component

parts are subjected to conditions which may only be expressed in terms of complex equations. If an analogue computer is set up to the appropriate equation, the results of changing any number of the variables may be assessed immediately. The analogue computer consequently saves the time involved in human calculation. If all the sets of conditions presented to the computer had to be worked out by normal methods, the work could occupy weeks, months, or even years.

The digital computer, on the other hand, deals with numbers. Discrete numbers are fed into the machine, and it is told to add them, subtract them, multiply them, and so on. If the solution of one part of a problem is required at a later stage it can be fed into a store, or "memory", from whence it may be extracted when needed. The digital computer may also work with information which has been stored on magnetic tape in the form of numbers and instructions. Practically all the very large computer installations one reads about, and particularly those which are employed for payroll calculation and the like, are digital computers.

The Binary System

If a digital computer has to work with numbers, it is necessary for these to be translated into electrical signals. In normal arithmetic we use the decimal scale, in which we have the numbers 0 to 9, the number following 9 being 10. In the decimal system, 10^2 is 100, 10^3 is 1,000, 10^4 is 10,000, 10^5 is 100,000, and so on. Also 10^1 is 10, and 10^0 is 1. So that the number 111,111 is really the sum of 10^5 , 10^4 , 10^3 , 10^2 , 10^1 and 10^0 .

If we try to employ the decimal system in a digital computer, we run into snags. A conceivable way of handling decimal numbers in a computer would consist of using signals having varying magnitudes between 0 and 9. Thus, if a transistor in the computer passed zero current, this could correspond to 0. A current of 1mA would correspond to 1, 2mA

¹ "In Your Workshop", March 1963.

to 2, 3mA to 3, and so on, up to 9mA corresponding to 9. However, transistors have spreads in their characteristics, and it would be well-nigh impossible to control their operation in practice so that they passed exactly the number of milliamps which corresponded to any particular number from 0 to 9.2

To overcome this problem, digital computers use the binary system of numbers. With the binary system there are only two numbers, these being 0 and 1. The 0 in binary is the same as the 0 in the decimal system. Similarly, binary 1 is the same as the decimal 1. There is, however, no 2 in the binary system, and this figure is shown as 10. Decimal 3 becomes 11 in binary, and decimal 4 becomes 100. Despite the very small quantity of numbers it uses, the binary system is quite easy to understand because it obeys the same basic rules as the decimal system. The highest single integer³ in decimal is 9, with the result that, if we add 1, we proceed to 10. With binary, the highest single integer is 1 so that, when we add 1, we similarly go to 10.

The binary system is exactly what is required for digital computers because it only has the two numbers 0 and 1. In consequence 0 can be represented by a device in one condition, and 1 by the same device in an opposite condition. Thus, 0 may be represented by a transistor which is cut off, and 1 by a transistor which is fully bottomed. Again, 0 may be represented by, say, a negative-going pulse and 1 by a positive-going pulse. If numbers have to be stored on a magnetic tape, they can be recorded such that 0 results in a magnetic field in one direction and 1 by a field in the opposite direction. Electronic effects can exist in one of two states (e.g. either "on" or "off", or either "positive" or "negative") and there is no risk of mistaking one for the other. As a result, electronic calculating circuits can handle binary numbers without error, since there is no ambiguity between the integers in the system.

Binary Calculations

In the decimal system the digit 1 infers a power of 10, as we have just seen. Almost the same applies to binary, the difference being that, in this case, the digit 1 applies to a power of 2. Thus the binary number

² It should be mentioned that a computer can operate in decimals by employing decade counting tubes. These are, however, too slow for high speed operation.

³ That is, a whole number, as opposed to a fraction.

11111 corresponds to $2^5+2^4+2^3+2^2+2^1+2^0$, which is $32+16+8+4+2+1$, or 63. The fact that binary numbers are made up in this manner enables any binary figure to be converted to decimal by adding up the 1's as powers of 2, and by ignoring the 0's. Thus 11010 in binary corresponds to $2^4+2^3+2^1$, which is equal to $16+8+2$ or 26. (See the accompanying Table which shows binary numbers up to 30).

TABLE

Decimal Number	Binary Number
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111
16	10000
17	10001
18	10010
19	10011
20	10100
21	10101
22	10110
23	10111
24	11000
25	11001
26	11010
27	11011
28	11100
29	11101
30	11110

It is just as simple to convert decimal to binary, this being done by repeatedly dividing the number by 2 and noting the remainders. Thus, to find the binary equivalent of 26 we carry out the following exercise:

$$\begin{array}{r} 2 \overline{)26} \\ 13-0 \\ 6-1 \\ 3-0 \\ 1-1 \\ 0-1 \end{array}$$

The remainders are then read upwards, giving us the binary number 11010.

Addition of binary numbers is quite an easy process, once one becomes used to the limited number of integers in the system. The thing to remember is that $1+1=10$. A typical binary addition is as follows:

$$\begin{array}{r} 1011 \\ 10010 \\ \hline 11101 \end{array}$$

The corresponding decimal sum is $11+18=29$.

Subtraction follows the basic decimal rules although "borrowing" tends, perhaps, to be a little confusing at the first attempt.

$$\begin{array}{r} 10100 \\ - 1101 \\ \hline 0111 \end{array}$$

In this example the right hand 1 in the lower line is subtracted, as with decimals, from the right hand 0 in the upper line. The result is 1, and 1 is "borrowed" from the next digit in the upper line. However, this is a 0 and so, in turn, it has to borrow a 1 from the next digit along. Third from the right on the lower line is 1, and this is now subtracted from what has become 0, to repeat the initial process once more. We carry out a similar "borrowing" procedure in decimal with figures such as these:

$$\begin{array}{r} 10100 \\ - 9909 \\ \hline 191 \end{array}$$

Incidentally, the decimal equivalent of the binary subtraction just given is $20-13=7$.

Multiplication in binary follows standard decimal rules, and all that one has to remember are the obvious facts that $0 \times 0=0$, $0 \times 1=0$, and $1 \times 1=1$. Thus to multiply 1101 (13) by 101 (5) we get:

$$\begin{array}{r} 1101 \\ \times 101 \\ \hline 1101 \\ 0000 \\ 1101 \\ \hline 100001 \end{array}$$

The result is equal to 65 in decimal.

Division similarly follows standard decimal rules, and we can show this by dividing the result of the last calculation by 101, or 5 in decimal. Thus:

$$\begin{array}{r} 1101 \\ 101 \overline{)100001} \\ \underline{101} \\ 110 \\ \underline{101} \\ 101 \\ \underline{101} \\ 000 \end{array}$$

The answer, as we would expect, is 1101, or 13 in decimal.

One Of Those Mysteries

It always seems to be assumed that the decimal system came into being because man had ten fingers

(including the thumbs, of course) to count on. If this is so, it seems logical that the circuits of a digital computer, which have no fingers and only two states (i.e. "on" or "off", etc.), should work with the binary system.

Numbers are fascinating things, and it is interesting to reflect that, but for the accident of evolution, we would not now have a numerical system in which $\frac{1}{3}$ appears as the inconvenient 0.3 recurring. Had we evolved with eight fingers we might

well have taken up an octal system of numbers, and had we evolved with twelve fingers we might have adopted a duodecimal system. Why Nature endowed us with ten fingers must, I presume, be just another of life's mysteries.

Non-Radiating Dummy Load

By S. G. Wood
G5UJ

THE R.F. OUTPUT OF A LOW POWER TRANSMITTER is often checked, or loaded, by an ordinary domestic lamp or a flash-lamp bulb. This does not always provide the best answer, however, and something more ambitious would seem to be indicated. The small unit described here has been successfully used by the writer for some time, and it provides an excellent dummy load.

As will be evident from the circuit shown in Fig. 1, there is nothing at all special about the unit, and the entire construction should not take long to complete since few components are required. The required matching conditions are achieved by connecting the appropriate dummy load resistor in series with the bulb, the load resistor consisting, in the writer's case, of ten 750Ω $\frac{1}{2}$ watt carbon resistors connected in parallel. These resistors are fitted around the periphery of two flat brass rings, as shown in Fig. 2, thereby allowing a resistive load of relatively low inductance to be obtained. The whole assembly takes up little space, and in fact its actual size is comparable with that of a 6V6 metal valve.

The lamp may be any m.e.s. type, the voltage not being as important as the current rating. A lamp that will light up appreciably when maximum r.f.

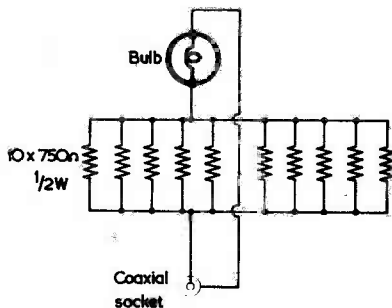


Fig. 1. Circuit of the dummy load

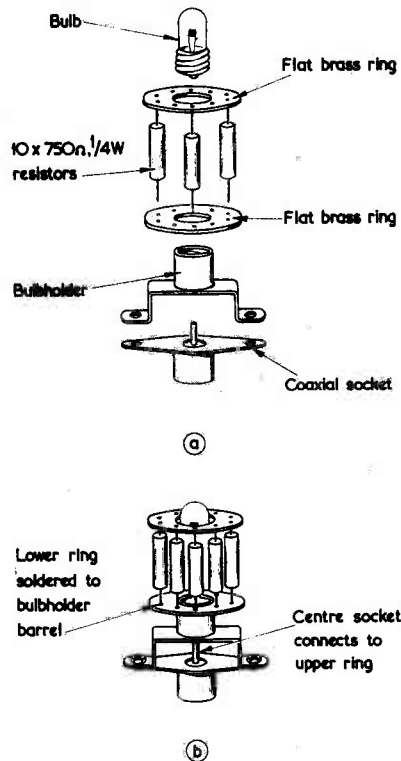


Fig. 2 (a). An exploded view
(b). The dummy load assembled

from the transmitter is provided would be suitable. The writer found that a 6.3 volt, 3 to 6 watt type functioned satisfactorily.

Although constructional details are given here, these need not be followed to the letter as there is plenty of scope for experiment with this piece of apparatus, which can be used to advantage in any progressive ham shack.

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continued on page 285

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continued from page 283

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continued on page 287

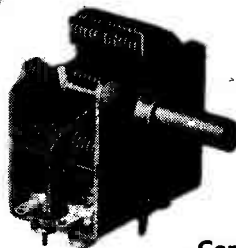
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continued from page 285

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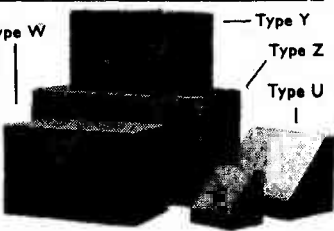
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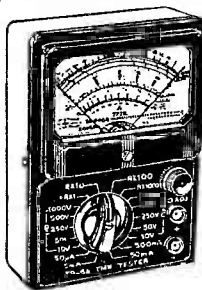
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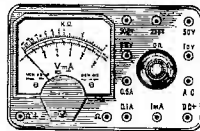
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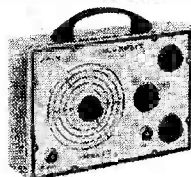
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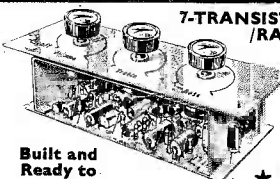
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Built and Ready to Use

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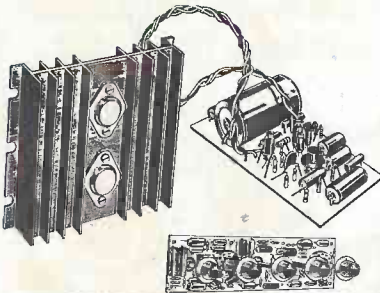
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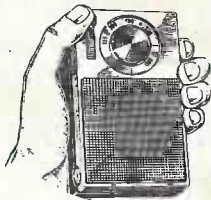


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