

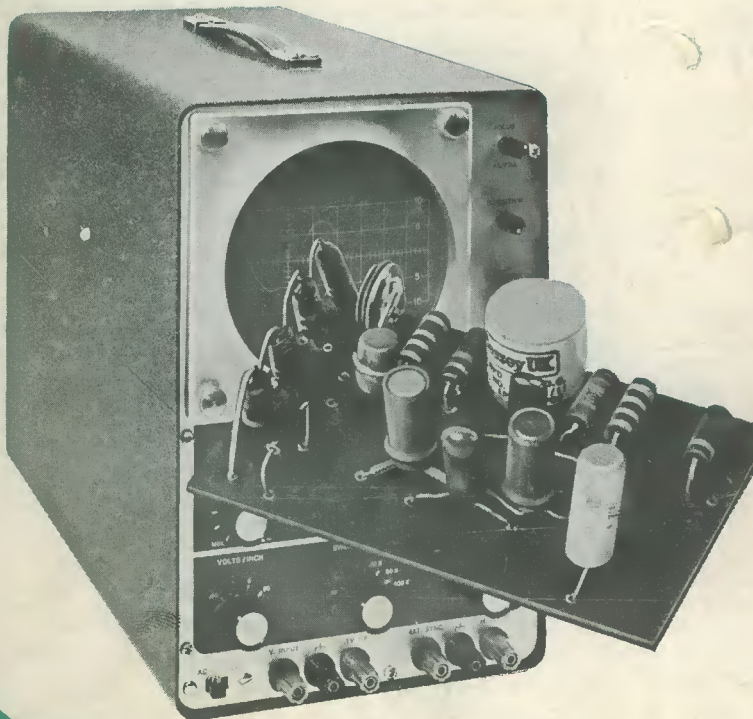
THE
RADIO CONSTRUCTOR

Vol. 21 No. 10

MAY 1968
3/-

A DATA PUBLICATION

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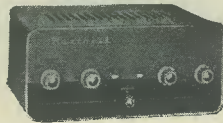
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**GARRARD
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SP-25**

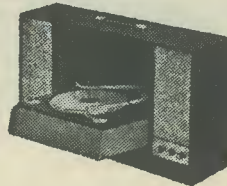


**S-33H
STEREO
AMP**

A basic system can consist of a suitable Record player unit such as the Garrard SP-25 with Deram cartridge, a Stereo Amplifier, Model S-33H and two SSU-1 Loudspeaker systems. Supplied as kits for a total cost of less than £60 FM Radio may be added at low cost at a later date. Our Technical Dept. will be pleased to advise on this or any other combination of Heathkit Hi-Fi Models.

LATEST! PORTABLE STEREO RECORD PLAYER, SRP-1

Kit £28.6.0 incl. P.T. p.p. 10/6
Ready-to-Use £35.4.0 incl. P.T. p.p. 10/6



Automatic playing of 16, 33, 45 and 78 rpm records. All transistor—cool instant operation. Dual LP/78 stylus. Plays mono or stereo records. Suitcase portability. Detachable speaker enclosure for best stereo effect. Two 8in x 5in. special loudspeakers. For 220-250V a.c. mains operation. Overall cabinet size 15 7/8 x 3 3/4 x 10 1/2in.

Compact, economical stereo and mono record playing for the whole Family—plays anything from the Beatles to Bartok. All solid-state circuitry gives room filling volume.



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INSTRUMENTS

3" LOW-PRICED SERVICE OSCILLOSCOPE. Model OS-2. Compact size 5" x 7 3/4" x 12" deep. Wt. only 9 1/2 lb. "Y" bandwidth 2 c/s-3 Mc/s ± 3dB. Sensitivity 100mV/cm. T/B 20 c/s-200 kc/s in four ranges, fitted mu-metal CRT Shield. Modern functional styling.

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

5" GEN-PURPOSE OSCILLOSCOPE. Model 10-12U. An outstanding model with professional specification and styling. "Y" bandwidth 3 c/s-4.5 Mc/s ± 3dB. T/B 10 c/s-500 kc/s.

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DE LUXE LARGE-SCALE VALVE VOLT-METER. Model IM-13U. Circuit and specification based on the well-known model V-7A but with many worth-while refinements. 6" Ernest Turner meter. Unique gimbal bracket allows operation of instrument in many positions. Modern styling.

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AUDIO SIGNAL GENERATOR. Model AG-9U. 10 c/s to 100 kc/s. switch selected. Distortion less than 0.1%, 10V sine wave output metered in volts and dB's.

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VALVE VOLTMETER. Model V-7AU. 7 voltage ranges. d.c. volts to 1,500. A.c. to 1,500 r.m.s. and 4,000 peak to peak. Resistance 0.1Ω to 1,000MΩ with internal battery. D.c. input resistance 11MΩ. dB measurement, has centre-zero scale. Complete with test prods, leads and standardising battery.

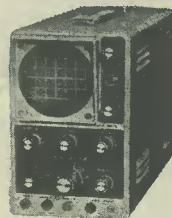
Kit £13.18.6 Ready-to-Use £19.18.6 p.p. 4/6

MULTIMETER. Model MM-1U. Ranges 0-1.5V to 1,500V a.c. and d.c.; 150μA to 15A d.c.; 0.2Ω to 20MΩ. 4 1/2" 50μA meter.

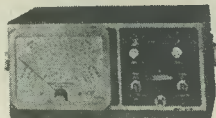
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R.F. SIGNAL GENERATOR. Model RF-1U. Up to 100 Mc/s fundamental and 200 Mc/s on harmonics. Up to 100mV output. Kit £13.18.0 Rdy-to-Use £20.8.0 p.p. 6/-

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OS-2



IM-13U



V-7A



RF-1U

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

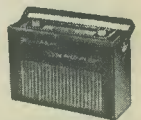


Will give you superb LW and MW entertainment wherever you drive. Tastefully styled to harmonise with any car colour scheme. Available for your convenience in two separate parts, RF Amp. Kit £1.15.0 incl. P.T. IF/AF Amp. Kit £11.3.6.

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

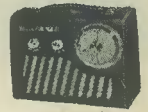
TRANSISTOR RADIOS

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



UXR-2

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UXR-1

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

STEREO TRANSISTOR FM TUNER

(Mono version also available)
14 transistor, 5 diode circuit. Tuning range 88-108 Mc/s. Designed to match the AA-22U Amplifier. Available in separate units, can be built for a total price.



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TFM-IS Kit (Stereo) £25.2.6 incl. P.T. p.p. 6/-
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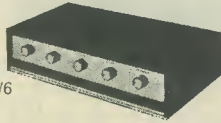
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12 × 12 watts output.

Kit **£30.10.0** less cabinet p.p. 10/6

Cabinet **£2.5.0** extra

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



FOR THIS SPECIFICATION

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

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

FULL SPECIFICATION SHEET AVAILABLE

LATEST! STEREO TAPE RECORDER, STR-1

Fully portable—own speakers

Kit **£58.0.0** incl. P.T. p.p. 10/6

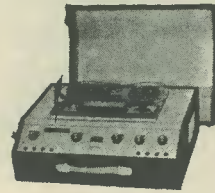
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FOR THIS SPECIFICATION

- ½ track stereo or mono record and playback at 7½, 3¼ and 1½ ips • Sound-on-sound and sound-with-sound capabilities • Stereo record, stereo playback, mono record and playback on either channel • 18 transistor circuit for cool, instant and dependable operation
- Moving coil record level indicator • Digital counter with thumbwheel zero reset • Stereo microphone and auxiliary inputs and controls, speaker/headphone and external amplifier outputs . . . front panel mounted for easy access • Push-button controls for operational modes • Built-in stereo power amplifier giving 4 watts rms per channel • Two high efficiency 8" x 5" speakers • Operates on 230V a.c. supply.

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

FULL SPECIFICATION SHEET AVAILABLE

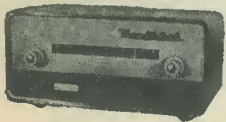


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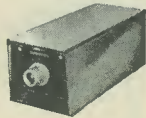
The instruction manual shows you how to build the model.



Low-priced STEREO FM RADIO



FM TUNER FM-4U



STEREO DECODER SD-1

HI-FI FM TUNER, Model FM-4U. Available in two units. R.F. tuning unit (£2.17.0 incl. P.T.) with I.F. output of 10.7 Mc/s, and I.F. amplifier unit, with power supply and valves (£13.13.0). May be used free standing or in a cabinet. Last Call. Total Kit **£16.10.0** incl. P.T. p.p. 10/6

Ready-to-Use price on request

STEREO DECODER, Model SD-1. Converts FM Mono receivers to stereo at low cost. Styled to match Heathkit models FM-4U and AFM-1 Tuners. Ready-to-Use **£12.5.0** p.p. 4/6



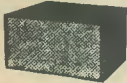
SSU-1

SPEAKER SYSTEMS

HI-FI SPEAKER SYSTEM, Model SSU-1
Ducted-port bass reflex cabinet in the white: Two speakers, vertical or horizontal models with legs. **Kit £12.14.6**, p.p. 7/6 without legs, **Kit £12.0.0** incl. P.T. p.p. 7/6

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6½" Bass, 3¼" Treble speakers and crossover unit. **Kit £5.2.0** incl. P.T. Beautiful Walnut veneered fully-finished cabinet, **£8.18.0**, Total price **Kit £14.0.0** incl. P.T. p.p. 10/6



"AMATEUR" EQUIPMENT

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

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

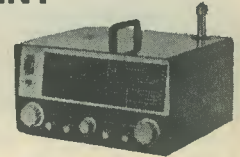
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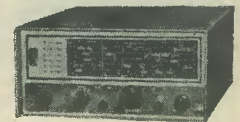
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Kit £39.16.0 Ready-to-Use **£53.0.0** p.p. 9/-



GC-1U



RG-1

3 + 3W Stereo Amplifier, TS-23



Incorporating all the essential features for good quality sound reproduction from record, radio and other sources. 16 Transistor, 4 diode circuit. Good frequency response 6 position selector switch. Modern slim line styling.

While stocks last.

Kit (less cabinet) **£17.15.0** p.p. 10/6



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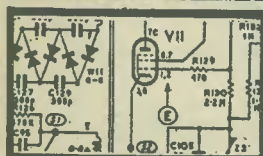
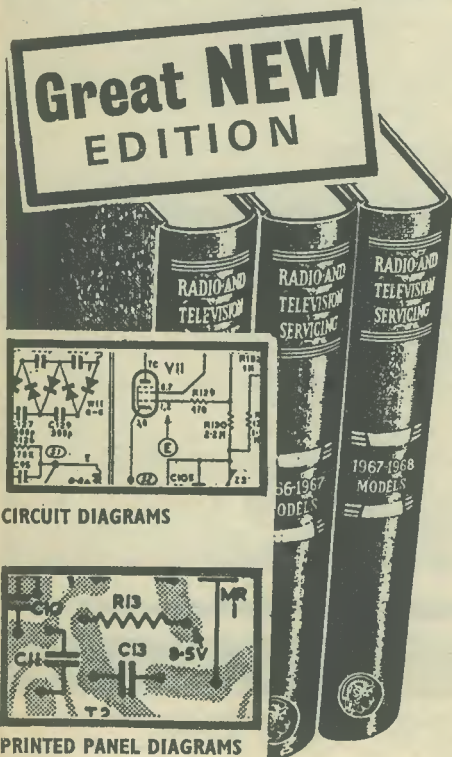
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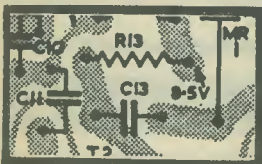
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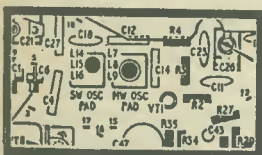
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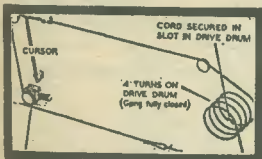
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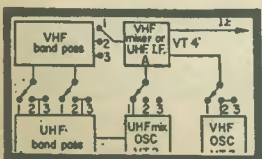
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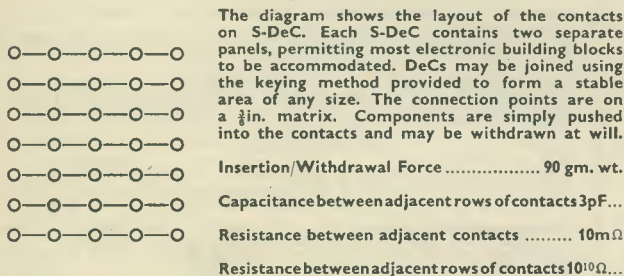
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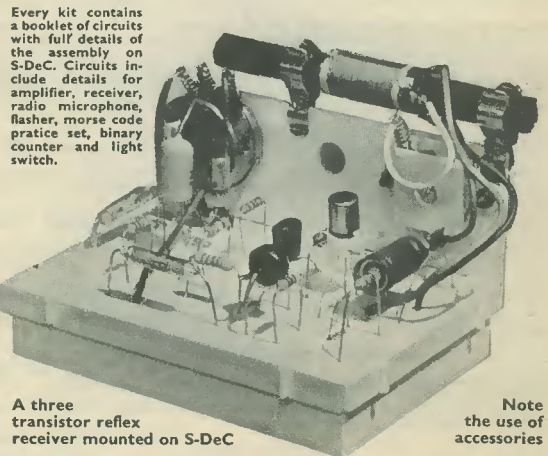
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THE Radio Constructor



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| | |
|--|-----|
| The "Spontaflex" S.A.4 Transistor Portable <i>by Sir Douglas Hall, K.C.M.G., M.A. (Oxon)</i> | 594 |
| Regenerative Wave-Trap for Medium Waves (Suggested Circuit No. 210) <i>by G. A. French</i> | 601 |
| Automatic Buzzer Alarm <i>by D. C. Wardman</i> | 604 |
| News and Comment | 606 |
| Simplifying Calculations <i>by E. Hughes</i> | 608 |
| Radio Constructors Data Sheet No. 7 (Inductive Reactance—Audio Frequencies) | 609 |
| Recent Publications | 610 |
| Adding Echo to a Tape Recorder <i>by J. Crawley</i> | 611 |
| Getting the Best from your Oscilloscope, Part 1 <i>by D. J. Griffiths</i> | 615 |
| Oscilloscope Voltage/Time Calibrator <i>by H. T. Kitchen</i> | 618 |
| Motor Speed Control Using a Thyristor <i>by N. Harding, B.A.</i> | 623 |
| Radio Constructors Data Sheet No. 8 (Inductive Reactance—Radio Frequencies) | 627 |
| Semiconductor Nuclear Counters <i>by J. B. Dance, M.Sc.</i> | 625 |
| Understanding Radio (Basic Superhet) <i>by W. G. Morley</i> | 632 |
| In Your Workshop | 636 |
| The Jet Set | 641 |
| Trade News | 642 |
| Radio Topics <i>by Recorder</i> | 643 |
| | 593 |

The "Spontaflex" S.A.4 Transistor Portable

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

Our contributor again presents an ingenious circuit which offers optimum performance from a minimum of transistors. By modifying the Spontaflex circuit to take a Super Alpha pair, the first two transistors can be reflexed on both r.f. and a.f. Also, the input impedance presented to the ferrite aerial coil becomes so high that exceptionally sharp selectivity is achieved with a single tuned circuit. To maintain the desired L/C ratio, the aerial coil is tuned by moving the ferrite rod in and out of its former

WHEN TWO TRANSISTORS ARE CONNECTED IN series, each in the common collector configuration, the result is known as a "super alpha pair" and, ignoring certain inevitable losses, the combination acts as a current amplifying device which provides the same amplification as would a single transistor with an amplification factor equal to the product of the amplification factors of the

two transistors. For example, two transistors, each with a gain of 100 will behave in a "super alpha pair" in the same manner as a single transistor with a gain of 10,000.

The circuit is normally used in low frequency pre-amplifiers where it is required to convert a high input impedance of, say, $1M\Omega$ to a low output impedance of about 100Ω .

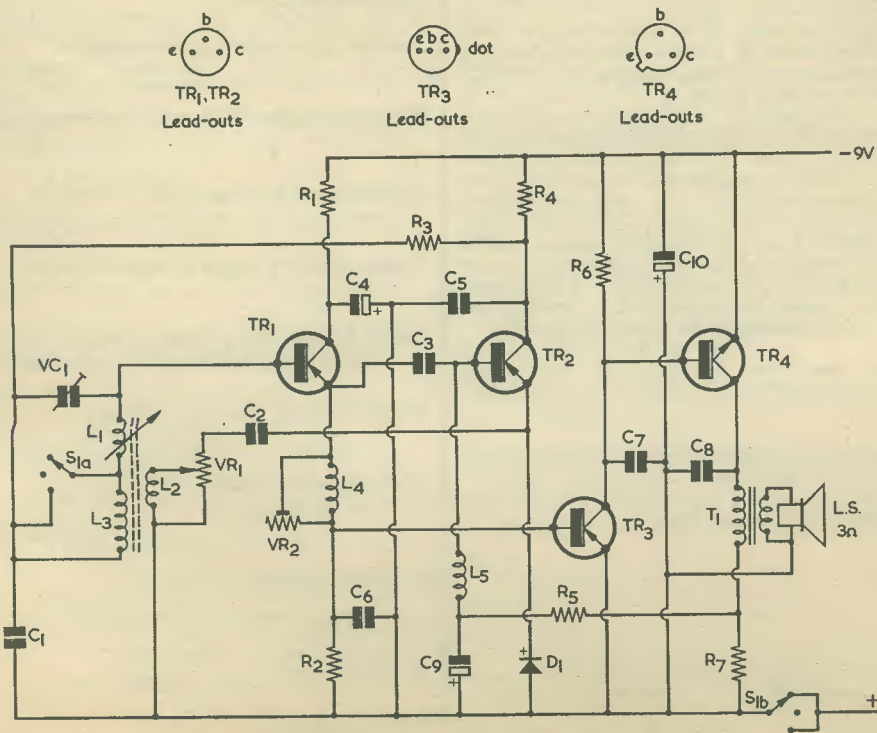


Fig. 1. The circuit of the Spontaflex S.A.4 receiver

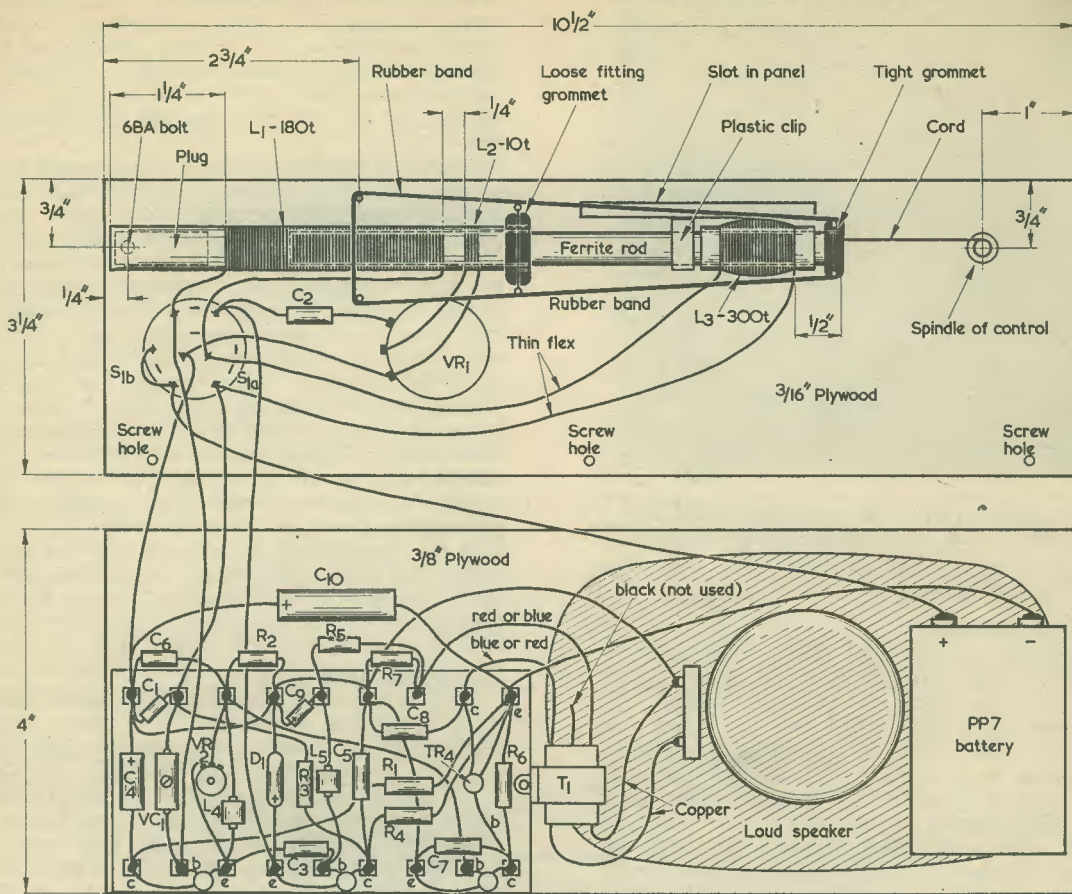


Fig. 2. Layout diagram, illustrating also the operation of the tuning mechanism

Resistors

(All fixed values 1/4 watt, 10%)

- R₁ 1kΩ
- R₂ 1kΩ
- R₃ 3.9kΩ
- R₄ 47kΩ
- R₅ 100kΩ
- R₆ 1kΩ
- R₇ 56Ω
- VR₁ 5kΩ potentiometer, linear
- VR₂ 10kΩ potentiometer, preset miniature

Capacitors

- C₁ 560pF
- C₂ 0.01μF
- C₃ 2,000pF
- C₄ 100 or 125μF, electrolytic, 10V wkg.
- C₅ 2,000pF
- C₆ 0.1μF
- C₇ 0.1μF
- C₈ 0.1μF
- C₉ 25μF, electrolytic, 2.5V wkg.
- C₁₀ 1,000μF, electrolytic, 10V wkg.
- V₁ 140pF trimmer

Inductors

- L_{1,2,3} Ferrite aerial assembly (see text)
- L₄ 2.5mH choke (Repanco)

L₅ 2.5mH choke (Repanco)

T₁ Output transformer type TT5 (Repanco)

Semiconductors

- TR₁ MAT101 or MAT121
- TR₂ MAT101 or MAT121
- TR₃ OC200
- TR₄ BSY26 or BSY27
- D₁ OA73

Switch

- S₁ 3-pole, 3-way, miniature rotary

Speaker

- 3Ω speaker, 6 x 4in

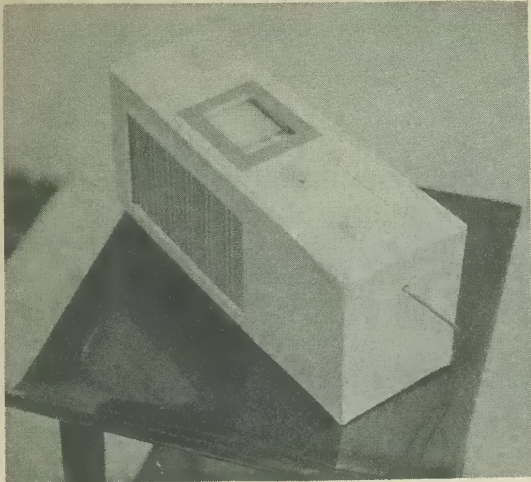
Battery

- 9-volt battery type PP7 (Ever Ready)

Miscellaneous

- Materials for tuning unit, including 6in, ferrite rod 3/8in diameter and Nylon tuning drive cord
- Battery clips
- 3 knobs
- 10-way groupboard type C114 (Bulgin)
- Materials for cabinet, etc.

COMPONENTS



The completed receiver in its cabinet. Note the rectangular window in the top panel above the tuning scale

Super Alpha Spontaflex

As regular readers will know, the author's Spontaflex circuit provides radio frequency amplification by the common collector mode, and experiments have shown that two transistors can be used in this circuit to provide much greater amplification and, as will be explained later, an unusual degree of selectivity from a single tuned circuit. The second transistor of the pair also provides audio frequency amplification by the common base mode, and it has been found perfectly practicable to feed its output back to the first transistor, which then reflexes as a common collector audio frequency amplifier. Double reflex action is therefore brought about, and phase relationships are such that any a.f. signals which tend to couple back from the first transistor (which is the second audio frequency amplifier) to the second transistor (which is the first audio frequency amplifier) produce a small degree of negative rather than positive feedback, so that stability is maintained.

With an impedance drop of about 10,000 to 1 it is vital for the input tuned circuit to have a very high Q. Not only must reaction be applied to overcome losses, but the circuit must have a high inductance/capacitance ratio. If the Q of the tuned circuit is not sufficiently high, the output impedance of the pair of transistors will be so low that the diode which follows the second transistor will be partially short-circuited, and the benefit of the extra radio frequency amplification will be lost. But if the Q is too high there may be so much amplification that uncontrollable instability occurs as reaction is increased, particularly at the high frequency end of the medium wave band where the impedance of the chokes serving as intermediate loads will be high. Experiments showed that a suitable compromise was reached when the capacitance across the input tuned circuit was held at about 50pF, the inductance in the tuned circuit being varied over a range which covered the medium waveband. It is therefore essential, with this circuit, that the special tuner which is described later

be constructed. If a conventional fixed inductor and variable capacitor is used the resultant circuit will prove unstable at 200 metres, very good for a patch round about 250 metres and then progressively less sensitive until, at 500 metres, results are no better than with a standard single r.f. stage Spontaflex.

The good selectivity of the arrangement appears to depend on the following factors. With the high inductance/capacitance ratio, and a good deal of reaction, it is possible to produce a very high input impedance. The impedance presented to the diode in these circumstances, although comparatively low, is a reasonable match for it. Now let us suppose that there is an interfering signal not many kc/s away from the one to which the circuit is tuned. With the efficient tuned circuit the impedance offered to the unwanted signal will be many times down and the signal will be attenuated accordingly. This effect, of course, occurs with all tuned circuits and provides normal selectivity. But with the "super alpha" arrangement used here a second effect takes place. The output impedance becomes lowered with the lower input impedance, and will drop to only a few ohms. As a result, the diode is virtually short-circuited at the frequency of the unwanted signal.

Circuit Operation

The passage of the incoming signal can be followed by studying the circuit of the receiver, which is shown in Fig. 1. It will be seen that the tuned circuit L_1 , VC_1 presents the signal to TR_1 , and thence to TR_2 , both transistors acting as common collector radio frequency amplifiers. D_1 demodulates the signal and then TR_2 functions as a common base a.f. amplifier followed by TR_1 as a common collector a.f. amplifier. From the emitter of TR_1 the signal passes to TR_3 , a p.n.p. silicon transistor which is directly coupled to TR_4 , an n.p.n. silicon transistor. Both TR_3 and TR_4 operate as common emitter amplifiers and because they are silicon devices about 0.65 volts is required on their bases before they will conduct. It is thus possible to dispense with emitter resistors and their accompanying bypass capacitors. Negative feedback of d.c. is over the entire circuit from the collector of TR_4 to the base of TR_2 .

Reaction is taken from the emitter of TR_2 to the base of TR_1 via C_2 and L_2 . Since the reaction is over the two stages it tends to cancel out losses due to stray capacitances, etc., throughout the whole of the r.f. part of the circuit. Also, because it is over two stages the reaction coil is very small, 10 turns serving to produce oscillation, if necessary, even on the long wave band where the total winding in the tuned circuit comprises 480 turns. Because, at a very low setting, VR_1 tends to damp the tuned circuit, it acts as a true volume control as well as controlling reaction. In Fig. 1 long waves is selected with $S_{1(a)}$ open and medium waves with $S_{1(a)}$ closed.

Construction

Construction should start with the special tuning unit, and Figs. 2 and 3 should be studied before work starts. First a sleeve is made, $4\frac{1}{2}$ in long and of such diameter that the $\frac{3}{16}$ in ferrite rod slides snugly but freely inside it. The best method

is to cut a piece of adhesive backed plastic, $4\frac{1}{2}$ in by about 2 in, leaving all the paper on except for a $\frac{1}{2}$ in strip along one of the $4\frac{1}{2}$ in edges. This is then wrapped round the rod, the paper-backed part first, not too tightly, and fixed in shape by its adhesive. Check that the size is right and then, with the rod inserted to give rigidity and starting the winding $1\frac{1}{2}$ in from one end, put on 180 turns of 32 s.w.g. enamelled wire with the turns touching. The ends should be fixed with adhesive tape. This coil is L_1 and should be about $2\frac{3}{4}$ in long or thereabouts. After a gap of $\frac{1}{4}$ in wind L_2 which consists of 10 turns of 32 s.w.g. enamelled wire with the turns touching. The winding must be in the same direction as that of L_1 .

L_3 is wound on a separate sleeve which is a tight fit on one end of the rod. The sleeve should be $1\frac{1}{2}$ in long and the winding, which is of 300 turns of 38 s.w.g. enamelled wire, should be pile-wound to a length of about $\frac{3}{4}$ in. The ends of this coil should be fixed with adhesive tape and cut short and bared. To each bared end a piece of fine flex of the type used for miniature earpiece leads is soldered. The joints should be insulated and bound to the coil with adhesive tape. The flexible leads need to be about 8 in long. The end of L_3 should be $\frac{1}{2}$ in from the end of the ferrite rod as shown in Fig. 2, and it is wound in the same direction as L_1 when the rod is inserted.

A 1 in length of $\frac{3}{8}$ in rod, either of wood or plastic, is cut and inserted in the end of the sleeve on which L_1 and L_2 are wound, as illustrated in Figs. 2 and 3. A turn or two of Sellotape round the plug will make it a tight fit in the sleeve. A hole is drilled through the sleeve and plug and the sleeve is bolted to a panel of $\frac{3}{8}$ in plywood, $10\frac{1}{2}$ in long and $3\frac{1}{2}$ in wide, as shown in the diagrams. Next, a loose fitting rubber grommet is passed over the other end of the sleeve and tied to the panel with cord, this passing through two holes in the panel. The cord must not be tied too tightly, or it may cause the rod to bind. At this stage the correct position for the slot in the panel, as shown in Fig. 2, should be marked, the sleeve temporarily removed from the panel, and the slot cut out with a fret saw. This slot takes a plastic clip with a tuning pointer on the other side of the panel, as in Fig. 3 (e).

The plastic clip is made from thin stiff plastic sheet and is fitted to the rod, close to L_3 , as shown in Figs. 2 and 3. The sleeve, this time with the rod in it, is again bolted and tied to the panel, the plastic clip passing through the slot. A 6BA bolt is secured to the outside end of the plastic clip as in Fig. 3 (e) to function as a tuning scale pointer. For appearance, the bolt may be filed to remove all the thread apart from that under its fixing nut and later painted white.

Next, a tight fitting grommet is fitted to the end of the ferrite rod, this serving to lock a length of

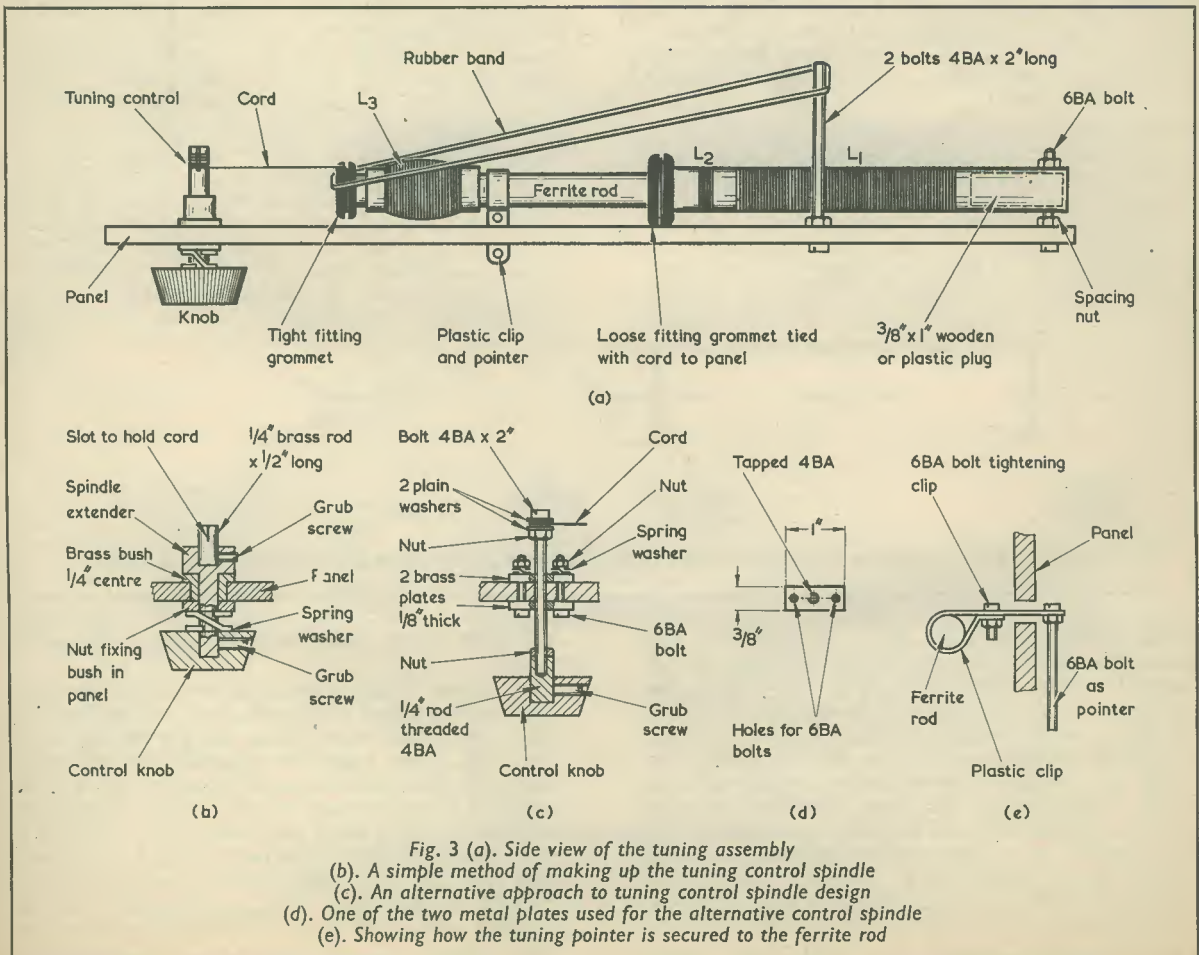


Fig. 3 (a). Side view of the tuning assembly
 (b). A simple method of making up the tuning control spindle
 (c). An alternative approach to tuning control spindle design
 (d). One of the two metal plates used for the alternative control spindle
 (e). Showing how the tuning pointer is secured to the ferrite rod

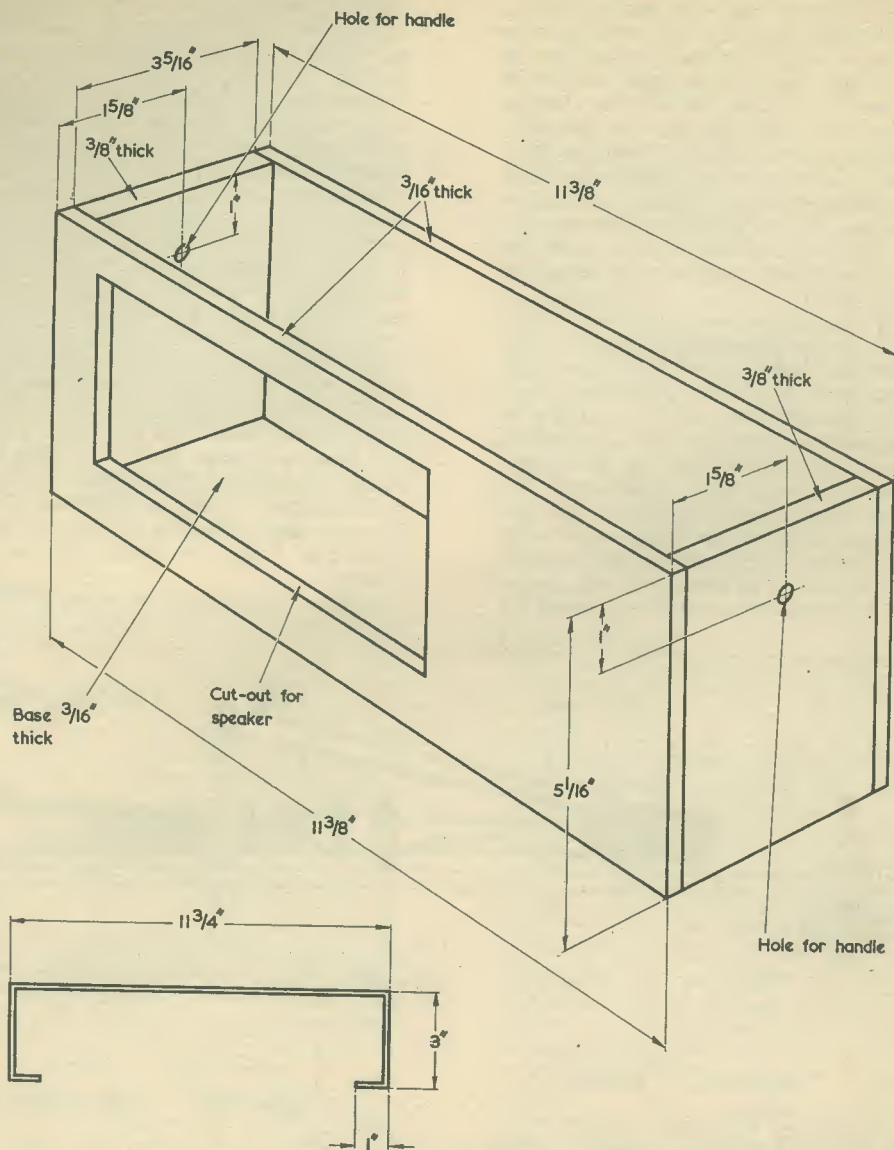


Fig. 4. A simple but effective case for the receiver. The handle may be made from stiff galvanised wire or similar

nylon tuning drive cord to it. A drive for this arrangement has then to be made. One simple method is fully explained by Fig. 3 (b). Note the slot cut in the $\frac{1}{2}$ in length of brass rod, in which the cord is held. If difficulty is experienced in finding a suitable spring washer, one can be made with about $\frac{1}{2}$ in length of compression spring with an internal diameter of $\frac{1}{2}$ in, held between two steel washers. The knob is fitted so as to compress the spring washer to a degree which prevents the elastic rubber band from taking control, but without making the whole arrangement too stiff. The two bolts holding the far end of the rubber band are shown in Figs. 2 and 3. The band passes round

the tight fitting grommet at the end of the ferrite rod.

A rather better alternative arrangement, which requires the use of a 4BA tap, is shown in Fig. 3 (c). The two small brass plates shown in Fig. 3 (d) are held, finger tight, on either side of the panel, and a 2in 4BA bolt is screwed through them. Correct stiffness is maintained by the degree of tightness of the two 6BA bolts and nuts which are used to hold the brass plates together. It should be pointed out that the long sides of the brass plates are parallel to the short sides of the panel. This is necessary to avoid the ferrite rod fouling one of the 6BA bolts.

Whichever form of drive is used, the cord is fitted so that with the knob turning in a clockwise direction the ferrite rod is entering the sleeve, movement being brought about by the rubber band. With the knob turning anticlockwise the cord pulls the rod out of the sleeve. Total movement for the medium waveband should be from a point where the end of the rod is about $\frac{1}{2}$ in inside L_2 to the point where it meets the wooden plug.

Mounting The Components

The switch, S_1 and the volume control, VR_1 , should be mounted as shown in Fig. 2, and the components on the panel wired up. It will be seen that one section of the switch is not used, as such, though two of its outside tags are employed as anchor points.

Next, the speaker panel should be cut out. This is $10\frac{1}{2}$ in by 4in with a suitable hole cut for the 6 x 4in speaker. The groupboard is a Bulgin type C114 with one pair of tags cut off, leaving 9 pairs and reducing its length to $4\frac{1}{2}$ in. Components should be wired as in Fig. 2, the cut end of the board being at the C_4 end. It should be noted that T_1 is turned on its end and screwed through the groupboard by one foot bent through 90° . The red and blue leads from this transformer should only be connected temporarily at this stage as it may be necessary to reverse them. It is convenient to make a small plywood platform for the PP7 battery fixed, by means of a bracket, to the appropriate speaker fixing screw. The battery can be held in position with a rubber band and will then stay in place whether the receiver is in its case or not.

The transistors will need to stand upright from the groupboard. It will also be necessary to solder a length of wire to the base lead of TR_4 to enable it to be taken to its connection point. The four transistors should be as specified and, especially with TR_1 , must be new, first grade specimens. It is essential for TR_1 to have negligible leakage current characteristics and if the transistor it is intended to use has already been soldered in and

out of experimental circuits it may well have suffered in this respect. It is worth while changing round TR_1 and TR_2 for best results. Ideally, oscillation on the medium wave band should start with VR_1 at about mid-travel and the oscillation point should remain fairly constant throughout the band. As regards the diode, very many different types were tried out and, although they all worked, the OA73, with its comparatively low impedance, proved the most satisfactory.

The control panel is next screwed to the speaker panel edge, and knobs are fitted. If desired, small angle brackets may be added to improve rigidity between the two panels. The leads from S_1 to the groupboard may then be finally wired in.

Setting Up

To set up the receiver, adjust VC_1 about 2 turns from fully tight, and VR_1 and VR_2 fully anticlockwise. Switch to the long waveband (S_1 knob clockwise). There may be a whistle present. If so, swivel T_1 one way or the other. If this does not stop the whistle, reverse the connections of the red and blue leads from T_1 . There is a right and a wrong way to connect these leads which depends on the direction of the windings on the ferrite rod.

Next, adjust the tuning control so that the ferrite rod is about three-quarters of its full way into the sleeve and turn VR_1 until a hiss denotes oscillation. Back down VR_1 a little and adjust VC_1 until the Light programme on 1500 metres is received. VR_1 may well have to be turned back further to prevent overloading unless the receiver is a long way from the transmitter.

With VR_2 still fully anticlockwise and inserting maximum resistance, switch to medium waves. Adjust the tuning control to near the minimum inductance setting and find a station on about 200 metres. Note whether reaction is smooth as VR_1 is advanced, and does not cause oscillation to start with a "plop" followed by complete silence (which can only be overcome by turning VR_1 a long way back again). If this happens, or if the

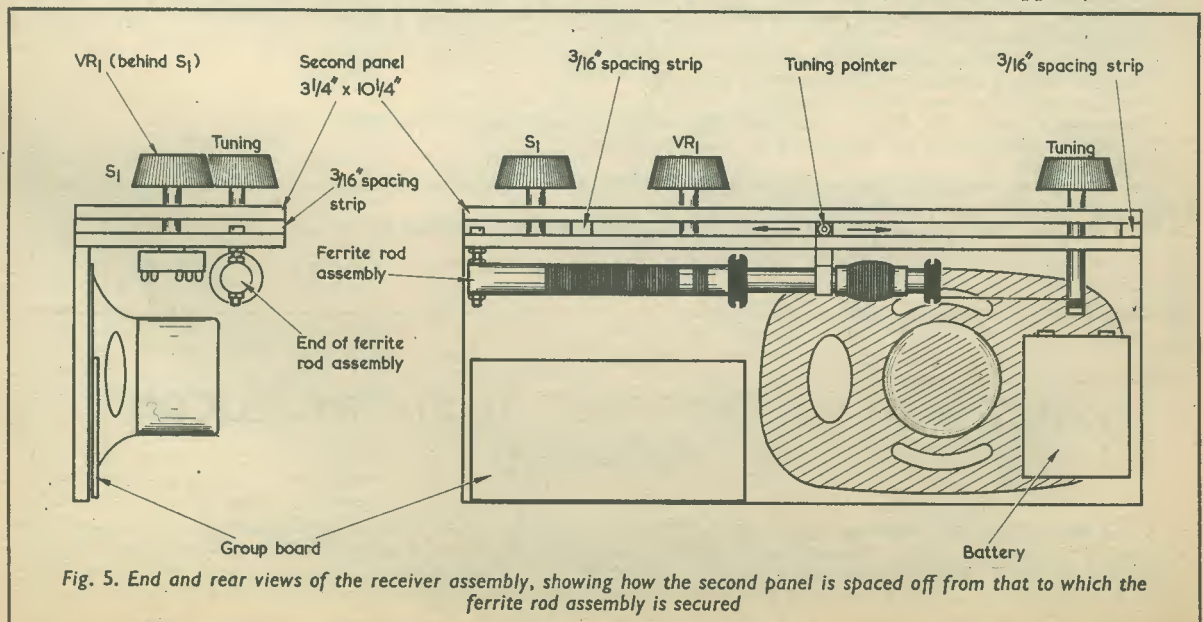


Fig. 5. End and rear views of the receiver assembly, showing how the second panel is spaced off from that to which the ferrite rod assembly is secured

onset of oscillation is accompanied by a fluttering sound, turn VR₂ clockwise until reaction is smooth. This procedure may not prove necessary, but is quite likely to occur if TR₁ and TR₂ are both very efficient specimens. The function of VR₂ is to damp the excessive impedance which may be offered by the r.f. chokes at the high frequency end of the waveband. But VR₂ should not be turned further clockwise than is necessary to preserve smooth reaction, or sensitivity will suffer.

The receiver is now ready for use.

Cabinet

A cabinet can be made very easily as shown in Fig. 4, using $\frac{1}{8}$ and $\frac{3}{16}$ in plywood, the pieces being held together with adhesive and panel pins. A tidy finish can be obtained by covering with "Contact". A neater control panel can be provided by cementing two narrow strips of $\frac{3}{16}$ in plywood on it and placing a second panel of $\frac{3}{16}$ in plywood over these. The receiver can be dropped into the cabinet from the top with a piece of speaker gauze in front of the speaker panel. The top, or false panel, will need a window cutting in it for the tuning indicator, as well as three holes for the controls. The two plywood strips just mentioned provide the necessary clearance for the tuning pointer. A wavelength

scale can be placed under the pointer and there should be no difficulty in calibration as many stations will be received. Fig. 5 gives end and rear views of the receiver with the second panel added.

Although the components used are few in number for a 7 stage receiver, the author realises that a good deal of constructional work is involved. However, he believes that there are many readers who, like himself, get far greater enjoyment from a task which involves a good deal of work, together with a little skill, than from just slinging together a set of components and wiring them up.

As regards sensitivity, the Home, Light and Third programmes can be received in South Devon on all the wavelengths on which they are broadcast, as well as very many Continental stations. An idea of the selectivity given can be obtained from the fact that, although the West Home station at Start Point is only 12 miles from the author's home, and is a local station in every sense of the expression, yet the Midland station, some 200 miles away and separated in frequency by only 36 kc/s, can be received loud and clear, and free from interference.

With the prototype, the emitter currents passed by the four transistors were 600 μ A, 150 μ A, 750 μ A and 9mA respectively.



ADVANCED PORTABLE OSCILLOSCOPE

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* Weight only 16 $\frac{1}{2}$ lb with internal battery.

* Accuracy of $\pm 3\%$ "X" and "Y" stabilized against temperature and input voltage changes.

* 5mV/div sensitivity at full bandwidth of D.C.—15 Mc/s.

* D.C. Trigger.

It is claimed that the CDU 130 has a sufficiently advanced specification to make it suitable for the servicing and maintenance of equipment of the highest professional standards.

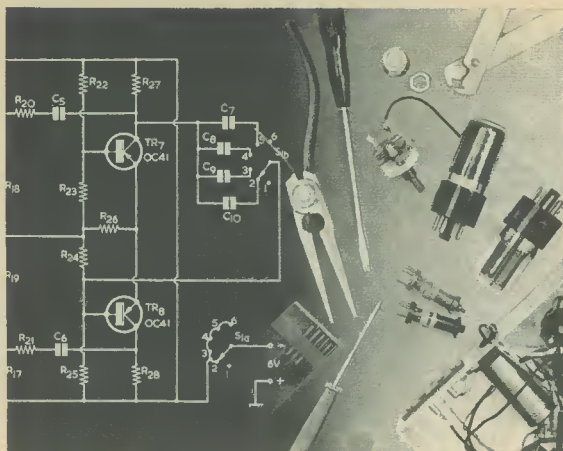
Price including battery is £195 0s. 0d. and comprehensive literature is available on request.

NEW HIGH VOLTAGE FAST RECOVERY SILICON RECTIFIER

A new high voltage fast recovery, silicon rectifier is announced by General Instruments (UK) Limited of Cromwell House, Cromwell Road, London, S.W.7. The rectifier features a reverse recovery time of 4 μ sec peak reverse voltage of 5 to 6 kV, and 300 mA average forward rectified current at 65°C and 16 KC/S. It is mounted on a cartridge type fuse holder which enables the rectifier to be placed anywhere in the EHT region without the need for special cards. The diode is suitable for use in any CRT circuit.

REGENERATIVE WAVE-TRAP FOR MEDIUM WAVES

by G. A. FRENCH



THERE ARE MANY VARIED INTERESTS within the broad spectrum covered by radio construction and its allied hobbies. One of these interests consists of Dx (long-distance) listening on the medium wave band, and this has a steady following by enthusiasts in the Dx field.

Dx listening on medium waves is not always easy to carry out, owing to the overcrowded conditions on this band and the presence of powerful transmitters in the U.K. and on the Continent. If an outside aerial is employed it can, in consequence, sometimes prove helpful to fit a wave-trap in series with the aerial input connection, this reducing the strength of any particularly troublesome station and thereby preventing interference (including cross-modulation in the early receiver stages) with weaker signals on neighbouring frequencies. Unfortunately, the usual type of wave-trap circuit provides attenuation over rather a broad band of frequencies, and has the disadvantage of offering, to signals close to the specific signal it is desired to suppress, almost as great a rejection level. As a result, the advantages given by a simple wave-trap circuit may not in practice be as great as might, at first sight, appear.

The writer has investigated the possibilities of artificially increasing the Q of a wave-trap circuit for medium waves to see whether it could offer an improved performance so far as the sharpness of the rejection range was concerned, and the result of his experiments forms the subject of this month's "Suggested Circuit" article. A sharper rejection range ensures, of course, that the particular signal it is desired to suppress undergoes greater attenuation than the signals on either side. Working from signal generator tests, the circuit

finally produced offers a rejection which is at least 20dB better than a normal wave-trap circuit, with a corresponding sharpening of the rejection response curve. Tests with an aerial indicated about the same order of improvement although results here are partly dictated by the aerial and earth system employed, and it may be found that the improvement at some points of the medium wave band is not as apparent as at others. The circuit should be regarded as being experimental in this respect. On the credit side, it requires only a few components and it can be assembled in a very short time.

The wave-trap described in this article may also be of help to those using an outside aerial (as opposed to a ferrite rod aerial) who listen to the medium wave band for entertainment, and who reside in an area where interference from a powerful local station causes difficulties in reception.

The Wave-Trap

The theory of operation of a wave-trap is very simple, and the basic circuit employed is illustrated in Fig. 1. A parallel tuned circuit is inserted between the aerial and the aerial input terminal of the receiver, and is adjusted to resonate at the frequency it is required to reject. The parallel tuned circuit offers maximum impedance at its resonant frequency, whereupon this frequency is subjected to greater attenuation than frequencies on either side. As has already been stated, the response curve of a single tuned circuit of this nature tends to be relatively broad.

Fig. 2 shows the "Suggested Circuit" devised by the writer. As in Fig. 1 there is a parallel tuned circuit in series with the aerial input connection, this being provided now by C₂ and L₁. C₂ and L₁ are tuned to the fre-

quency it is desired to reject and, when S₁ is in the Off position, function in the same manner as the tuned circuit of Fig. 1. When S₁ is set to On, power is applied to transistor TR₁ and its components, and circuit operation is then modified. This is because TR₁ offers regeneration and can be brought to a point which is just below oscillation at the resonant frequency of C₂ and L₁. Thus, in the same manner as occurs in an a.m. detector circuit with reaction, the effective Q of C₂ and L₁ becomes increased by a considerable amount, with the result that the rejection offered by these two components is both increased and made sharper in terms of frequency.

TR₁ is an OC44 transistor whose normal function is that of mixer/oscillator in medium and long wave transistor radio receivers. Thus it is

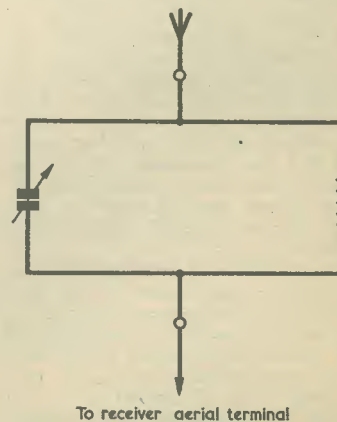


Fig. 1. A conventional wave-trap consists of a parallel tuned circuit in series with the aerial input connection to the receiver

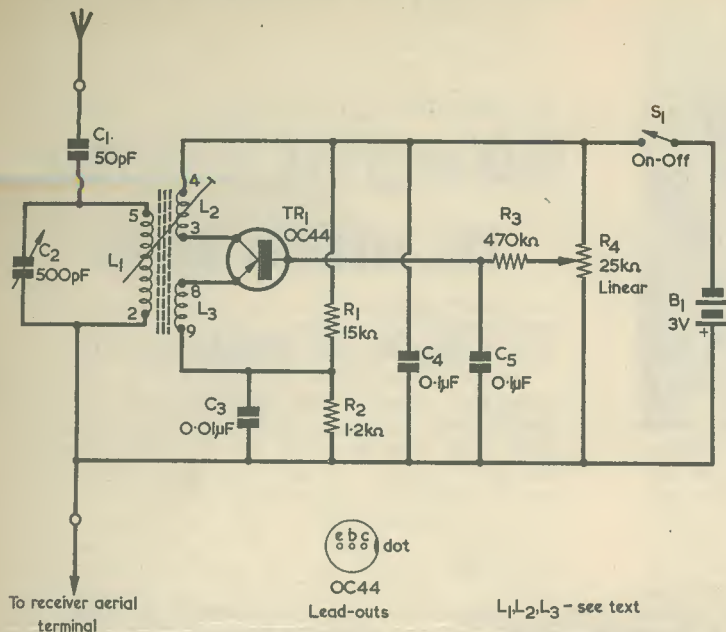


Fig. 2. The wave-trap circuit described in the text. TR₁ provides regeneration and increases the effective Q of the tuned circuit

quite capable of oscillating at frequencies in the medium wave band. L₁, L₂ and L₃ are, respectively, the tuned and coupling windings of a Denco Miniature Dual-Purpose Green coil, Range 2. This is a medium wave coil intended for use in a valve leaky-grid detector circuit with reaction, but it is ideally suited for the present purpose. In the valve application, L₂ is the reaction feedback winding whilst L₃ is the coupling winding for connection to a preceding r.f. amplifier anode circuit, or to the aerial and earth. Winding L₁ would normally be tuned by a 310pF tuning capacitor. A 500pF capacitor (C₂) is used here, however, because additional capacitance across the winding is given by the aerial system and because it is desirable to set the dust-iron core of the coil in a position which still enables the higher medium wave frequencies to be covered and which also ensures optimum working conditions for the transistor circuit. Increasing the tuning capacitance to 500pF allows the full medium wave band to be covered under these conditions.

The transistor appears in an oscillator circuit reminiscent of the type employed in the mixer/oscillator stages of transistor superhet receivers. Energy from the collector circuit is fed back to the emitter circuit via L₂, L₁ and L₃, in that order. If oscillation occurs, it then takes place at the resonant frequency of L₁ and C₂.

The base of TR₁ is bypassed for r.f. to the positive supply line by way of C₅, the upper end of L₂ is

bypassed by C₄, and the lower end of L₃ is bypassed by C₃. R₁ and R₂ keep the emitter slightly negative of the positive supply line to ensure that the transistor is cut off (or, as we shall see shortly, approaches cut-off) when R₄ slider is at the lower end of its track.

R₄ is the regeneration control and it functions in the same basic manner as the reaction control of an a.m. detector. As R₄ slider is brought up from the lower end of its track it applies an increasing negative bias, via R₃, to the base of TR₁, until the amplification offered by this transistor is sufficiently high to allow oscillation to occur. If R₄ is maintained at a setting just below oscillation point the regeneration offered by the transistor causes the tuned circuit to have an effective Q which is considerably higher than its natural value.

Results With The Prototype

The author's prototype circuit employed an air-spaced variable capacitor fitted with a slow-motion drive in the C₂ position, a slow-motion drive being essential since the tuning of this component can be quite sharp, particularly at the higher frequencies. The circuit was then inserted in series with a medium wave receiver fitted with a tuning indicator, and a 30ft aerial. An earth connection to the receiver was also provided.

The circuit performance was evaluated by initially tuning in a signal on the receiver then adjusting C₂, with S₁ in the Off position, and

noting the attenuation which resulted. S₂ was then switched on with R₄ slider at the lower end of its track and C₂ retuned for maximum attenuation. R₄ was next slowly advanced, rocking C₂ about the desired frequency of rejection until a setting in R₄ was obtained which caused greatest attenuation to be given. The desired setting in R₄ was quite marked, and as its slider went above this setting attenuation decreased for a small movement in the slider before the circuit went into oscillation. Over most of the band, and particularly at the high frequency end, the slider of R₄ had to be advanced over only a few degrees from the lower end of the track to reach the optimum position. If desired, R₄ could be replaced by a 5kΩ potentiometer with a fixed 20kΩ resistor inserted between the upper end of its track and the negative supply line, in order to "open out" the adjustment it offers. However, the setting up of the 25kΩ potentiometer as it stands is not difficult to carry out even though much of the upper end of its track is unused, and the writer did not feel that the extra resistor was justified.

With the prototype it was found that signals which were comfortably audible using C₂ and L₁ on their own could be suppressed completely when the transistor circuit was switched in. The strength of more powerful signals was reduced by about the same proportion, as shown by the tuning indicator fitted to the receiver. A signal generator was applied in place of the aerial and earth, and it was found that its output voltage had to be increased at least 10 times to achieve the same deflection in the tuning indicator when attenuation was provided by the transistor circuit as opposed to attenuation by C₂ and L₁ on their own. This test was carried out on various frequencies throughout the band. An increase of 10 times in output voltage corresponds to an increase in attenuation of 20dB. Such a figure does not indicate a spectacular improvement in signal rejection; but it does represent a very useful improvement which, to the writer's mind, justifies the small quantity of components required to bring it about.

Three further points concerning operation of the circuit need to be mentioned. First, it is very desirable that the receiver with which the device is used should be fitted with a tuning indicator or tuning meter, as it is difficult to judge the results obtained by listening tests only. Second, the setting of C₂ which offers maximum rejection when the transistor circuit is switched in is slightly removed from the setting given with the transistor circuit out of action. Since the rejection response sharpens as R₄ is advanced, it is necessary to rock C₂ whilst adjusting R₄ to ensure that the optimum setting in the tuning capacitor is not missed. The final adjustment in C₂

with R_4 correctly set up can be quite critical. Third, since both C_2 and R_4 are at aerial potential, hand-capacitance effects will be present as these components are adjusted.

The current drawn by the prototype circuit, when set up, from the 3-volt battery was 0.25mA only.

The Regeneration Circuit

The component values around TR_1 were found, empirically, to offer the smoothest control of regeneration (using the word "smoothest" in the sense in which it applies in an a.m. reaction circuit). However, they result in TR_1 being operated in a somewhat unconventional manner.

If the emitter of TR_1 were returned direct to the positive supply line (via L_3) it may be found that the transistor would be capable of oscillation at some frequencies even when the slider of R_4 is at the bottom of its track. By making the emitter slightly negative (by means of R_1 and R_2) this difficulty is eradicated. TR_1 still tends, nevertheless, to provide regeneration when R_4 is only slightly advanced and when it might be assumed that the transistor is cut off. TR_1 is operating, under these conditions, virtually with leakage current only. This fact is accepted because the circuit provides, in practice, a smooth control of regeneration with a minimum of components, and because there is the secondary advantage that current consumption from the 3-volt battery is very low.

Since transistor leakage current is a qualifying factor in circuit operation, there is, nevertheless, a risk that some specimens of the OC44 may offer a different performance than others. What may possibly occur is that some transistors might go into oscillation even with R_4 slider fully at the lower end of its track, whereupon the only solution would be to try another transistor or to increase the value of R_2 until the tendency towards oscillation clears. The writer experienced no trouble of this sort with the prototype, and merely mentions the point in case it occurs with readers' versions of the circuit. Two OC44's were checked in the prototype unit and both gave identical results.

For interest, an OC170 was also checked and this similarly gave identical results. It would appear from these checks that the possible risk just mentioned is not liable to give much trouble in practice. It would be of advantage, though, to make certain that TR_1 is a good component (preferably marked with the name or mark of a reliable manufacturer) and is not one of the "re-marks" which, regrettably, sometimes appear on the home constructor market.

It will be found that the setting of the dust core in the coil, although not critical, has a bearing on circuit performance. The writer found that best results were given if the core was adjusted such that the threaded brass stem protruded by about 1/32in outside the plastic housing.

It will be noted that the lower end of the tuned circuit, L_1C_2 , is made common with the positive supply line. This connection improves the stability of the regeneration circuit. The 50pF capacitor, C_1 , is included to avoid the risk of excessive damping of the tuned circuit by the aerial. It is possible, with some aerials, that the value of C_1 could be increased without upsetting circuit operation, and this point can, if desired, be checked by experiment.

Components And Construction

A few words need to be given concerning components.

If it is decided to use a normal variable capacitor for C_2 it would be preferable to choose an air-spaced type, and to avoid employing a solid-dielectric component. Some constructors may prefer to use a trimmer in the C_2 position instead, setting this up permanently for a single frequency. Such a trimmer can be air-spaced or mica, bearing in mind the fact that the final adjustment is critical and that hand-capacitance effects are present when it is adjusted. R_4 may similarly be preset, if desired.

The coil has already been specified. It is capable of being fitted in a B9A valveholder; an advantage for experimental work as soldered connections can then be made and altered at the valveholder tags without risk of damage to the plastic former of the

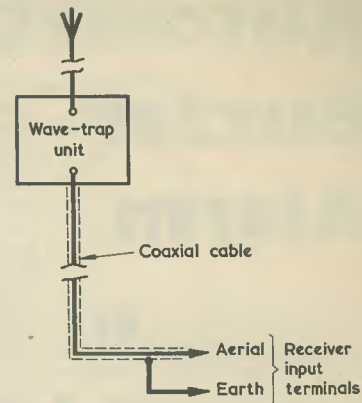


Fig. 3. The output of the wave-trap unit may, if desired, be coupled to the receiver via coaxial cable

coil. The figures in the diagram indicate the valveholder pins at which connections to the coil are made.

All the fixed resistors are standard 1/4 watt 10% components.

Due to the low operating current, the 3-volt supply can be provided by any small battery or pair of cells in series. The circuit is not unduly voltage sensitive and there appears to be little point in providing voltage stabilisation. The battery should be replaced when its voltage falls below about 2.8.

Since all the components in the wave-trap unit are effectively at aerial potential, the circuit should be assembled in a small insulated case, ensuring that the output lead to the receiver is spaced well away from the aerial input lead. The lead to the receiver could consist of a short length of coaxial cable, the braiding of which is connected to the earth terminal of the receiver, as in Fig. 3. If the receiver has a live chassis (i.e. connected to one side of the mains supply) full isolation *must* be provided at its aerial and earth input terminals. Whether a screened or unshielded lead to the receiver is employed its length should, in any case, be kept short.



TWO NEW ADD-ON MODULES

Gresham Lion Electronics Limited, Twickenham Road, Hanworth, Middlesex, announce the introduction of two new add-on modules, for their range of GX Power Supplies, to give protection to voltage sensitive loads against overvoltage and to avoid the undetected malfunction of any circuit due to undervoltage conditions. For the overvoltage unit the voltage window is normally preset at +20% of the output voltage. The discrimination is better than 2% and operating speed is approximately 5-10 μ sec. With the over and under voltage unit the voltage window is normally preset at \pm 20% of output voltage with a discrimination of 2% and operating speed of 5-10 μ sec.

Automatic Buzzer Alarm

by

D. C. WARDMAN

This ingenious circuit provides an audible warning whenever a beam of light is interrupted. The design has the advantage that inexpensive germanium transistors may be employed in the switching and multivibrator stages

THE SIMPLE PHOTO-ELECTRIC DEVICE DESCRIBED HERE was designed as an automatic door buzzer, although it may be used as a burglar alarm or in any other application which requires an audible warning when a beam of light is interrupted. Its main features are that it operates without a relay or any other mechanical device, and that it can be made up with low-cost components.

Circuit Operation

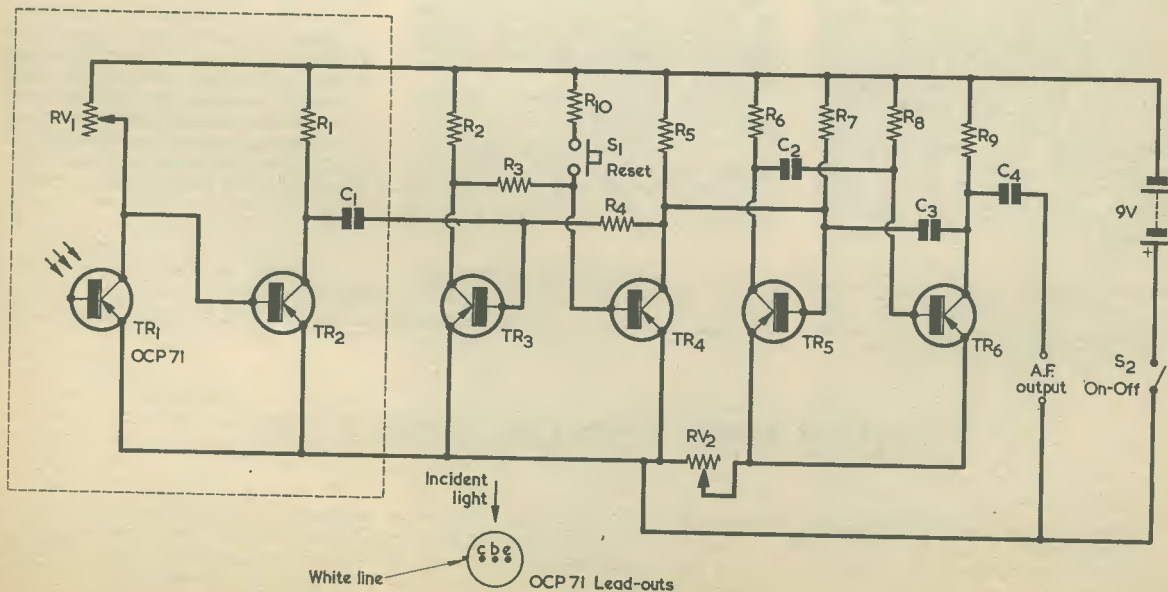
In the circuit, which appears in the accompanying diagram, TR₁ is a phototransistor type OCP71 which is normally illuminated, whereupon it exhibits a low resistance. No connection is made to TR₁ base for the present application.

TR₃ and TR₄ form a bistable in which TR₄ is normally conducting, or "on". When TR₄ is "on" a large positive voltage relative to TR₅ emitter is applied to the base of TR₅. TR₅ and TR₆ form a multivibrator capable of running at an audio frequency, and the positive voltage from TR₄ collector prevents this multivibrator from operating. RV₂ is adjusted to lower the supply voltage to the multivibrator to around 2 to 3 volts. This voltage is very critical as the multivibrator can stand quite a large positive voltage on TR₅ base before it cuts off.

RV₁ is adjusted so that TR₂ is cut off when TR₁ is illuminated. Under this condition, the collector of TR₂ approaches the negative supply potential and C₁ becomes charged, via R₁ and the base-emitter junction of TR₃, to nearly the fully supply voltage.

If the illumination to TR₁ is cut off due to the beam of light on this phototransistor being broken it exhibits a high resistance and TR₂ becomes conductive. Its collector then goes positive, whereupon the voltage across C₁ drops and this capacitor loses some of its charge through TR₂, TR₄ and R₄. If, then, the intensity of light on TR₁ increases, TR₂ collector goes negative and C₁ charges via R₁ and the base-emitter junction of TR₃. The charging current in this junction is sufficient to make TR₃ conductive and the bistable changes over, with TR₃ conductive and TR₄ "off".

The collector of TR₄ now goes negative, removing the bias from TR₅. TR₅ and TR₆ then run as a normal multivibrator, giving an audible warning that the light beam has been interrupted. The circuit can only be returned to its original state by momentarily closing the Reset switch S₁ with TR₁ illuminated. This applies a negative voltage to the base of TR₄ and the bistable then reverts to its original condition.



The circuit of the automatic buzzer alarm. Due to the design, transistor requirements are non-critical

Sensitivity

It will be apparent that the larger the value of C_1 the greater the charging current which flows in the base-emitter junction of TR_3 when illumination increases, and the surer the switching. The prototype worked quite satisfactorily with C_1 at the value specified and using no lenses at the lamp or at the phototransistor. With this value it was found possible to interrupt the illumination to TR_1 without tripping the alarm, but the stealth needed was much greater than would normally be the case. If, in the prototype, C_1 was increased to $0.2\mu\text{F}$, the alarm operated no matter how slowly the illumination was resumed, but a lens system was required to prevent the circuit tripping due to changes in ambient light.

Components

In the author's version TR_1 was an OC71 of the old glass type with the enamel scraped off. An OCP71 will function equally well. Other types of photoelectric device should also operate in a similar manner, but these have not been checked by the writer. After the circuit has been made up, the best type of light source to meet the constructor's circumstances may be found by experiment, but requirements here are not critical. Transistor types are also not critical and virtually any p.n.p. germanium types could be employed. (TR_5 and TR_6 should, however, have a reverse emitter-base voltage rating of 9 or more, and a suitable type here would be the OC71.—Editor.) The transistors used by the writer were from a batch of the unmarked and untested variety, obtained at 50 for ten shillings.

The audio output, via C_4 , may be fed to the gram input socket of a radio for further amplification before application to a loudspeaker, or a transistor output stage may be added to make the unit completely self-contained. If it is decided to add on an output stage, the author suggests that the components in the block

COMPONENTS

Resistors

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

| | |
|----------|-------------------------------------|
| R_1 | 2.7k Ω |
| R_2 | 2.2k Ω |
| R_3 | 5.6k Ω |
| R_4 | 5.6k Ω |
| R_5 | 2.2k Ω |
| R_6 | 1k Ω |
| R_7 | 22k Ω |
| R_8 | 22k Ω |
| R_9 | 1k Ω |
| R_{10} | 5.6k Ω |
| RV_1 | 100k Ω potentiometer, linear |
| RV_2 | 50k Ω potentiometer, linear |

Capacitors

$C_{1,2,3,4}$ 0.1 μF

Transistors

TR_1 OCP71 (see text)
 $TR_{2,3,4,5,6}$ (see text)

Switches

S_1 s.p.s.t. push-button
 S_2 s.p.s.t. toggle

Battery

9-volt battery

enclosed by the broken line be mounted separately with TR_1 . Since the device is essentially an alarm, no volume control has been provided.

The current drawn from the 9-volt battery in the untripped condition is of the order of 7mA. *

MULLARD DTL INTEGRATED CIRCUITS

Mullard Ltd. has received a further order from The English Electric Company Ltd., for 30,000 DTL integrated circuits for use in their Mark 2 Datapacs. This will bring the total number of these devices supplied by Mullard for use in Mark 2 Datapacs to more than 80,000 over a twelve month period.

The circuits are in ten lead TO-5 encapsulation and have been specially produced by Mullard to meet a stringent English Electric specification calling for a device with a high noise margin of 3V and capable of operating from a 12V d.c. supply rail.

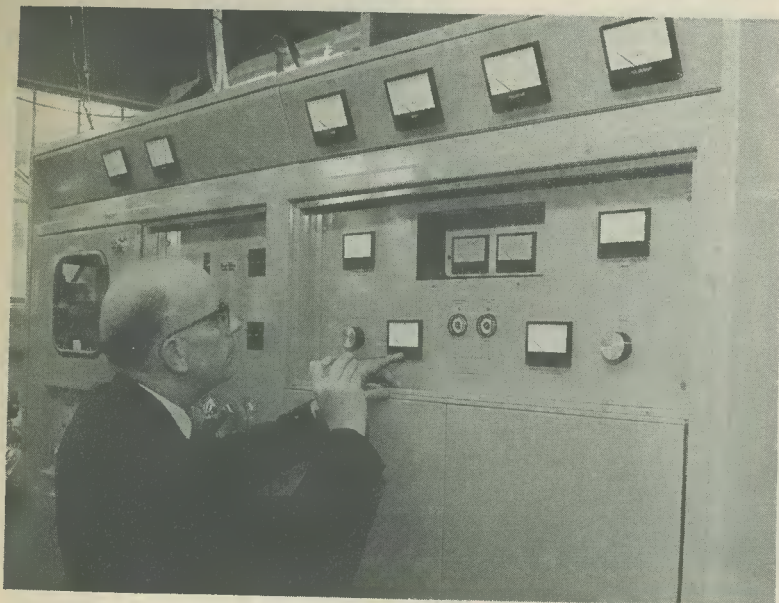
EMI PULSED TV

EMI Electronics have developed a pulsed television system, which demonstrates the ability of a new intensified-vidicon tube to operate in a high-speed pulsed mode. The equipment was one of fifteen exhibits at the Physics Exhibition, held at Alexandra Palace during March.

The intensifier section of the camera tube is gated "on" for a period of 25 microseconds every 20 milliseconds. The information stored during the gated period is then scanned off as in a conventional vidicon.

This is demonstrated by projecting a pulsed light, synchronised with the gated period of the camera tube, on to a constantly illuminated scene. The camera records the two images in proportion to their peak illumination levels and the pulsed source is clearly visible on the monitor. An observer, viewing the scene directly, is only able to compare mean illumination levels and the pulsed light source is not visible to him.

SIFAM INSTRUMENTS MONITOR NEW BBC 2 COLOUR TV TRANSMITTER



Sifam "Director" style measuring instruments being set at the works of Pye TVT Ltd., Cambridge, during prototype testing of a new colour television transmitter destined for the B.B.C. 2 network.

The 10 kw transmitter, one of a number, of various powers, due to be installed throughout the U.K. to extend coverage of the B.B.C. 2 colour programmes, incorporates many advanced features designed to enable the station to operate entirely unmanned. These include an automatic "solid-state" switching and control system. In the event of failure of either the sound or vision klystron amplifier, it will automatically arrange for both sound and vision to be switched through the remaining amplifier to continue transmission at reduced power.

More than 30 instruments, supplied by the Torquay manufacturers, Sifam Electrical Instruments Co. Ltd., are used throughout the installation to monitor the voltages and currents in the klystron amplifier. They enable inspecting engineers to see at a glance the electrical condition of the different parts of the transmitter thus speeding up considerably any corrective adjustments. In addition, of course, the overall performance is indicated.

INTERNATIONAL BROADCASTING CONVENTION 1968

The International Broadcasting Convention is next to be held in London from the 9th-13th September 1968, at the Grosvenor House Hotel, Park Lane, and will be sponsored jointly by the Electronic Engineering Association, the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (U.K. and Republic of Ireland Section), the Institution of Electronic and Radio Engineers, the Royal Television Society and the Society of Motion Picture and Television Engineers.

The Television Conference already announced by the learned societies for 1968 is incorporated within this Convention at which a wide cross-section of the latest broadcasting equipment will also be shown.

The Convention Secretariat address is to be:

The International Broadcasting Convention,
Savoy Place, Victoria Embankment,
London, W.C.2.

Further information may be obtained through any of the above mentioned bodies.

NEW SKEW-WOUND MICRO-MOTORS IN EXTENDED RANGE

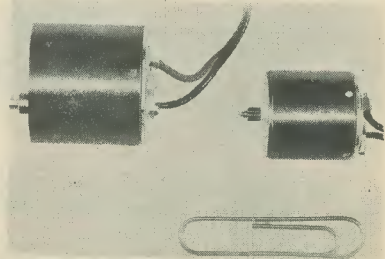
High output efficiency and low weight with extreme miniaturisation are the features of two new groups of d.c. electric motors in the revised and expanded Micromotors range.

There are three models in each group—designated 050 and 030—but all have a common configuration. Those in the 050 range have identical dimensions—diameter 15mm, length of casing 16mm and weight 12 grammes. Slightly larger, at 20mm diameter and 17mm long, are the three 030 models which weigh 20 grammes. By employing skew-winding with three rectangular coils and an ironless bell-shaped armature, there are two major advantages. Starting time can be speeded and the spindle diameter can be very small—reducing friction losses on the communication and giving low contact resistance between the precisely matched gold alloy bushes and the 95% silver alloy collector. Low friction idling results in high efficiency and long motor life.

Examples of performance from motors in each range are impressive. The 5,23c/m starting torque of the type 050/0055 motor develops to a specific torque of 29,40c/m/A with a starting time of 68ms. Its no load running speed of 19,100rpm can be reduced by slip-on gearboxes in the ratios 3,45:1; 11,8:1; 141:1, 5750:1.

With an armature resistance of 50hms and a measuring voltage of 3V, the 030/010 motor develops a specific torque of 16,90c/m/A. Fitted with gears to reduce the 17,300rpm no load running speed in the ratios 4:1; 15:1 and 59:1, the model's designation becomes 031/010; 032/010 and 033/010 respectively.

Comprehensive technical details of ten types of micromotors, all improved, are set out in a booklet available from the UK agents, B & R Relays Limited, of Temple Fields, Harlow, Essex.



The extreme miniaturisation of Micromotors in the new 050 and 030 range is illustrated by comparison with a paper clip. The smaller motor is an 050 type

COMMENT

BUGGING THE LECTURER

It is nothing very new these days to learn that hotel rooms, offices and the like have been "bugged" with hidden microphones or that telephones have been tapped. Recently however, Newmarket Transistors who market a range of miniature Packaged Circuit Amplifiers, heard of an interesting twist to the bugging idea. Instead of having a microphone planted unbeknown to him a University lecturer planted the microphone on himself!

This particular lecturer disliked, like many others we suspect, being interrupted by students entering the lecture room after he had begun his lecture. His answer to the problem was simple. He placed a microphone on his desk and connected it via a Newmarket PC Amplifier to a small speaker and push button switch on the door outside the lecture room.

Latecomers to the lectures now hold the switch down and listen to the lecture and wait for a suitable pause before entering. We have not yet had a report of half the class of students listening to the lecture outside the door!

This is perhaps one of the more unusual uses of a Newmarket Packaged Circuit—there are many more conventional ones, and to assist potential users the Company have produced fuller details of the complete range of PC's on pages suitable for insertion into their current Products Portfolio. Send to Newmarket Transistors Ltd., Exning Road, Newmarket, Suffolk for full details.

TOO LOW A MEMBERSHIP?

We have received a number of comments on the item, as above, which appeared in "News and Comment" in the March issue.

The comments included a letter of appreciation from the Radio Society of Great Britain. All the correspondents were in general agreement with what we said.

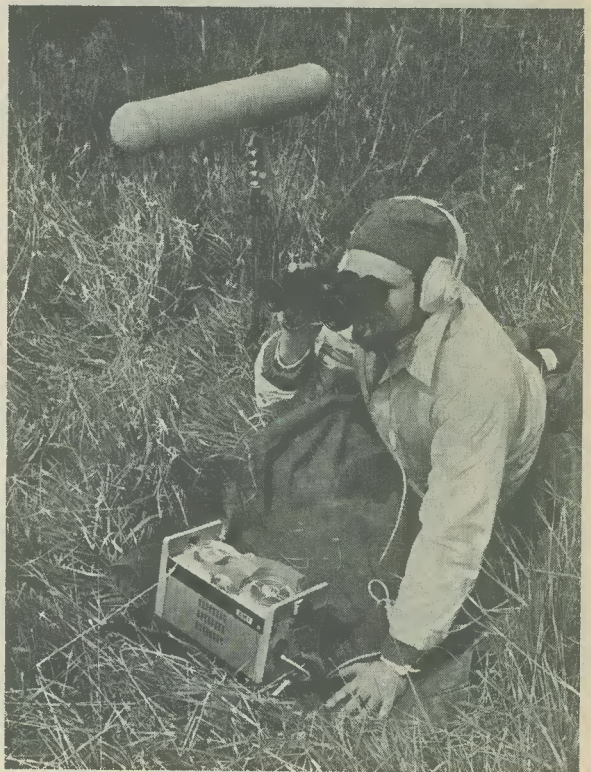
We understand that the Society has some 7,200 members who hold transmitting licences which is only 55%, approximately, of the total number of licence holders. In the U.S.A. the position is even worse the proportion being around 35%, but in Germany the D.A.R.C. have about 75% of the total as members.

It surely must be bad for amateur transmitters that the national society only represents a little over half their number when conducting negotiations with the government and various national and international bodies.



"Yes, it's about time you 'earthed' that old set!"

NOT STRICTLY FOR THE BIRDS



To record the songs of British birds, this enthusiast is using an EMI L4 tape recorder and a Sennheiser gun microphone

For tape recording enthusiasts, of which there are an estimated 40,000 in this country, one of the most rewarding and challenging of outdoor subjects is recording the songs of the 425 species of British birds. Not only is the sound source very small, but background noise must be filtered out. Patience and a highly directional microphone are the two greatest assets a would-be Ludwig Koch can possess, in addition to his high-quality portable tape recorder.

The EMI L4 recorder and the Sennheiser gun microphone, complete with its zeppelin-like windshield, is an excellent combination for this particular type of field work.

Used by television outside broadcast teams, the L4 produces recordings of broadcast-quality which can be monitored on headphones in either the record or replay modes. Weighing less than 11lb, the L4 incorporates many invaluable features including two microphone inputs with mixing facilities, bass-cut switch for reducing unwanted low-frequency noise and, for the cine-enthusiast, full or half-track film sync versions are available.

Next month's issue of *THE RADIO CONSTRUCTOR* contains something new in journalism. See announcement page 638.

SOME OF THE CALCULATIONS IN RADIO AND TELEVISION work are very unwieldy. A typical instance is given by the equation for two resistors in parallel:

$$R_x = \frac{R_1 R_2}{R_1 + R_2}$$

where R_x is the total resistance of R_1 and R_2 in parallel. Some means of easing this calculation would be very desirable.

Changing The Form

One possible way of doing this is to change the form of the mathematical expression involved. For instance

the term $\frac{R_1 R_2}{R_1 + R_2}$ can easily be changed to a more suitable form.

Suppose we put $R_2 = nR_1$ then,

$$\begin{aligned} R_x &= \frac{R_1 nR_1}{R_1 + nR_1} \\ &= \frac{R_1 2n}{R_1(1+n)} \\ &= \frac{R_1 n}{1+n} \end{aligned}$$

Applying this to two resistors of $R_1 = 100\Omega$ and $R_2 = 300\Omega$,

$$\begin{aligned} n &= \frac{300}{100} \\ &= 3 \\ \therefore R_x &= 100 \times \frac{3}{4} \\ &= 75\Omega. \end{aligned}$$

This form is advantageous because R_1 and R_2 are divided, one into the other, giving a small ratio which simplifies the operation, whereas multiplying R_1 and R_2 complicates it.

There is, however, another angle to the parallel resistor situation, namely that of adding a second resistor to an existing resistor to give a required result. In order to use the same notation as above, it is assumed that R_x is given as the required result, and that R_2 is the unknown.

Then,

$$\frac{R_x}{R_1} = \frac{n}{1+n}$$

but it is necessary to invert the expression to avoid working with negative signs. The result would be the same, but it is less convenient. Putting $\frac{R_1}{R_x} = p$, the

SIMPLIFYING CALCULATIONS

by

E. HUGHES

Our contributor describes an unusual and helpful approach to the perennial problem of evaluating parallel resistance and series capacitance

expression becomes:

$$\begin{aligned} pn &= n + 1 \\ \therefore pn - n &= 1 \\ \therefore n(p - 1) &= 1 \\ \therefore n &= \frac{1}{p - 1} \end{aligned}$$

Substituting this in $R_2 = nR_1$ gives:

$$R_2 = \frac{1}{p - 1} R_1$$

As an example, let us find the parallel resistance which, added to 100Ω gives a combined resistance of 25Ω .

$$\begin{aligned} p &= \frac{100}{25} \\ &= 4 \\ \therefore R_2 &= \frac{1}{3} \times 100 \\ &= 33.3\Omega. \end{aligned}$$

The same techniques can, of course, be used to simplify calculations for two capacitors in series, where similar basic equations are employed.



"KING KARAD" CAR AERIAL BOOSTER

Following the appearance of the "Car Aerial Booster Circuit" described in Suggested Circuit No. 208 in our March issue, we have been asked by Gordon J. King (Enterprises) Ltd. to mention that that Company holds Patent No. 1047484 dated 31st January 1964 which covers a variety of aspects dealing with the use of transistorised portables in cars. Whilst the article published in *The Radio Constructor* in no way infringes on this patent, potential manufacturers of car aerial boosters employing like principles should first ascertain that no patent infringement would be involved.

A new model of the King Karad booster, with improvements, is shortly to be launched. As with the present model this boosts signals from a car radio aerial over the entire long and medium wave bands as well as into the short wave bands. There is no switching or tuning required with either model, and both can be used with any type of receiver aerial input coupling, capacitive or inductive.



RC/DS17

RADIO CONSTRUCTORS DATA SHEET

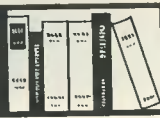
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INDUCTIVE REACTANCE—AUDIO FREQUENCIES

The Table gives reactance in ohms at the inductances and frequencies indicated. $X_L = 2\pi fL$. Use also in conjunction with Data Sheet No. 5 (published last month) as a rough guide for resonant circuits. Thus, 5H (3,140Ω) and 0.5μF (3,180Ω) will resonate near 100 c/s.

| Inductance | 25 c/s | 50 c/s | 100 c/s | 400 c/s | 500 c/s | 1 kc/s | 5 kc/s | 10 kc/s |
|------------|--------|--------|---------|---------|---------|-----------|-----------|------------|
| 250H | 39,300 | 78,500 | 157,000 | 628,000 | 785,000 | 1,570,000 | 7,850,000 | 15,700,000 |
| 100H | 15,700 | 31,400 | 62,800 | 251,000 | 314,000 | 628,000 | 3,140,000 | 6,280,000 |
| 50H | 7,850 | 15,700 | 31,400 | 126,000 | 157,000 | 314,000 | 1,570,000 | 3,140,000 |
| 25H | 3,930 | 7,850 | 15,700 | 62,800 | 78,500 | 157,000 | 785,000 | 1,570,000 |
| 10H | 1,570 | 3,140 | 6,280 | 25,100 | 31,400 | 62,800 | 314,000 | 628,000 |
| 5H | 785 | 1,570 | 3,140 | 12,600 | 15,700 | 31,400 | 157,000 | 314,000 |
| 2.5H | 393 | 785 | 1,570 | 6,280 | 7,850 | 15,700 | 78,500 | 157,000 |
| 1H | 157 | 314 | 628 | 2,510 | 3,140 | 6,280 | 31,400 | 62,800 |
| 500mH | 78.5 | 157 | 314 | 1,260 | 1,570 | 3,140 | 15,700 | 31,400 |
| 250mH | 39.3 | 78.5 | 157 | 628 | 785 | 1,570 | 7,850 | 15,700 |
| 100mH | 15.7 | 31.4 | 62.8 | 251 | 314 | 628 | 3,140 | 6,280 |
| 10mH | 1.57 | 3.14 | 6.28 | 25.1 | 31.4 | 62.8 | 314 | 628 |
| 1mH | 0.157 | 0.314 | 0.628 | 2.51 | 3.14 | 6.28 | 31.4 | 62.8 |
| 100μH | 0.0157 | 0.0314 | 0.0628 | 0.251 | 0.314 | 0.628 | 3.14 | 6.28 |
| | | | | 0.251 | 0.314 | 0.628 | 3.14 | 6.28 |
| | | | | 0.0628 | 0.0314 | 0.0628 | 0.628 | 6.28 |

RECENT PUBLICATIONS



COLD CATHODE TUBES. By J. B. Dance, M.Sc., B.Sc. 125 pages, $5\frac{1}{2} \times 8\frac{3}{4}$ in. Published by Iliffe Books Ltd. Price 33s.

Regular readers require no introduction to the author of this book, who has contributed many articles to *The Radio Constructor* over the last eight years. In *Cold Cathode Tubes* J. B. Dance deals with a subject which by no means always receives the attention it merits.

The number of cold cathode tubes in use today cover a multitude of applications, these ranging from the simple neon bulb to the laser and the Geiger-Muller tube. All tubes employing cold cathodes are dealt with in detail in the work under review, and the approach is practical and concise with a minimum of mathematics. The nine chapters in the book deal with fundamental principles, gas discharge lamps and diodes, trigger tubes, the glow thyatron, voltage stabilisation, stepping tubes, indicator tubes, detectors for nuclear radiation and high current tubes. Included in this wide array are such esoteric types as the Cerberus "touch button" which ionises and energises a relay when its envelope is touched, the Multi-Gap Stabiliser which offers four stabilised voltages (70, 140, 210 and 280 volts) from a single tube, and the Digitube which can be connected to a collector in a transistor bistable and glows for one state of that bistable. Where necessary, circuit diagrams are provided for the applications discussed.

The book has been carefully planned, gives useful references for further reading, and has an excellent index. It can be recommended with confidence for anyone, whether amateur experimenter or professional engineer, who seeks guidance in an interesting and rewarding branch of present-day electronics.

EVERYMAN'S WIRELESS BOOK. Revised by R. E. F. Street. 368 pages, $5 \times 7\frac{1}{4}$ in. Published by George Newnes Limited. Price 21s.

The first edition of *Everyman's Wireless Book* appeared in 1934, and it has passed through many editions since that year. This is the fourteenth, and it incorporates a text which has been completely revised by R. E. F. Street. Very little material has been retained from previous editions.

The title of the book might give the impression that it is intended for the layman, but this is by no means entirely the case since it contains much that will be of value to the fairly experienced amateur experimenter and constructor. There is an opening chapter which introduces readers to the theory of radio reception and electrical circuits, followed by two chapters on resistors and capacitors. There is also a chapter on soldering—an essential subject for anyone who intends to embark on home-construction or servicing.

The equipment covered by the book consists of domestic sound radio receivers and record reproducers. A great deal of attention has been paid to servicing, as it is felt by Mr. Street that this is where the amateur needs most advice. A chapter near the end of the book deals with moving-coil meters and the testmeter circuits in which they may be used, whilst the final chapter is devoted to useful data and circuit symbols.

BETTER SOUND—STUDY NOTES. 16 pages, $5\frac{1}{2} \times 9\frac{1}{4}$ in. Published by the British Broadcasting Corporation. Price 2s. 6d.

Readers may already be aware of the series of broadcasts under the title "Better Sound" which is to be transmitted by the B.B.C. This series, consisting of four programmes, is scheduled for Fridays at 7.00 to 7.30 p.m. from May 3rd to 24th, in Study Session on the Radio network. The four programmes will be repeated on Saturday mornings at 11.00 to 11.30 a.m. on Radio 4 from August 17th to September 24th (excluding August 31st, which falls on the Bank Holiday). There will also be two additional programmes on Saturdays, September 21st and 28th, to deal with requests from listeners for more information. The aim of the series is to enable listeners to get the best from their hi-fi equipment, tape recorders and radios.

The publication under review provides background information for the transmitted programmes, and is particularly intended for the less technical person. Most of its pages are devoted to sound reproduction and recording from the aspect of the loudspeaker and microphone. There is, for instance, very useful advice on the best positioning of a loudspeaker or microphone in ordinary rooms or classrooms for obtaining maximum clarity. Further subjects dealt with are mono and stereo reproduction, hi-fi equipment, and the advantages of reception.

Obviously, the booklet complements the B.B.C. "Better Sound" transmissions, but it is nevertheless a helpful publication in its own right. It may be obtained direct from B.B.C. Publications at 2s. 6d. plus 5d. postage.

AUDIO ANNUAL 1968. 130 pages (44 advertisements) $8\frac{1}{2} \times 11$ in. Published by Link House Publications Ltd. Price 7s. 6d.

This publication is similar to *Hi-Fi News*, with the same type of magazine cover and presentation of contents. It includes seven articles by leading writers in the hi-fi world, these dealing with subjects including concert hall acoustics, equalisation and the problems of hi-fi retailing.

There is also a large section (of some 58 pages) containing reviews of commercially manufactured equipment, this carrying 37 reprints of reports previously published in *Hi-Fi News* and *Tape Recorder* during 1967. *Audio Annual 1968* will have greatest appeal for the audiophile, but it also has useful value as a reference work for those who deal with hi-fi equipment only on occasion.

(Continued on page 631)

IN this article it is proposed to describe a means by which echo effects may be achieved with an ordinary tape recorder. The requirements are minimal, and the whole thing may be done at quite a low cost. Before plunging into constructional details, a brief description of general echo techniques may be in order.

Adding Echo to a Tape Recorder

by J. CRAWLEY

Echo Techniques

There is some confusion between the two effects "echo" and "reverberation". Echo consists of successive repetitions of the original sound, each somewhat fainter than the one before, so that they die away within a certain time. Reverberation imitates the effect of a large hall or cavern and sustains the incoming signal for a short period after it has ceased, thus simulating the "reverberation time" of a large room and giving "spaciousness" to the sound. Indeed, employed in moderation, reverberation may be used in a Hi-Fi set-up to imitate the acoustics of a concert hall, even in a small room.

This second effect can be achieved in several ways. The most common

A tape recorder can be made to provide interesting and pleasing echo effects and, in this article, our contributor describes an approach he has used successfully. It must be emphasised that it is necessary to fit an additional head to the tape recorder and that this may not be possible with all machines; also, the constructor has to plan and make the necessary modifications himself. Some experiment may be required before the desired final effect is achieved

added is an extra tape head, and a matching and equalising preamplifier. It may be added that the tape recorder employed by the writer was a home-

Working System

The block diagram of the system is shown in Fig. 2, and is intended for use when it is desired to reproduce the original input, with added echo, at the same time as it is applied to the system. The existing tape recorder is set to Record, and a tape loop, whose length is immaterial, is allowed to move past the heads. An auxiliary head is affixed to the deck in a suitable position after the existing heads and the tape loop passes this also. The incoming signal from the microphone (or guitar or what-have-you) is recorded on to the tape by the recorder and is heard, at the same time, over the loudspeaker. This is presuming that the recorder has a "monitor" outlet socket or facilities for hearing the recorded signal over the recorder's loudspeaker. Otherwise, an external

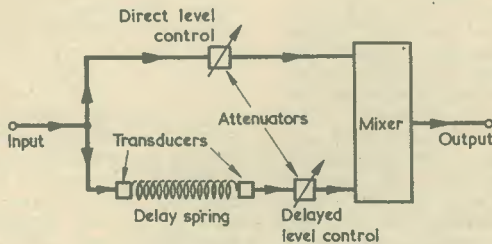


Fig. 1. A simple means of obtaining reverberation

method is to use a coiled metal spring to delay the signal, with electro-mechanical transducers at each end. Possible transducers could be of the piezoelectric ceramic type (say, converted pick-ups). If an incoming signal is divided between a direct path to the output and a path delayed by its passage through the spring, then the delayed signal will be heard a fraction of a second after the original. It is quite easy to adjust the relative levels of the two signals to achieve the desired effect (see Fig. 1). Another way of arriving at roughly the same effect is to use a room with smooth walls, rather like a bathroom, with a loudspeaker at one end, and a microphone at the other!

However, the system to be described in this article uses a tape deck, and provides the first effect, that of "multiple echoes". Reverberation is also possible, depending on head spacing and tape speed, but the character of the effect is different, lacking the uneven response and odd resonances of the coiled spring method. The cost is not too high if a tape recorder capable of being modified is available, since all that must be

built set-up, using a Stern-Clyne "Double-Feature" preamplifier, a Stern-Clyne "JL-10" power amplifier and a ½-track Magnavox "363" tape deck.

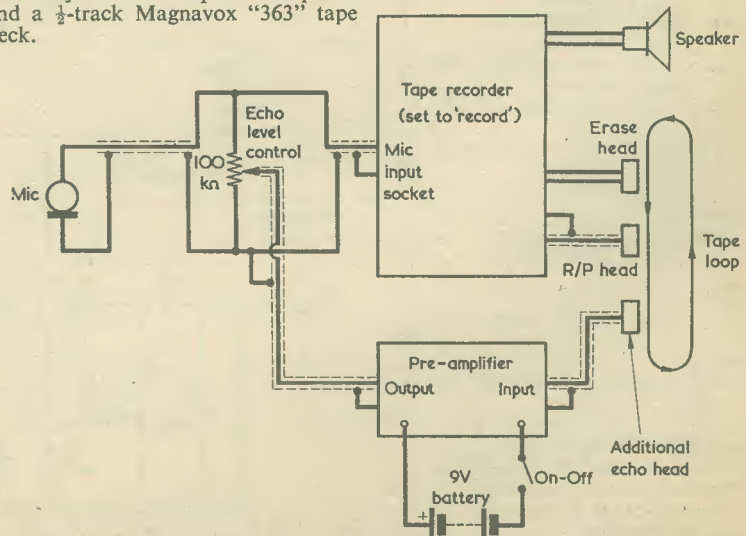


Fig. 2. The basic system for adding echo. A tape loop is employed when it is desired to reproduce the input signal with echo at the same time that it is applied

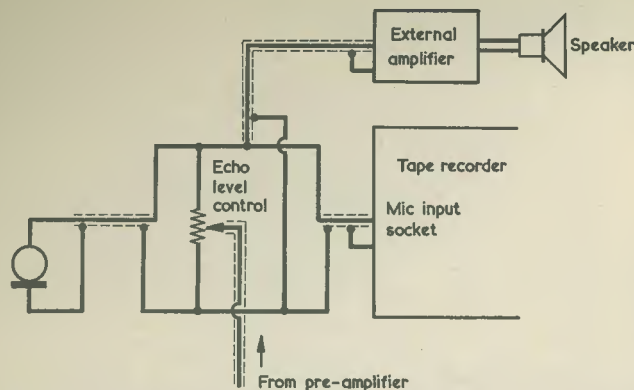


Fig. 3. If the tape recorder has no loudspeaker output facility on "Record", an external amplifier should be coupled into circuit

COMPONENTS

(Fig. 4)

Resistors

(All fixed values high-stability, 1/4 watt, 5%)

- R₁ 68kΩ
- R₂ 10kΩ
- R₃ 10kΩ
- R₄ 12kΩ
- R₅ 270Ω
- R₆ 1.8kΩ
- R₇ 2.2kΩ
- R₈ 560Ω
- R₉ 680Ω
- R₁₀ See text

Echo Level Control (Fig. 2)
100kΩ potentiometer, linear

Capacitors

- C₁ 10μF electrolytic, 16V wkg. (Mullard)
- C₂ 64μF electrolytic, 10V wkg. (Mullard)
- C₃ 100μF electrolytic, 4V wkg. (Mullard)
- C₄ 160μF electrolytic, 10V wkg. (Mullard)
- C₅ 500μF electrolytic, 12V wkg.
- C₆ 0.1μF paper or polyester
- C₇ 0.01μF polyester

Transistors

- TR₁ OC44 (Mullard)
- TR₂ OC44 (Mullard)

Switch

- S₁ s.p.s.t. on-off switch

Battery

- 9-volt battery type PP3 (Ever Ready)

Miscellaneous

- Tape head, medium impedance, general purpose (see text)
- Veroboard, 0.2in matrix, 2 1/2 x 1 1/2 in (see Fig. 5)
- Screened wiring, mounting for additional head, etc.

power amplifier may be used, as in Fig. 3.

If a recording is to be made, and the echo is not required live, then a normal continuous reel is used in place of the loop.

The signal, having been fed on to the tape loop, is picked off again by the auxiliary replay head and transferred back to the "mic input" socket, via the transistorised preamplifier, thus introducing a delay which depends on the tape speed and the head spacing. The delayed output from the preamplifier is mixed with the incoming signal and passes on to the power amplifier and speaker. Since the recording take-off comes after the echo feed-in, the echo will be recirculated until it dies away. The result is a pleasing "multiple echo" effect. If the record level control on the tape recorder or the echo level control of Fig. 2 is set too high, so that the loop gain of the system is greater than unity, the

echoes will build up instead of dying away and the system will oscillate in a manner rather reminiscent of a "sonar" echo sounder.

In the writer's version of the system shown in Fig. 2 a microphone was used, this being a dynamic type with built-in transformer offering an output impedance of 50kΩ. The echo level control presents too low a resistance for a crystal microphone. The output impedance of the echo preamplifier is low, but it is not normally necessary for the echo level control to be turned sufficiently high for this impedance to seriously reduce that into which the microphone works. The "mic input" of the tape recorder amplifier is high, at approximately 1MΩ.

Transistor Preamplifier

The circuit of the transistor preamplifier following the additional head is shown in Fig. 4. The configuration is a direct coupled 2-transistor circuit, with d.c. negative feedback, and was based by the writer on a circuit recommended by Sinclair Radionics Ltd. A.C. feedback is provided from TR₂ collector to TR₁ emitter, via R₁₁ and C₇, to equalise the frequency response from the tape head. The value of R₁₀ should be chosen to suit the tape speed to be used. At 7 1/2 i.p.s. it is 6.8kΩ; at 3 1/2 i.p.s. it is 15kΩ; and at 1 1/2 i.p.s. it is 27kΩ.

The amplifier may be built on a piece of Veroboard with a 0.2in hole matrix, and a suitable layout is shown in Fig. 5. The copper may be easily cut with an ordinary pen-knife to achieve the strip geometry required. Because of the small size of the board employed, and to achieve high density packing, most components are mounted vertically. It is best to solder in the resistors first, these being the least heat-susceptible; then the capacitors should follow, the

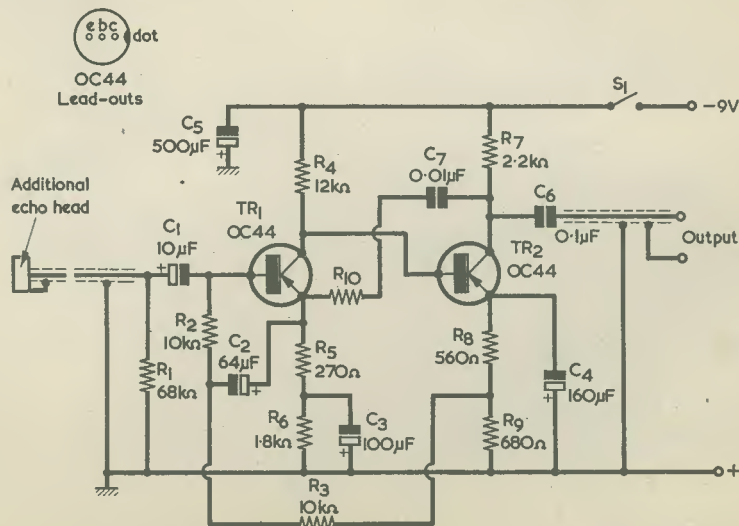


Fig. 4. The circuit of the preamplifier which follows the additional echo head

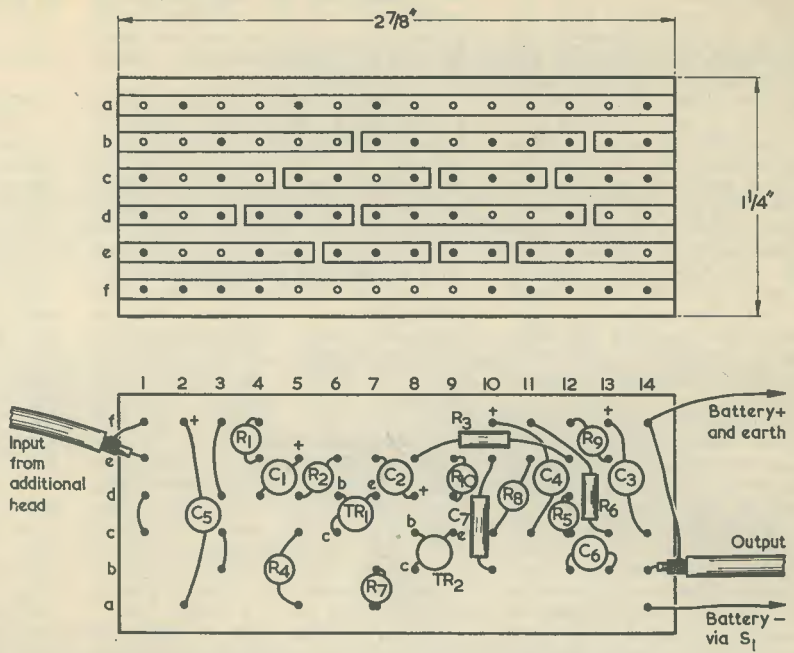


Fig. 5. The copper and component sides of the Veroboard panel on which the preamplifier is assembled. Switch S_1 is external to the board

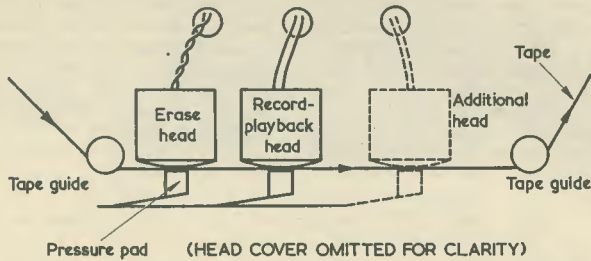
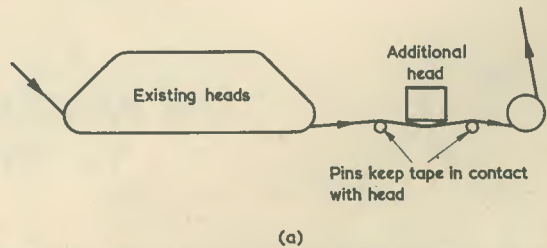
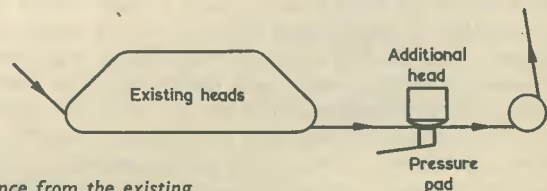


Fig. 6. The basic layout when the additional head immediately follows the existing heads



(a)



(b)

Fig. 7 (a). If the additional head is positioned some distance from the existing heads, the method shown here may be used to keep the tape in contact with the head

(b). Alternatively, a pressure pad assembly may be fitted at the additional head

electrolytic capacitors having their positive ends nearer the board. The two transistors should be last, not forgetting to use heat shunts during soldering. It may be wondered why the unused sections of the board near the input connection are shown as earthed in Fig. 5, but the writer considered it desirable to have a certain amount of earthed metal around the sensitive input end of the preamplifier.

With reference to the Components List, high stability resistors were chosen to cut down noise in this low level circuit. If the OC44's are found to be too noisy a different specimen may be tried. The writer has found that an alternative, the GET 880, offers low noise in a circuit of this type. The values of the electrolytic capacitors are not critical.

Once the board is complete it may be wired into circuit. The main thing to watch is capacitive feedback from TR₂ collector to TR₁ base, since the phasing of the transistors is such as to promote positive feedback, and hence oscillation, if any coupling between the leads occurs. Since both the input impedance and sensitivity are high it is easy for feedback to occur, so that screened input and output leads should be used. The lead from the tape head should be fairly short, since treble loss may occur in the capacitance of a long length owing to the high input impedance. The output lead is connected to the 100k Ω echo level control of Fig. 2, the centre core to the middle tag, and the screening to the lower tag. The two outer tags are connected across the "mic input" of the tape recorder, in parallel with the microphone output, ensuring that the tag which connects

with the screening of the cable from the preamplifier is connected to the earthy side of the amplifier input socket. To reduce hum, the echo level control and its immediate wiring should also be screened.

A suitable battery for the unit is a PP3, since the current drawn is only a few milliamps. If there is room available in the tape recorder, the preamplifier and battery (not forgetting the on-off switch) may be housed inside, together with the echo level control. However, if the recorder is a valve model it is probably advisable, to avoid hum pick-up, to house the preamplifier in a tobacco tin, or something similar. Alternatively, the echo amplifier and associated controls may be housed separately, and plugged in when required.

The Additional Head

The additional head requires to be a general purpose medium impedance type, and the choice is fairly wide. However, a head that provides a fairly high output is preferable, and a good choice with a $\frac{1}{2}$ track recorder would be the Marriott R/RP1. This is available from Henry's Radio, Ltd.

There is often room in the tape recorder for the third head immediately after the record-playback head. This space can be utilised to mount the echo head, as in Fig. 6. The result of this positioning, especially at the higher tape speeds, will be an effect tending towards reverberation, providing a "cavernous" impression. Alternatively, the second head may be mounted up to 6in away from the other heads, as in Fig. 7 (a) or (b). In this case, some sort of tape guiding arrangement must be provided,

together with a pressure pad or some other form of tensioning to keep the tape in constant contact with the head. This arrangement will provide the multiple echo effect.

Setting-Up

To set up the equipment it is only necessary to supply a signal to be echoed. The echo level control and the record level control (on the tape recorder) are then adjusted until the echoes take the desired time to die out. The noise introduced into the system by the preamplifier can be reduced by setting the record level control high, and the echo level control fairly low, but if this is carried too far overloading of the preamplifier or tape will result. It will probably be found that a fairly fast repetition rate gives the most pleasing results, calling for a rapid tape speed or close head spacing.

If results are disappointing, with a lack of treble in the echo resulting in a rapidly increasing muffled quality, then it is likely that the echo head is not aligned correctly, azimuth adjustment being important. By adjusting the angle of the head gap relative to the tape, the optimum position will soon be found.

The apparatus described in this article should, if fitted correctly, give good results on a tape recorder, providing a fascinating and entertaining effect which is particularly helpful for electronic music. The original apparatus has been used very successfully to provide an echo effect for the voice of "Marley's Ghost" in an amateur production of "A Christmas Carol".



EMI WINS MALAYAN TV ORDER

EMI Electronics have recently won a major share of a contract to equip the largest centralised broadcasting complex in south-east Asia. In strong competition with American and Japanese manufacturers, EMI secured the £180,000 order for the mixing, switching and communications equipment in the Malaysian Government's new television and radio centre at Pantai Valley, Kuala Lumpur. Programmes, in several languages, will be broadcast from Pantai Valley and networked throughout the Malay peninsula.

The EMI installation includes the Master Control, with sound and vision mixers, a Transicom studio intercommunications network, the pulse system and test gear. The Master Control receives input signals from four main studios, a network and two continuity suites, four telecine machines and video tape recorders, routing the final broadcast signal to two programme channels and a feed to network.

Consultants for the Pantai Valley scheme are N. J. Pappas & Associates of Montreal, Canada. The installation will be completed by November, 1968.

Getting the Best from your Oscilloscope

by
D. J. GRIFFITHS

Part 1

This article is the first of a four-part series which is specifically intended to illustrate how maximum advantage can be taken of the oscilloscope. In this issue our contributor describes two ways in which the oscilloscope may be used for frequency determination

MANY CONSTRUCTORS REALISE THE TREMENDOUS value of an oscilloscope and the rise in popularity of this instrument over recent years has been enormous. This versatile instrument is often, wisely, constructed soon after the "first" general purpose testmeter, but many enthusiasts are unfamiliar with all that it can offer. The purpose of this series of articles is to explain in as few words as possible how the constructor can get the best out of his 'scope.

We shall deal, this month, with frequency determination.

Frequency Determination By Lissajous Figures

Lissajous patterns are caused by alternating voltages applied to both plates of the oscilloscope c.r.t., and may be used for frequency determination. If a sine wave of 50 c/s is applied to both X and Y plates, a figure similar to either Fig. 1 (a), (b) or (c) will be produced, according to the phase difference between the sine waves. When both inputs are at *exactly* the same frequency the pattern remains stationary, but with slight differences in frequency the figure will appear to rotate, passing through all three modes.

If the frequency applied to the vertical plates, which we shall call F_y , is doubled to 100 c/s a pattern similar to either Fig. 2 (a), (b) or (c) will be given, depending on the phase relationship of the two signals. The ratio of F_y to F_x (the frequency applied to the horizontal plates) may be determined by drawing tangents to the

top side of the figure and counting the number of loops touching each tangent, as in Fig. 3 (a). The following equation is then applied:

$$F_x = \frac{\text{No. of loops touching horizontal tangent}}{\text{No. of loops touching vertical tangent}}$$

The known frequency is normally applied to the horizontal plates, and the unknown to the vertical plates, so we then work from the equation.

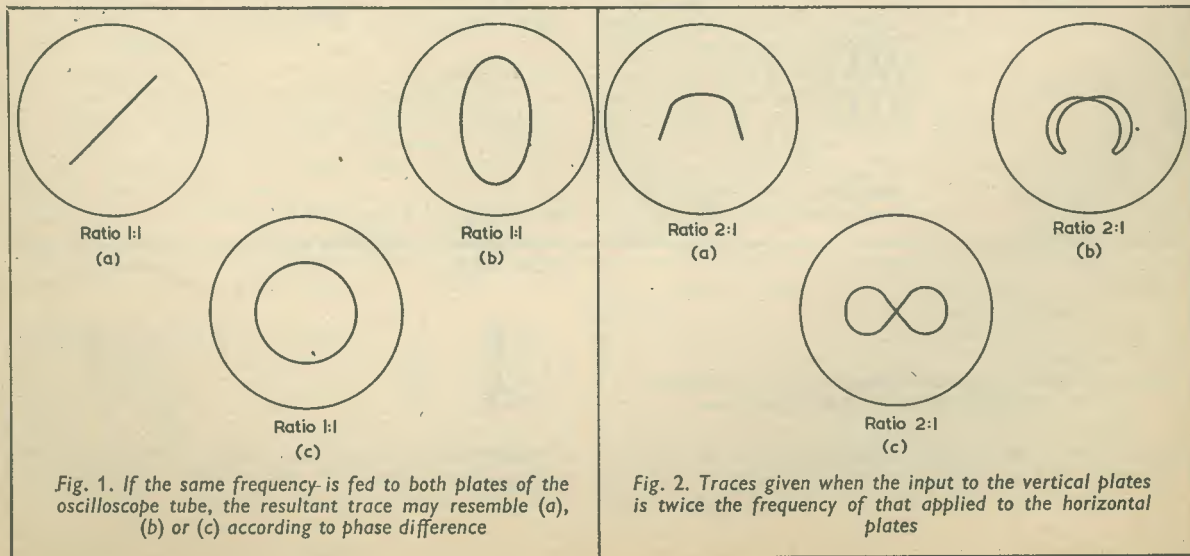
$$F_y = \frac{F_x \times \text{No. of loops touching horizontal tangent}}{\text{No. of loops touching vertical tangent}}$$

Application of this formula makes the interpretation of Figs. 3 (b) and (c) quite clear. In Fig. 3 (b) the unknown frequency is 3 times the known frequency, and in Fig. 3 (c) it is 5 times the known frequency.

In Fig. 4 (a) we have one loop touching the horizontal tangent and two loops touching the vertical tangent. F_y is therefore F_x multiplied by $\frac{1}{2}$. In other words the unknown frequency is half the known frequency. In Fig. 4 (b) F_y is $\frac{1}{3}$ of F_x .

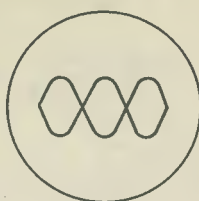
The Lissajous patterns of Figs. 3 and 4 may be used for ratios up to 5:1 or 1:5. Higher ratios will be more difficult to interpret, particularly if they cannot be kept stationary.

The figures considered up to now are for whole number ratios. Fractional ratios can also be indicated by Lissajous figures. Typical instances are given in Fig. 5 where the ratio of $F_y:F_x$ is 3:2 in (a), 3:4 in (b) and 5:2 in (c). It will be noted that the 5:2 ratio is quite complicated. In the interests of accuracy it is

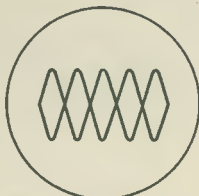




Ratio 2:1
(a)



Ratio 3:1
(b)



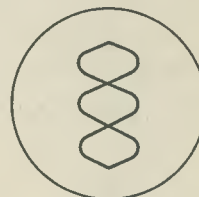
Ratio 5:1
(c)

Fig. 3. The frequency ratio may be determined as shown in (a). The trace given for a vertical frequency three times horizontal frequency is illustrated in (b), and that for a vertical frequency 5 times the horizontal frequency in (c)

Fig. 4. The oscillogram given when the vertical frequency is (a) half the horizontal frequency and (b) one-third of the horizontal frequency



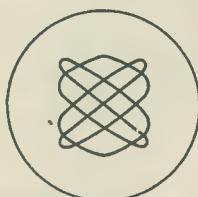
Ratio 1:2
(a)



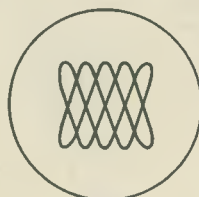
Ratio 1:3
(b)



Ratio 3:2
(a)



Ratio 3:4
(b)



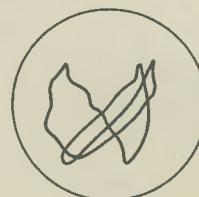
Ratio 5:2
(c)

Fig. 5. Vertical to horizontal ratios of: (a) 3:2, (b) 3:4 and (c) 5:2

Fig. 6. Harmonics on either input can cause distortion of the Lissajous figure, as demonstrated here



Ratio 3:1
(a)



Ratio 3:2
(b)

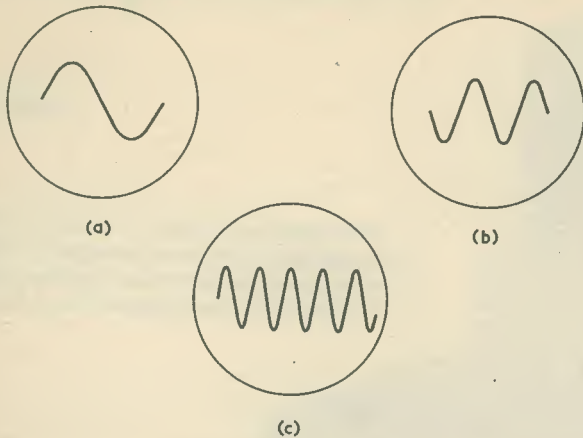
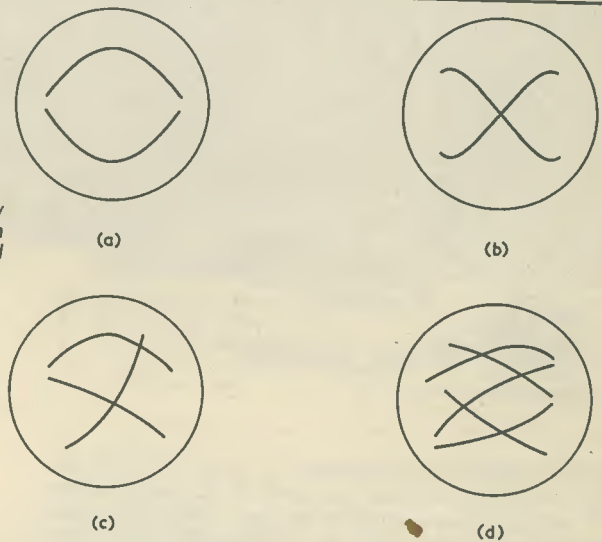


Fig. 7. An approximate measure of a frequency may be obtained by comparing it with horizontal sweep frequency. In (a) the unknown frequency is the same as sweep frequency, in (b) it is twice and in (c) it is five times the sweep frequency

Fig. 8. Typical traces given when the unknown frequency is a fraction of sweep frequency. In (a) and (b) the unknown frequency is half sweep frequency, in (c) it is one-third and in (d) it is one-fifth of sweep frequency



preferable to avoid attempting to interpret more complicated figures.

If frequency ratios are not exact, the pattern will change in shape as the phase relationships alter. As this happens, some of the loops may not appear in their entirety when two of their sections coincide. Readings should only be taken when all loops are fully and obviously exposed.

Occasionally, one or more harmonics are present in one or both inputs, whereupon considerable distortion of the Lissajous figure may result. Typical instances are illustrated in Figs. 6 (a) and (b).

Comparison With Sweep Frequency

An approximate measurement of frequency may be made by comparing the unknown frequency with the horizontal sweep frequency. To obtain reasonable accuracy the horizontal timebase should be unsynchronised; but this method still gives a good approximation with a synchronised timebase, and is often used to obtain a quick approximation of the unknown frequency. The main advantage of this method is that the frequency of quite complicated waves may be

determined easily, especially if the sweep is "slower" than the unknown frequency.

In Fig. 7 (a) the unknown frequency is the same as the sweep frequency. In Fig. 7 (b), in which two full cycles appear, the unknown frequency is twice the sweep frequency, whilst in Fig. 7 (c) it is five times the sweep frequency. As is to be expected, a small fraction of the unknown frequency is "lost" during flyback.

When the unknown frequency is a fraction of the sweep frequency, a number of lines appear on the screen, this number corresponding to the number of times sweep frequency is higher than the unknown frequency. Thus, in Figs. 8 (a) and (b), there are two lines, which means that the unknown frequency is half the sweep frequency. In Fig. 8 (c) there are three lines, indicating that the unknown frequency is a third of the sweep frequency; whilst in Fig. 8 (d) there are five lines, showing that the unknown frequency is one-fifth of sweep frequency. The lines may take up different positions on the screen to the examples illustrated in Fig. 8.

(To be continued)

Oscilloscope Voltage

by H. T. KI



Intended primarily for use with an oscilloscope waveform whose voltage is closely controlled, accurate for routine frequency measurements; diode network which ensures that a square



Cover Feature

THE SMALL UNIT DESCRIBED IN THIS ARTICLE WAS originally designed and built to provide a series of reference voltages for an oscilloscope that lacked these facilities. It was subsequently found that, provided two precautions were observed, the frequency stability was of a sufficiently high order to enable many of the routine frequency measurements required in the amateur home laboratory or workshop to be carried out. The prototype was built on a printed circuit board measuring $1\frac{1}{2} \times 2\frac{1}{2}$ in, this being fitted inside the author's oscilloscope.

Circuit Operation

The circuit is shown in Fig. 1. As will be seen, the unit consists of a pair of switching transistors connected as a free-running multivibrator. The frequency of oscillation is determined by the values of R_2 , C_1 and R_3 , C_2 . These components have values which cause the operating frequency to be approximately equal to 1 kc/s.

The output of the multivibrator, at TR_2 collector, is close to a true square wave, but it is nevertheless too distorted to be useful for the present application. The distortion is removed by the diodes D_1 and D_2 , as is described later.

The lengths of successive peaks and troughs in the square wave is known as the mark-space ratio, or m.s.r., and is determined by the values of R_2 , C_1 and R_3 , C_2 . The m.s.r. will be 1:1 when R_2 is equal to R_3 ,

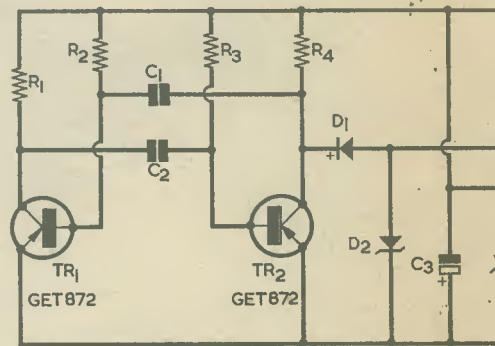
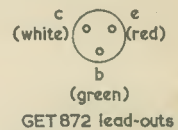


Fig. 1. The circuit of the combinator unit. The diodes D_1 and

Resistors

(All fixed values $\frac{1}{2}$ watt 5% high-stability)

- R_1 1k Ω
- R_2 33k Ω
- R_3 33k Ω
- R_4 1k Ω
- R_5 9k Ω
- R_6 900 Ω
- R_7 90 Ω (or 91 Ω)
- R_8 10 Ω
- R_9 120 Ω (see text)
- VR_1 5k Ω skeleton preset, vertical mounting

Capacitors

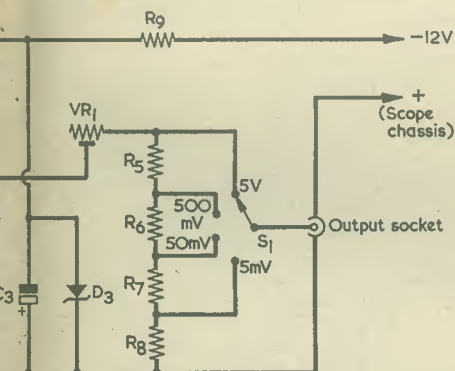
(All 12V wkg. or more)

- C_1 0.02 μ F Mylar or polyester
- C_2 0.02 μ F Mylar or polyester
- C_3 100 μ F electrolytic

Age/Time Calibrator

KITCHEN

scope, this calibrator unit offers an output controlled and whose frequency is sufficiently elements. A particularly attractive feature is a square wave of good waveform is produced



es D_1 and D_2 ensure that a good square wave is produced

COMPONENTS

Semiconductors

- TR₁, TR₂ GET 872
- D₁ Silicon diode, OA202 (Mullard) or similar
- D₂ 5.6 volt 5% zener diode (Radiospares), or OAZ242 (Mullard)
- D₃ 9.1 volt 5% zener diode, OAZ207 (Mullard)

Switch

- S₁ 1 pole, 4 way, rotary

Miscellaneous

- Coaxial output socket
- Knob, for switch
- Printed circuit board, 1½ x 2½ in

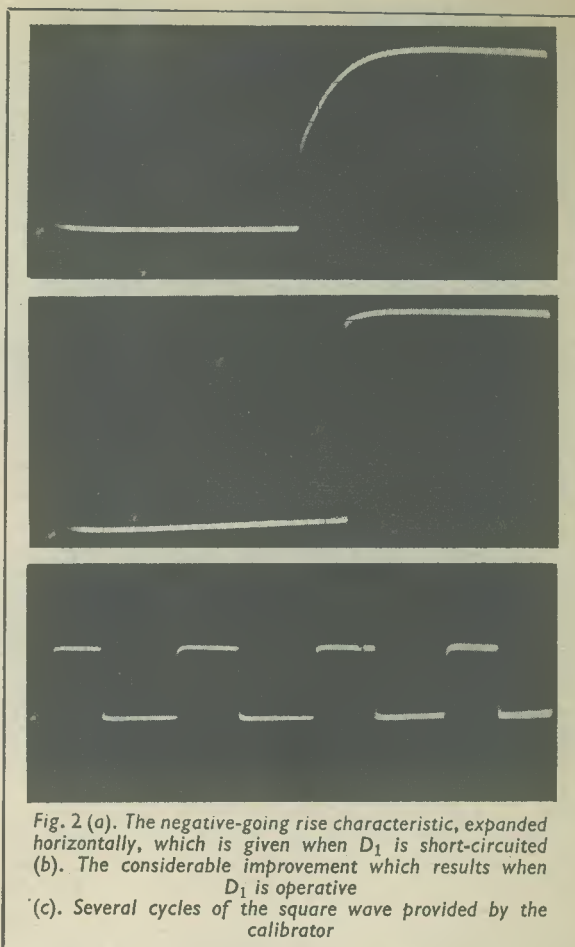


Fig. 2 (a). The negative-going rise characteristic, expanded horizontally, which is given when D_1 is short-circuited (b). The considerable improvement which results when D_1 is operative (c). Several cycles of the square wave provided by the calibrator

C_1 is equal to C_2 , and TR₁ is equivalent to TR₂. For applications where the unit is to be used as a frequency reference, the m.s.r. should be as close to 1:1 as possible. Otherwise, errors will creep in where, for example, the start of a peak is used as a first reference and the start of a trough as a subsequent reference. When the unit is to be used solely as a voltage reference, the m.s.r. can be ignored. It must be confessed, however, that the writer personally prefers an m.s.r. of 1:1 even if only because it looks much more "tidy" on the oscilloscope screen!

If D_1 and D_2 were not in circuit, the waveform at the collector of TR₂ would vary from virtually the negative supply voltage of about 9 volts (stabilised by D_3) when the transistor is cut off, to within a volt or so of the positive supply line when the transistor is fully bottomed. This represents an amplitude in the region of 7.5 volts peak-to-peak. The negative excursion is, however, limited by the silicon diode D_1 and the 5.6 volt zener diode D_2 , and the clamp provided by these two diodes results in the production of an excellent square wave across the zener diode. It might be thought that diode D_1 is not required, and that D_2 would provide sufficient clamping of the negative-going signal on its own. In practice, D_1 considerably sharpens up the negative-going rise, as is shown by the waveforms in Fig. 2. Fig. 2 (a) shows, in expanded form, the rising section of the waveform across D_2 with D_1 short-circuited, whilst Fig. 2 (b) illustrates the rising section

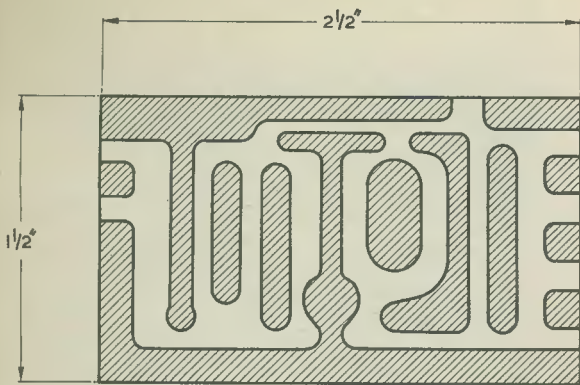


Fig. 3. The copper side of the printed circuit board, with the copper areas shown shaded. This is reproduced full-size and may be traced directly

with D_1 operative. The improvement in wave shape provided by D_1 is very evident. Fig. 2 (c) shows several cycles of the waveform across D_2 when D_1 is in circuit, and it will be seen that this has very good rise and fall sections, flat tops and a good mark-space ratio.

Apart from its role in "cleaning up" the waveform, D_2 carries out a second important function. This is that of stabilising the amplitude of the square wave before it is passed to the attenuator given by VR_1 and R_5 to R_8 . Output amplitude stabilising is assisted by zener diode D_3 , which holds the supply potential for TR_1 and TR_2 steady at about 9.1 volts. Thus, the amplitude of the waveform at TR_2 collector would be reasonably constant without D_2 in circuit. D_2 operates, after a circuit having standard supply voltage conditions, whereupon the final waveform amplitude obtained has an extremely high stability. The presence of D_3 also assists, incidentally, in maintaining oscillator frequency stability.

The waveform across D_2 is next applied to the attenuator section. Since D_2 is rated at 5.6 volts $\pm 5\%$, the peak-to-peak amplitude obtained across this diode will depend upon the actual component employed. The preset variable resistor, VR_1 , is set up so that exactly 5 volts peak-to-peak appears across R_5 to R_8 . These resistors have values which then enable S_1 to "tap off" waveforms having peak-to-peak amplitudes of 5 volts, 500mV, 50mV, or 5mV.

As a result of the method of construction adopted, stray capacitances are kept to a very low order. The wave shape, as viewed on a 6in wide oscilloscope screen, remains substantially unaltered irrespective of the degree of attenuation applied. This is a very useful property as it allows high gain amplifiers to be subjected to square wave testing, thereby further extending the usefulness of the unit.

The value of the series resistor R_9 should be such as to allow a current in the region of 15mA to flow through D_3 . About 10mA flows in the multivibrator circuit itself, so that R_9 may be chosen to pass some 25mA overall. The value specified in the Components List for R_9 is suitable for a 12 volt supply. It is important to note that the zener current through D_3 itself must not exceed 25mA, as this approaches the maximum for the OAZ207 without a heat sink. Should the supply voltage be higher than 12, the value of R_9 has to be

increased accordingly. The supply voltage should, of course, be at least several volts greater than the nominal zener voltage of D_3 .

The accuracy of the frequency provided by the unit will depend mainly upon the values, within tolerance, of R_2 , R_3 , C_1 and C_2 . R_2 and R_3 are specified as 5% in the Components List, although closer tolerance components can be employed, if desired. Close tolerance capacitors for C_1 and C_2 may be difficult to obtain, but standard components will produce a square wave frequency sufficiently close to 1 kc/s for normal routine work. For very high levels of accuracy in terms of frequency, it will probably be found most convenient to slightly adjust the values of R_2 and R_3 , as required.

Construction

Readers may have their own ideas on construction, but the writer found that the printed circuit board assembly illustrated in Figs. 3 and 4 enabled the unit to be made up with little difficulty, and provided a neat and compact layout. Construction using the printed circuit board approach will, in consequence, be described next.

The prototype, excluding the switch S_1 , is built on a piece of printed circuit board measuring $2\frac{1}{2} \times 1\frac{1}{2}$ in, this size being considered a satisfactory compromise between space occupied within the oscilloscope and ease of construction. Fig. 4 illustrates the "wiring" required, from the component side of the board, whilst the copper side of the board is shown in Fig. 3. Fig. 3 is reproduced full size, and may be traced directly, if desired.

The copper pattern should be lightly outlined on to the actual board to be used, in pencil, and then the copper to be retained should be painted over with cellulose paint. When painting is completed and the paint has been allowed to dry the laminate can be etched. However, experiments have shown that, provided good quality paint is used, it is possible to immerse the laminate, wet paint and all, into the etching fluid. This is a solution of 250 gm of ferric chloride dissolved in about 500 millilitres of water.

The circuit board is placed in an old whole plate ($8\frac{1}{2} \times 6\frac{1}{2}$ in) developing dish, and the fluid is poured in. Fresh fluid, at this strong dilution, should complete the etching process in roughly 20 minutes at normal room temperature. Weaker solutions, or used solutions that are nearing saturation point, will take longer to etch the board.

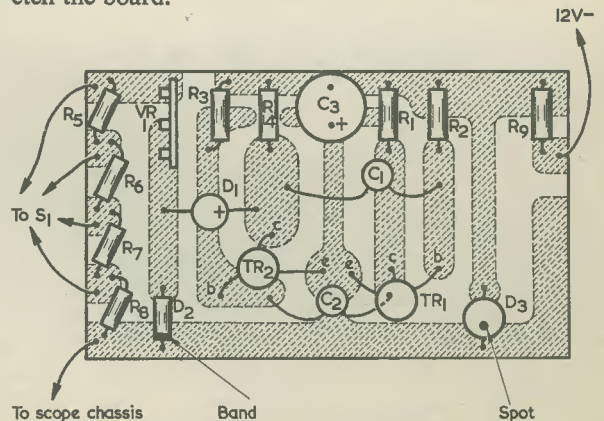


Fig. 4. The component side of the board, showing layout and connections

When etching is complete the board should be removed from the solution, thoroughly washed in running water and then dried. The paint can now be removed with the appropriate thinners and the board drilled for the component wires. A small $\frac{1}{32}$ in pin drill makes very neat holes but requires care to avoid breakage, particularly if used in a hand drill. After drilling, the board is prepared for soldering by scrubbing it thoroughly with a good cleaning powder. It is essential that the copper be free from grease and surface dirt, otherwise soldering will be difficult, leading to overheated (and probably damaged) components, together with poor joints.

The use of a heat shunt is essential when soldering the transistors and diodes, especially if their leads, as in the prototype, have been cut short. The high-stability resistors, also, are more likely to live up to their name if a heat shunt is used during soldering.

On the prototype, short stiff leads are used to connect the circuit board to the attenuator switch S_1 . This dodge enables the unit to be self-supporting behind the switch, the latter being mounted on the front panel of the oscilloscope. The negative supply line is introduced to the board by means of a thin flexible lead, the positive supply connection being made by way of the output socket.

Power Supply

As has already been mentioned, the calibrator unit requires a supply of 12 volts at some 25mA. If it is intended that the unit be operated from a battery, no further comment is required here.

On the other hand, should the unit be made integral with an oscilloscope it will be more convenient for it to draw its power from the oscilloscope supply. Conventional oscilloscopes have a 6.3 volt heater supply, whereupon it becomes possible to use a voltage doubling rectifier circuit, as in Fig. 5 (a) or 5 (b). The circuit in

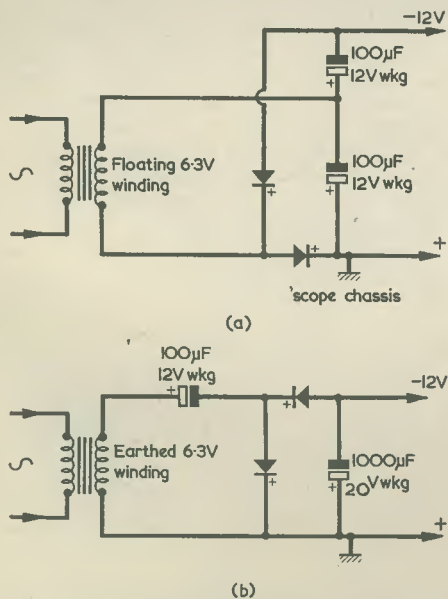


Fig. 5 (a). A simple voltage doubling rectifier circuit which may be used to power the calibrator
 (b). An alternative voltage doubler, in which one side of the 6.3 volt winding is at chassis potential

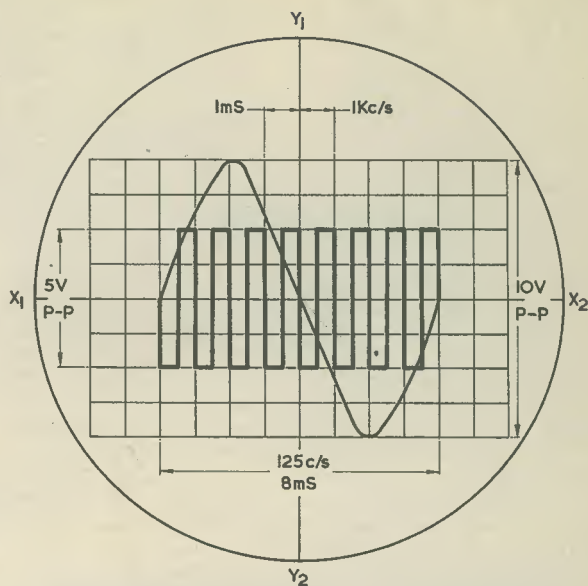


Fig. 6. Illustrating the display given when checking the frequency of a 125 c/s sine wave. In this instance, the peak-to-peak amplitude of the sine wave is twice that of the square wave given by the calibrator

Fig. 5 (a) applies to a 6.3 volt mains transformer winding which is "floating" whilst that of Fig. 5 (b) can be used with a 6.3 volt winding which has one end connected to chassis. As the current requirements are not high, the two rectifiers could be germanium diodes type OA81, or similar.

An alternative scheme could consist of adding a small 6.3 volt heater transformer to the oscilloscope and using one of the two circuits of Fig. 5. If the additional transformer has a 12 volt winding a half-wave or bridge rectifier could be employed instead.

It is possible that any of these rectifier circuits will provide a voltage in excess of 12 volts at 25mA. In consequence, the rectified negative output should at first be applied to R_9 (Fig. 1) by way of a variable resistor having a value of the order of 250 Ω . This resistor should initially insert maximum resistance, after which it may be adjusted until 12 volts is applied to R_9 . A fixed resistor of the appropriate value (if needed) may then be inserted in series with the negative supply to the unit.

In Fig. 1, no on-off switch is shown, as it is assumed that the unit will be running all the time that the associated oscilloscope is switched on. If it is desired to add an on-off switch this may be inserted in series with the negative supply to R_9 .

Operating Temperature

We come now to the two precautions mentioned at the beginning of this article with reference to frequency stability. One of these is already satisfied by the stabilising of the supply voltage, which will have a beneficial effect on frequency stability. The remaining precaution is to ensure that the ambient temperature around the calibrator unit is maintained reasonably constant. Ideally, the circuit board should be mounted in a position where the ambient temperature will remain

constant, from the instant of switching on, for an indefinite period. This is not likely to be easily realised in practice if the unit is fitted inside an oscilloscope, so that an alternative position where the air rapidly reaches working temperature and then stays constant will have to be sought.

Apart from the question of frequency stability, the circuit board should, in any case, be kept well away from sources of heat, particularly rectifier valves whose operating temperatures are likely to be high. Failure to observe this simple requirement could lead to the necessity of replacing one or more of the semiconductors.

Setting Up Output Voltage

When the calibrator is completed and operating, it is necessary to set up VR₁ so that the output at the maximum setting of S₁ is 5 volts peak-to-peak. Since any attempt at measuring the output voltage directly on a moving-coil testmeter calibrated in r.m.s. is doomed to failure, indirect means have to be employed.

First of all, it is important to understand the difference between peak-to-peak and r.m.s. voltages. Without going into basic theory too deeply, the peak-to-peak voltage of a sine wave is 2.8 times its r.m.s. value. The converse also applies.

To set up VR₁ the following steps are taken. A potentiometer of around 100Ω is connected across the secondary of a heater transformer, and the Y input of the oscilloscope connected to the slider of the potentiometer and one end of the secondary. Also connected to these two points is a moving coil testmeter capable of reading low a.c. volts. The potentiometer is adjusted for a reading in this meter of 5 divided by 2.8, i.e. 1.8 volts r.m.s. to the nearest decimal. The oscilloscope attenuator is then adjusted until the waveform height which results lines up against suitable reference points on the graticule. The transformer, potentiometer and meter are then disconnected from the Y input, and the output of the calibrator fed in instead. VR₁ is next adjusted, with S₁ in the "5V" position, until the waveform height is the same as before. The voltage reference unit is then set up and ready for use.

Since the mains transformer in the oscilloscope will almost certainly have a 6.3 volt winding which has one end, or a centre-tap, connected to chassis, the 1.8 volts r.m.s. for the potentiometer and testmeter can, if desired, be conveniently taken from the oscilloscope heater line.

Using The Calibrator

To conclude, a few words on operating the unit, particularly for the beginner, may be helpful.

In order to use the unit as a voltage and frequency standard, it will be necessary to equip the oscilloscope with a graticule over the c.r.t., this consisting of

horizontal and vertical lines 1cm apart forming a grid.

In order to find the amplitude of an unknown alternating voltage, adjust the Y attenuator until it just fills the working area of the c.r.t. On a 3in oscilloscope this will be some 6cm and on a 6in oscilloscope some 12 or 13cm. The unknown voltage is then disconnected from the Y input terminal or socket and the output from the calibrator is fed in. The oscilloscope Y attenuator is left severely alone, and the output switch of the calibrator is adjusted until the c.r.t. displays a waveform having an amplitude less than the unknown voltage; say, 1.5cm on a 3in oscilloscope, or ¼ of the voltage. If the calibrator attenuator is set to, say, 500mV peak-to-peak, the amplitude of the unknown voltage will be 4 x 500mV=2,000mV or 2V peak-to-peak. Whatever the actual figures, the output voltage from the calibrator multiplied by the ratio of the two amplitudes displayed will always give the amplitude of the unknown voltage.

Since the output frequency from the unit is known, unknown frequencies above and below it can be measured. Fig. 6, which assumes a graticule grid of 12 by 8cm, shows how this can be done. Since the output frequency is 1 kc/s, one complete cycle will take 1/1000 second, or 1mS, so that if the oscilloscope timebase and X gain controls are adjusted so that one complete cycle occupies 1cm on the graticule, the timebase speed will be set at 1cm/mS. The timebase will then take 10mS to cover 10cm on the graticule. The calibrating waveform is disconnected and the unknown frequency is fed into the Y amplifier. Without touching the timebase and X gain controls, the distance occupied by one full cycle of the unknown frequency is measured on the graticule. Suppose it takes up 8cm. Since it occupies 8cm its frequency will be ⅘ that of the calibrating frequency, i.e. 125 c/s.

If a cycle of the unknown frequency occupies less than 1cm, its frequency is higher than that of the calibrating waveform and a somewhat different approach becomes necessary. The timebase and width controls are adjusted so that one full cycle of the calibrating frequency occupies 10cm. The unknown frequency is now fed in and, again, the timebase and X gain controls are left untouched. The "length" of one complete cycle is measured on the graticule. Let us say that it is 1cm.

Now, for one complete cycle at 1 kc/s to occupy 10cm, the timebase must be running at 10cm/mS. Since one complete cycle of the unknown waveform is 1cm long, its frequency will obviously be ten times faster, i.e. 10 kc/s.

By following the basic principles just outlined, other frequencies which are capable of being compared with the calibrating frequency in the same manner may be determined just as readily.



S.T.C. Triple Crystal Units

On page 486 of our issue dated March 1968 we listed sixteen of these units together with the applicable frequencies. Recently however, S.T.C. have added a further two crystal units to the range—the details being shown below.

| STC Crystal Type | Crystal Frequencies Mc/s | | |
|------------------------|--------------------------|-------|-------|
| | Light | Third | Home |
| 4434/T | 78.15 | 80.35 | 82.55 |
| 4434/U | 77.4 | 81.8 | 84.0 |

Motor Speed Control using a Thyristor

by N. HARDING, B.A.

Using readily available components, this article describes a circuit which gives a smooth speed control for small series-wound motors.

EFFICIENT CONTROL OF THE SPEED OF UNIVERSAL electric motors has been simplified by using thyristors (silicon controlled rectifiers) in the control circuit. The author was stimulated to investigate this application when it was found necessary to provide, in his laboratory, an efficient and inexpensive control of low-speed universal motors operating at 0°C. At this temperature the motor speed gradually varied due to increase in the viscosity of the lubricant of the motor bearings and the effects of condensation. The motor thus slowed and would finally stop if the series rheostat was not readjusted. It was particularly inconvenient to have to do this after midnight! The control circuit finally adopted has also been found useful for low-speed work with an electric drill.

Thyristor Control Circuits

The principle of thyristor operation has been described previously in this journal¹, and may be simply demonstrated as follows. If a suitable thyristor is connected to a 3-volt d.c. supply in series with a torch bulb (Fig. 1) the bulb will not light until a voltage is applied to the trigger electrode. The bulb is not then extinguished by disconnecting the bias from the trigger electrode, but may be extinguished when the 3-volt supply is disconnected. When the supply is restored, the lamp remains extinguished until a bias pulse is again applied to the trigger electrode.

¹J. B. Dance, "Illumination Control Using Silicon Controlled Rectifiers", *The Radio Constructor*, May 1966.

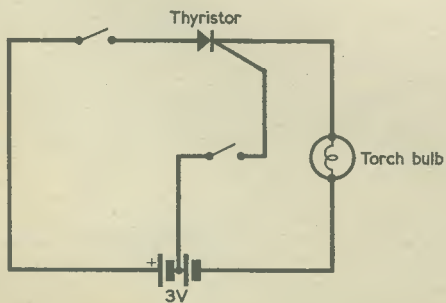
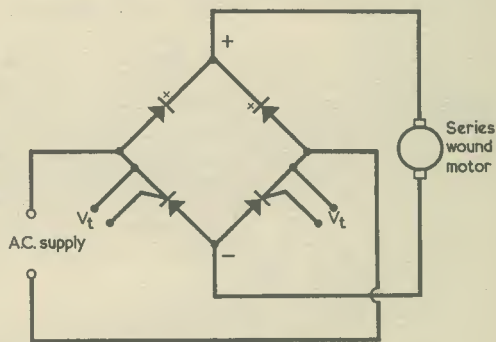
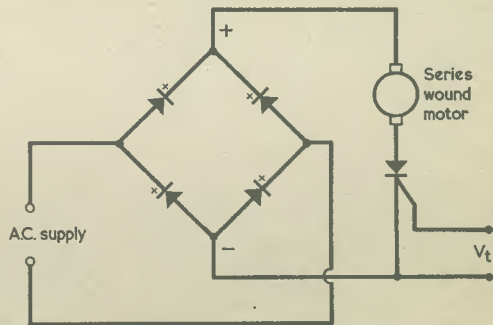


Fig. 1. A basic thyristor control circuit. Here, the thyristor load is in series with the cathode (as occurs in the control circuit of Fig. 3)

This experiment illustrates the problems of using thyristors to control smooth d.c. In such an application not only does the trigger voltage have to be generated but also the thyristor has to be switched to the non-conducting state in order to obtain control. However, with a.c. or rectified unsmoothed d.c. the natural switching action of the supply may be used to switch the thyristor to the non-conducting state, leaving only the problem of supplying the trigger voltage.



(a)



(b)

Fig. 2 (a). Half-controlled thyristor bridge. V_t refers to the trigger voltage applied at the points shown (b). Full-wave diode bridge with single thyristor control

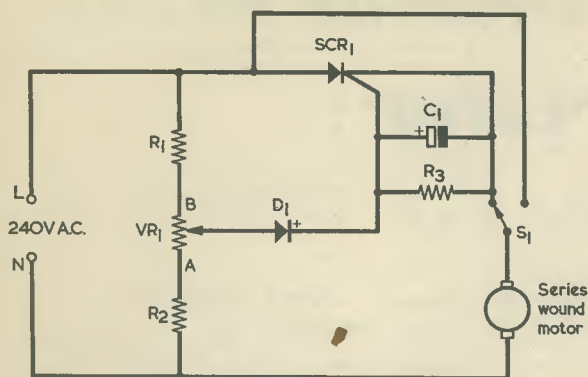


Fig. 3. Half-wave thyristor motor speed control circuit. VR_1 is the speed control. "A" and "B" refer to points on the curves of Fig. 4

Thyristor and diode bridge circuits may be used with an a.c. supply (Figs. 2 (a) and (b)), but smooth control may be difficult to obtain with the half-controlled bridge (Fig. 2 (a)) and the full-wave circuit requires expensive avalanche diodes in the bridge (Fig. 2 (b)). However, the circuit of Fig. 2 (a) and the S.T.C. circuit given in the previous article in this journal provide control on each successive half-cycle, which may in some circumstances be advantageous.²

These objections may be overcome by using a half-wave control circuit, as in Fig. 3, in which the bridge diodes are omitted and the trigger voltage is derived from a potential divider across the main supply. For control of shunt-wound motors, the control circuit is usually in series with the armature and the field coils are supplied with uncontrolled d.c. The circuit of Fig. 3 was found to be satisfactory with series-wound motors and avoided the need for a separate field supply.

Circuit Operation

The circuit in Fig. 3 provides controlled pulses from the positive (therefore alternate) half-cycles of the supply. At full thyristor conduction the motor is supplied with a voltage about 40–60% of the r.m.s. supply value. During non-conduction of the thyristor on the negative half-cycles of the supply the back-e.m.f. generated by the motor opposes the trigger voltage derived from the supply. Since the back-e.m.f. generated by the motor is proportional to armature speed, increased delay in firing of the thyristor occurs with increased armature speed. This results in reduced power being supplied to the motor under these conditions at any setting of the trigger supply potentiometer, VR_1 . Also, as the motor slows the back-e.m.f. falls and the thyristor fires earlier, thus supplying more power from each positive half-cycle of the supply.

These effects are illustrated by the performance curves of Fig. 4, which apply to the circuit in Fig. 3 using a series-wound motor designed for a 240 volt a.c. supply. In this case the load consisted of a

²An avalanche rectifier is designed such that, if reverse breakdown takes place due to overvoltage it does so over the whole junction area rather than at discrete points in the junction or at the surface. In consequence, a high reverse power can be safely dissipated.—Editor.

COMPONENTS

Resistors

- R_1 18k Ω 5 watt
- R_2 200 Ω ½ watt (see text)
- R_3 820 Ω ½ watt
- VR_1 500 Ω potentiometer, linear wirewound (dissipation 1 watt)

Capacitor

- C_1 4 μ F electrolytic, 6V wkg.

Semiconductors

- SCR_1 Thyristor, rated 3 amp forward current type CRS3/40 AF (S.T.C.)*
- D_1 Silicon diode, type RS 240BF (S.T.C.) or OA210

*Type CRS3/40, available from Henry's Radio, is suitable.

Switch

- S_1 s.p.d.t. switch (see text)

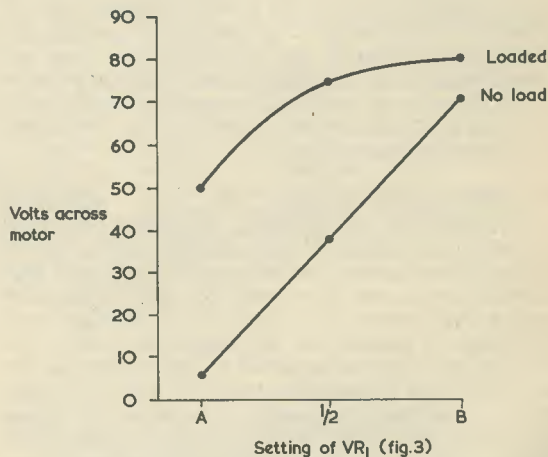


Fig. 4. Voltage across 240 volt series-wound motor (used in circuit of Fig. 3) related to setting of speed control potentiometer and load on motor armature. Voltage was measured on the 100 volt d.c. range of a Taylor Model 100A multimeter

constant frictional brake applied to a disc attached to the motor spindle.

In Fig. 3, R_2 is nominally 200 Ω . Its value may be varied between 100 Ω and 300 Ω , however, to meet particular low speed requirements. Switch S_1 should have contacts suitably rated for the motor load.

Circuit Construction

Layout was not critical, except for R_1 which was mounted well away from other components since it gets appreciably warm. The circuit was built as a unit inside an MK moulded box List No. 2032, the output being wired to a 13 amp socket mounted at one end of the box. A separate single-pole 2-way switch may be used as the a.c. by-pass, carrying out

Motor Speed Control using a Thyristor

the function of S_1 in Fig. 3.³ The speed control, VR_1 , was mounted on a piece of Formica cut to fit the section of the box not covered when the socket was secured in position.

The thyristor was mounted on a small heat sink, this being secured to the box with Araldite. For motors rated up to 600VA at 240 volts a.c., an aluminium heat sink measuring 3cm x 2cm x $\frac{1}{8}$ in thick has proved satisfactory at normal room temperatures. With thyristors differing from the type specified or with different working conditions, the size of the heat sink may need to be modified and alternative ventilation arrangements provided.

³The moulded box List No. 2032 is manufactured by MK Electric Ltd. It is intended for surface mounting, further MK Electric accessories (such as sockets) being fitted to it as required. The dimensions are 3 $\frac{1}{4}$ x 5 $\frac{1}{2}$ x 1 $\frac{1}{2}$ in, the box is available in brown or ivory, and it is obtainable through electrical contractors and retailers.—Editor.

Effects of Thyristor Control Upon The Motor

Sparking at the brush-commutator connection was more noticeable, and the motor generated more audible noise and electrical interference when under thyristor control than when running on a.c. alone. This is probably due both to the switching effect on successive positive half-cycles of the supply and to high voltage transients developed by the thyristor switching an essentially inductive load. However, after considerable experience with this control, no motor or thyristor failures have occurred. The only defect found after stripping a motor subjected to a long period of thyristor control was that the commutator sections were blackened on their leading edges, but had not otherwise suffered unduly from spark corrosion.

Acknowledgements

The author gratefully acknowledges the help of Mullard Ltd., Associated Electrical Industries Ltd., and S.T.C. Semiconductors Ltd., for their supplies of data, and of the last-named Company for the scheme of the circuit in Fig. 3.



Semiconductor Nuclear Counters

by J. B. DANCE, M.Sc.

Readers may recall our contributor's article, "Gas Filled Detectors For Nuclear Radiation", which appeared in the March 1968 issue. In the present article an alternative type of detector, employing semiconductor materials, is discussed

SEMICONDUCTOR DEVICES CAN REPLACE VARIOUS types of electronic tubes in most applications, including that of counting the particles emitted by the nuclei of radioactive atoms. Whilst semiconductor (or solid state) nuclear particle counters have certain advantages over the more conventional Geiger-Müller, proportional and scintillation counters, each of these forms of detector has its own specific advantages for certain applications.

Basic Principles

When nuclear or X radiation passes through matter, ions are formed. Alpha and beta particles (which have positive and negative charges respectively) exert electrical forces on the electrons of the material through which they are passing. Some of the electrons leave the atoms so that ions are produced. Gamma and X rays produce ions in matter by slightly more complicated processes.

In proportional and Geiger-Müller tubes, the ions formed by the passage of radiation through the

gas enclosed in the tube are attracted to the opposite electrodes by the applied electric field. However, when the electrons approach the anode wire in such tubes, they are accelerated so much that they gain enough energy to remove electrons from further molecules of gas by collision. The electrons thus produced are in turn accelerated and produce further ionization. A single electron can therefore cause an avalanche of electrons to reach the anode wire. The process is known as gas amplification. In a Geiger tube the gas amplification may be as high as 10^8 , but in proportional counters is typically about 1,000.

A Geiger-Muller or proportional counter tube is used in the type of circuit shown in Fig. 1. Each time an avalanche of electrons reaches the anode wire, the charge of the electrons is collected and the potential of the anode falls. The potential rises again as current flows through the resistor R from the h.t. supply to recharge the capacitor C. A negative going pulse is thus produced at the output each time a nuclear particle forms ions in the tube. In the case of a Geiger

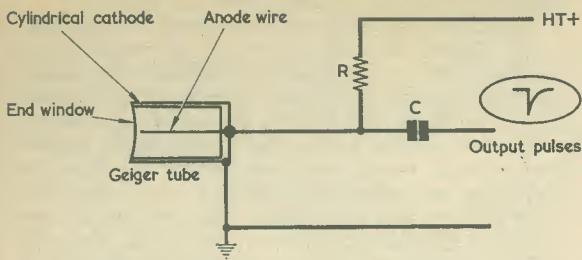


Fig. 1. The basic circuit for a Geiger tube

tube the negative-going output pulse may have an amplitude of the order of 10 volts, but in proportional counters it is typically of the order of 1 millivolt, owing to the lower gas amplification in this type of tube.

Semiconductor Detectors

The same principles of ion collection are used in semiconductor detectors, but no gas amplification can occur. It might be thought that one could merely take a lump of a suitable semiconductor material, fit two electrodes to it and obtain output pulses by using it in place of the Geiger tube in the circuit of Fig. 1. Unfortunately, however, there are many complicating factors.

The semiconductor material used must have a high resistivity (i.e. specific resistance) or the stray statistical fluctuations in the current passing through the device (i.e. "noise" pulses) will produce output pulses as large as the wanted pulses; the noise pulses would then be counted. It is most unfortunate that all of the known semiconductor materials which have an adequate resistivity contain too many electron traps and/or hole traps to be satisfactory for the purpose. These traps are regions of the crystal where electrons or holes may be delayed or more or less permanently lost.

Pure silicon and pure germanium have few traps, but unfortunately their energy band gap is not great enough for an adequate resistivity to be obtained at room temperature. However, semiconductor detectors

may be made by cooling a piece of silicon to liquid air temperatures or a piece of germanium to liquid helium temperatures, since the resistivity is greatly increased by cooling. Such detectors are known as homogeneous detectors since they consist of a homogeneous piece of the semiconductor material with suitable electrodes fitted to it. They have not been widely used outside research laboratories.

Junction Detectors

A more practical approach involves the use of a semiconductor p.n. junction as a detector. In a p.n. junction holes diffuse from the p type material across the junction into the n type material, whilst electrons diffuse in the opposite direction from the n type material into the p type. The potential which is formed across the junction by this diffusion process builds up until further diffusion is prevented; equilibrium is thus established. Owing to the potential gradient across the junction, both holes and electrons are repelled away from the junction region itself. There are therefore no mobile charge carriers in this region to carry a current. It is referred to as the depletion region, since it is depleted of charge carriers. Such a region has a very high resistivity even at room temperature when it is reverse biased and, if the semiconductor material is silicon, the depletion region can be used for nuclear particle detection at normal temperatures. Germanium junction detectors must be cooled to liquid air temperatures, however.

Advantages and limitations of Junction Detectors

The output pulses from junction detectors are much smaller in amplitude than those from Geiger tubes, owing to the lack of gas amplification. The output pulses from a Geiger tube require little, if any, amplification before being fed into a scaler (which counts the pulses and indicates the number of counts) or into a ratemeter (which indicates the frequency of the pulses on a meter). Thus, the output pulses from a semiconductor detector must be amplified before they can be used to operate a normal scaler or ratemeter. Although no amplification of the number of ions formed by the radiation occurs in a semiconductor

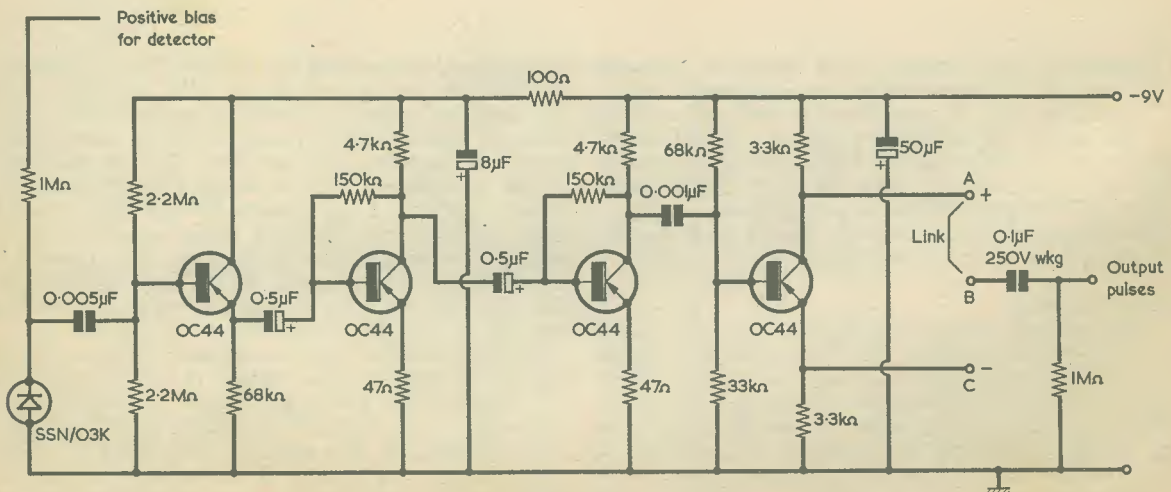


Fig. 2. The Twentieth Century Electronics amplifier type DSA/2. The SSN/03K solid state detector is shown on the left hand side of this circuit

RC/DS/8

RADIO CONSTRUCTORS DATA SHEET

8

INDUCTIVE REACTANCE—RADIO FREQUENCIES

The Table gives reactance in ohms at the inductances and frequencies indicated. $X_L = 2\pi fL$. Use also in conjunction with Data Sheet No. 6 (published last month) as a rough guide for resonant circuits. Thus, $500\mu\text{H}$ (3,140 Ω) and 50pF (3,180 Ω) will resonate near 1Mc/s.

| Inductance | 100 kc/s | 300 kc/s | 1 Mc/s | 3 Mc/s | 10 Mc/s | 30 Mc/s | 100 Mc/s | 300 Mc/s |
|-------------------|----------|-----------|-----------|------------|------------|------------|------------|------------|
| 1H | 628,000 | 1,880,000 | 6,280,000 | 18,800,000 | 62,800,000 | 18,800,000 | 18,800,000 | 18,800,000 |
| 100mH | 62,800 | 188,000 | 628,000 | 1,880,000 | 6,280,000 | 18,800,000 | 18,800,000 | 18,800,000 |
| 50mH | 31,400 | 94,200 | 314,000 | 942,000 | 3,140,000 | 9,420,000 | 9,420,000 | 9,420,000 |
| 20mH | 12,600 | 37,700 | 126,000 | 377,000 | 1,260,000 | 3,770,000 | 3,770,000 | 3,770,000 |
| 10mH | 6,280 | 18,800 | 62,800 | 188,000 | 628,000 | 1,880,000 | 1,880,000 | 1,880,000 |
| 5mH | 3,140 | 9,420 | 31,400 | 94,200 | 314,000 | 942,000 | 942,000 | 942,000 |
| 2mH | 1,260 | 3,770 | 12,600 | 37,700 | 126,000 | 377,000 | 377,000 | 377,000 |
| 1mH | 628 | 1,880 | 6,280 | 18,800 | 62,800 | 188,000 | 188,000 | 188,000 |
| 500 μH | 314 | 942 | 3,140 | 9,420 | 31,400 | 94,200 | 314,000 | 942,000 |
| 200 μH | 126 | 377 | 1,260 | 3,770 | 12,600 | 37,700 | 126,000 | 377,000 |
| 100 μH | 62.8 | 188 | 628 | 1,880 | 6,280 | 18,800 | 62,800 | 188,000 |
| 50 μH | 31.4 | 94.2 | 314 | 942 | 3,140 | 9,420 | 31,400 | 94,200 |
| 20 μH | 12.6 | 37.7 | 126 | 377 | 1,260 | 3,770 | 12,600 | 37,700 |
| 10 μH | 6.28 | 18.8 | 62.8 | 188 | 628 | 1,880 | 6,280 | 18,800 |

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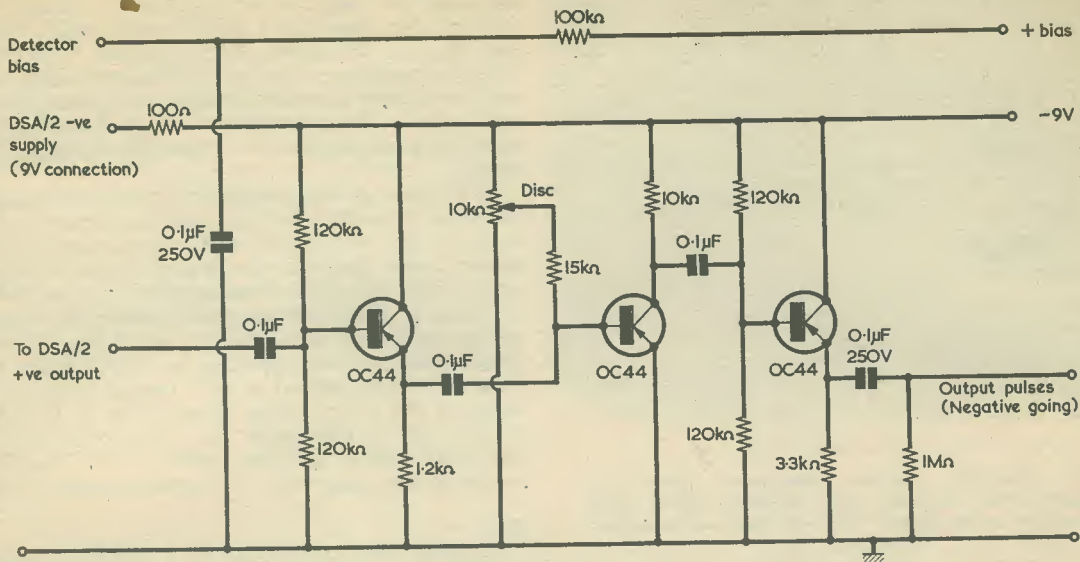


Fig. 3. The Twentieth Century Electronics DSA/3 amplifier. This amplifier may be added to the circuit of Fig. 2 for beta or gamma counting

detector, a specified particle of radiation of a certain energy will produce nearly ten times as many ions in the semiconductor material as the same particle will produce in a gas.

Semiconductor junction detectors are especially useful for the counting of alpha particles in elementary educational experiments. Alpha particles produce a pulse of some millivolts at the output from a semiconductor particle detector, whereas beta and gamma particles produce very much smaller output pulses. It is therefore much easier to distinguish between the pulses due to alpha particles and the noise pulses than between pulses due to beta or gamma particles and noise. The output pulses from a Geiger tube are not dependent on the type of incident radiation. Semiconductor detectors can be manufactured with extremely thin windows of evaporated gold (20 to 50 micrograms/sq. cm) over the junction area, whereas the mica windows of Geiger tubes cannot be made much thinner than about 1 to 2 milligrams/sq. cm. Thus alpha particles can penetrate more easily to a semiconductor junction than through the thicker window of a Geiger tube. In the case of beta or gamma radiation, the window thickness is not so important, since these types of radiation can penetrate matter much more easily unless the particle energy is very low.

Silicon semiconductor junction detectors are especially useful in research work for the plotting of the energy spectra of alpha sources. They provide very high resolution; that is, they make it possible to distinguish between alpha particles which have very slightly different energies. Special lithium drifted germanium detectors are available for high resolution gamma ray spectrometry, but they must be used at very low temperatures.

Economical Detectors

The economically priced silicon semiconductor junction detectors which are produced for educational work in schools and colleges have the disadvantage that their junction area is much smaller than the area

of a typical end window Geiger tube and therefore the resulting counting rates are correspondingly lower. The price of these economical detectors is not very different from that of a typical Geiger tube (of the order of £10). Junction detectors with a much larger sensitive area are available, but their cost is very much greater.

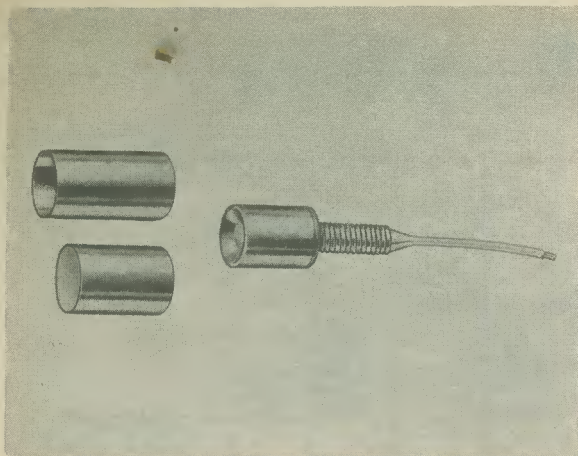
Circuitry

The basic circuit for the use of a semiconductor junction detector is that shown in Fig. 1, except that the detector replaces the Geiger tube. It is essential that the p.n. junction of the detector is reverse biased.

For simple educational experiments the output pulses from the detector are fed into an amplifier which has enough gain to produce output pulses which are capable of operating the scaler or ratemeter to be used. A circuit developed for alpha particle counting by Twentieth Century Electronics Ltd. using their SSN/03K or SSN/03P economical detectors is shown in Fig. 2. This is a simple circuit using four OC44 transistors which can easily be made up by a group of schoolboys. It provides a gain of the order of one thousand, this gain depending on the gain of the individual transistors employed in the circuit. An alpha particle of 5 Mev energy incident on the detector will cause the amplifier to provide an output pulse of about $1\frac{1}{2}$ volts in amplitude. If the output link is connected between A and B, positive-going output pulses will be produced whilst, if it is connected between B and C, the output pulses will be negative-going. Thus the circuit may be used with a scaler requiring either positive or negative going pulses.

The SSN/03K detector is shown in the photograph. The SSN/03P detector is a very similar type of economical detector, but the electrodes are connected to a coaxial lead which terminates in a P.E.T. plug; most people will find the SSN/03P rather more convenient than the SSN/03K.

If the same types of detector are to be used for beta or gamma counting, an amplifier of higher gain than



The Twentieth Century Electronics economical semiconductor detector type SSN/03K (right) with protective sleeve (upper left) and neutron conversion foil (lower left)

that shown in Fig. 2 is required. The Twentieth Century Electronics amplifier type DSA/3, which is shown in Fig. 3, has been developed as an add-on stage to the DSA/2 circuit of Fig. 2. Another three OC44 transistors are employed in this unit. In addition a discriminator (marked 'Disc') is included in Fig. 3. The discriminator is adjusted so that small stray pulses due to noise cannot pass to succeeding stages of the amplifier and hence operate the scaler or ratemeter. The discriminator should be adjusted so that no noise pulses are counted when no radioactive source is in the vicinity of the detector. Complete suppression of the noise pulses may, however, cause some loss of the wanted pulses. The use of the DSA/3 unit also enables alpha counting to be undertaken with up to ten feet of coaxial cable between the detector and the input stage of Fig. 2.

When the DSA/3 unit is employed, the circuit of Fig. 2 should be set so as to provide positive going pulses; that is, the output link should be connected between points A and B.

Low energy radiation produces only very small output pulses from the detector. These pulses must be of an amplitude greater than that of the noise pulses or it will not be possible to detect them separately from the noise. A lower limit on the energy of the radiation which can be detected is therefore imposed by the noise level of the first stage of the amplifier. In order to obtain the best possible results, it is necessary to select the input transistor of the Fig. 2 circuit for low noise.

The circuit of Fig. 3 provides only negative-going output pulses. Geiger tubes also provide negative-going output pulses and the circuit of Fig. 3 is therefore suitable for connection to a scaler used for counting the input pulses from a Geiger tube. If positive-going output pulses are required, an additional phase inverter stage of low gain may be added.

When used with simple equipment, silicon junction detectors are much more satisfactory for alpha counting than for beta or gamma work. If a suitable thin foil of uranium-235 or boron-10 is placed in front of the detector window, they may also be used for the counting of neutrons. The neutrons produce a nuclear reaction

in the foil and the particles produced in this reaction are counted by the semiconductor detector. For counting fast neutrons, a thin film of a plastic material may be placed in front of the detector window. The fast neutrons knock protons (hydrogen nuclei) out of the plastic film and the protons are counted. Suitable conversion foils are available for use with the economical detectors designed for educational use (see photograph).

A number of manufacturers are producing small transistor amplifiers for use with the economical type of detectors manufactured for educational use. In general, such amplifiers have a performance which is very similar to that of the circuits of Figs. 2 and 3.

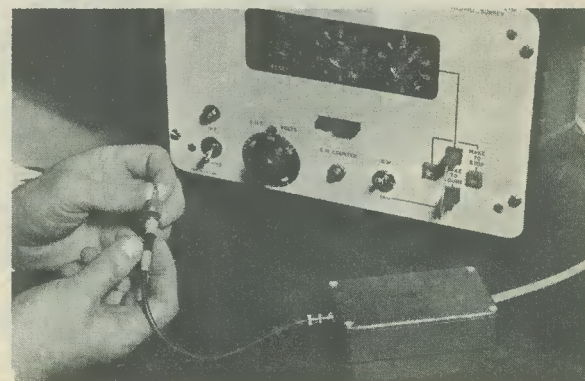
Special pre-amplifier units are available for research and professional use. Many of these are charge sensitive pre-amplifiers which produce an output pulse of an amplitude proportional to the charge passed to the input of the pre-amplifier rather than to the change of potential at the input. Such charge sensitive pre-amplifiers enable accurate results to be obtained in energy spectrometry work with semiconductor detectors.

Bias

Although the bias applied to a junction detector is by no means critical, it is nevertheless important to apply a bias of the correct order of magnitude. The greater the reverse bias applied to the detector, the farther the free charge carriers will be drawn away from the junction and the larger the depletion region. In addition the junction capacitance will be reduced as the bias is increased. However, an excessive bias will result in an increased reverse current flowing through the device and therefore in increased noise. The optimum bias varies with the resistivity of the semiconductor material used and with the type of particles being detected. In the case of the economical detectors discussed above, the bias values may be typically in the range of 10 to 100 volts. However, some special detectors may be used with an applied bias of over one kilovolt.

Special Detectors

Semiconductor "transistor" type detectors have been produced in which the current flowing through a p.n. junction is amplified by an internal transistor



A small Americium source is being held near a solid state detector. The small box in the foreground is the Panax Equipment AD-1 amplifier and the scaler is the Panax Equipment Type 102ST. (Readers are warned not to handle a radioactive source unless they are quite certain of the correct way to do this and are aware of the risks involved)

action. However, these devices do not offer an improved signal-to-noise ratio and are therefore not widely used.

Workers at Harwell have combined a phosphor with a photodiode. When nuclear radiation strikes the phosphor it is converted into light which enables the photodiode to produce an output pulse.

Semiconductor detectors are damaged by extremely high radiation fields (such as those inside a nuclear reactor) and this limits their application in such work.

Conclusion

Semiconductor detectors are of vital importance in certain types of research work and have enabled at least one new element to be discovered. They are also very useful as alpha particle detectors for simple educational work in schools and colleges. Some types of economical semiconductor detector have been

approved by the Nuffield Foundation for use in educational establishments which are adopting the Nuffield syllabus for the teaching of modern physics. However, all semiconductor detectors require a pre-amplifier between the detector and scaler whereas Geiger tubes do not. For this reason simple Geiger counting equipment can be purchased rather more cheaply than economical semiconductor counting apparatus. In general the writer believes that Geiger tubes are more satisfactory for most elementary educational experiments, but semiconductor junction detectors are quite useful for alpha work.

Acknowledgement

The writer is indebted to Messrs. Twentieth Century Electronics Ltd. and to Messrs. Panax Equipment Ltd. for providing the photographs which have been reproduced in this article. *

RECENT PUBLICATIONS



(Continued from page 610)

THE TAPE RECORDER, 2nd Edition. By C. G. Nijssen. Published by Iliffe Books Ltd. 157 pages. 59 illustrations plus 24 pages of plates and 1 fold-out. Size 8½ x 5½ in. Price 18s. net (by post 18s. 11d.).

This book has been specially written in clear, simple, non-technical language for that rapid growing band of enthusiasts for whom the tape recorder is as indispensable as a radio, a record player or a camera. It shows how the best possible results can be obtained from a recorder, whether it is used for pleasure or educational purposes.

After describing in detail the recording process, sound quality, and the various types of microphones and loudspeakers, it discusses the various accessories available and their uses. A chapter follows on maintenance and faults, Stereophonic recording, a subject currently arousing much interest, is fully discussed, and advice is given on the choice of recorder, the types available and their capabilities.

Recordings, studio arrangements and the editing of tape are discussed in detail, as is the synchronisation of sound and film. Chapters are also devoted to use of the recorder in general education, the study of music, and "tape clubs". Another chapter briefly deals amongst other things with recording in professional studios, sound reproduction in cinema and theatre, tape-copying machines, automatic and continuous recorders, magnetic sound tracks on miniature film and magnetic recording of pictures.

In this second edition a chapter on cassette recorders has been added, explaining the principles and the advantages of this system for the user who above all wants "simplicity of operation".

Finally, two tables are included; one on faults and their remedies, the other setting out in alphabetical order the hundreds of possible uses of tape recorders. Undoubtedly these are the most comprehensive tables of their kind published to date. Because of its practical approach, this book, by an author with many years of experience in all branches of sound recording, will be easily understood even by those new to the subject, and will assist all those reading it to improve the standard of their recording.

THE SUPERHET RADIO RECEIVER DIFFERS FROM THE type of receiver we have considered in earlier articles because much of the amplification it provides, before detection, is carried out over a fixed band of frequencies regardless of the frequency of the signal picked up by the aerial. This method of operation confers considerable advantages, as we shall see in the present article, but it requires that the input signal frequency be changed to the frequency at which amplification occurs. Since this is a process we have not previously examined, all of last month's article was devoted to the basic principles involved.

We saw last month that, if two r.f. signals of different frequency are applied to a grid-leak detector, a third heterodyne signal, whose frequency is equal to the difference between the two input signals, becomes available at the detector anode. In order that a usable heterodyne signal can be obtained it is necessary for the valve to which the input signals are applied to distort the waveform which results from their combination, and this distortion is provided by the grid leak detector because of the inherent rectifying action which takes place at its grid.

and short waves; and a practical version was, in fact, described in "Understanding Radio" in the issues for November and December 1966, and January, April and May 1967. (We shall be giving a practical superhet design, similarly based on the Lektrokit chassis system, later in this series.)

The selectivity we achieve with a receiver of the type shown in Fig. 1 depends upon the performance of the tuned circuits in the r.f. amplifier and detector stages. To ease operating difficulties, both these circuits are tuned by separate sections of a 2-gang capacitor, and it is obvious that the parallel capacitance in the tuned circuits will be much greater at the low frequency end of any band being tuned than at the high frequency end. This fact causes the tuned circuits to offer a different degree of selectivity at the two ends of the band. Actually, the selectivity is less at the low frequency end where the tuning capacitance is greater.

Thus, the selectivity offered by the receiver of Fig. 1 is that given by two tuned circuit only (plus reaction at the detector) and even this varies over the band being received.

In Fig. 2 we have a block diagram for a superhet

UNDERSTANDING RADIO

Basic Superhet

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






by W. G. Morley

Basic Superhet

When a grid leak detector is employed in a superhet to provide a heterodyne signal from two input signals, it is referred to as a *mixer*. In practice, grid leak detectors are employed as mixers in valve f.m. and television superhets which receive signals above 40 Mc/s or so, whilst, in valve superhets intended for the long, medium and short wave bands, an alternative type of mixer valve is used. The latter also provides the basic signal combination and distortion required for the production of a heterodyne signal, and we shall consider its operation in a later article. It may also be mentioned that other terms are used to describe the mixer, or the mixer stage of a superhet. We shall introduce these terms when we describe the alternative type of mixer valve.

To appreciate the benefits resulting from superhet operation we must first briefly examine the type of receiver it supersedes. A typical instance of the latter is given in the block diagram of Fig. 1, where we have an r.f. stage with an input tuned circuit resonant at signal frequency, a detector stage with an input tuned circuit also resonant at signal frequency, an a.f. amplifier stage and an a.f. output stage. To improve selectivity the detector stage incorporates a reaction circuit. Such a receiver is suitable for reception on long, medium

receiver suitable for the long, medium and short wave bands. The input signal is applied to a tuned circuit resonant at signal frequency and is then passed on to a mixer stage. Also fed to the mixer stage is the output from a *local oscillator*. (The adjective "local" merely means that the oscillator is in the receiver, adjacent to the mixer.) The mixer then provides, at its output, a heterodyne signal whose frequency is equal to the difference between the signal frequency and the oscillator frequency. This is described as the *intermediate frequency*, or *i.f.*, of the receiver.

The tuning capacitors for the r.f. signal tuned circuit and for the oscillator tuned circuit are ganged, and the two tuned circuits are so arranged that their resonant frequencies are spaced by the intermediate frequency regardless of the ganged tuning capacitor setting. Thus, as the ganged tuning capacitor is rotated, the oscillator provides an output signal whose spacing from the input signal accepted by the r.f. tuned circuit is always equal to the intermediate frequency. The result is that, whatever the frequency of the input signal to which the aerial tuned circuit is resonant, the heterodyne output signal from the mixer is always at the intermediate frequency.

The heterodyne signal from the mixer is applied to an intermediate frequency amplifier which has fixed

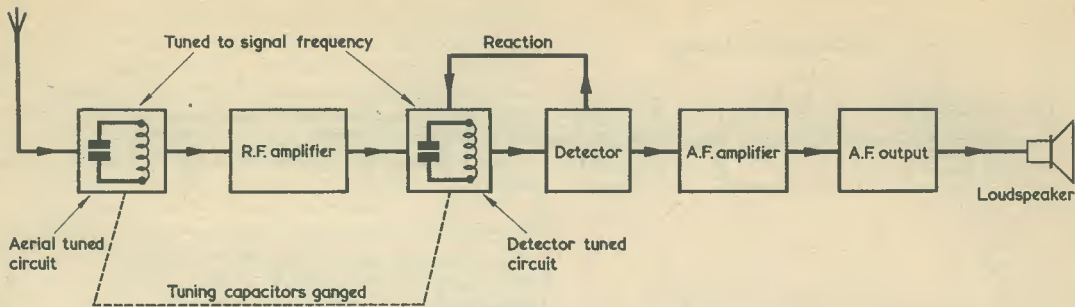


Fig. 1. Block diagram for a simple a.m. receiver suitable for long, medium and short wave reception

tuned circuits resonant at the intermediate frequency. This i.f. amplifier enhances the level of the signal and next applies it to the detector. The detector causes the modulation originally present on the input signal to be reclaimed and this is finally applied, as a.f., to an a.f. amplifier and output valve and, thence, to a loudspeaker.

The important difference between Fig. 1 and Fig. 2 is that, in Fig. 2, the signal undergoes amplification at a fixed frequency in the i.f. amplifier before detection. Since the tuned circuits in the i.f. amplifier have to work at one frequency only they can be designed to offer optimum performance at that frequency, whereupon they provide considerably higher selectivity than is possible with the two tuned circuits of Fig. 1, which have to cover a wide range of frequencies. A further small increase in selectivity is provided in Fig. 2, incidentally, by the variable tuned circuit immediately preceding the mixer.

With the simplified presentation given in Fig. 2 only two i.f. tuned circuits are shown in the i.f. amplifier "block". In a practical i.f. amplifier there will normally be four or more tuned circuits.

We have referred, up to now, in terms of the improved selectivity offered by the superhet. The superhet can also offer a greater degree of amplification of the received signal. The fact that the i.f. amplifier stages all function at a fixed frequency enables these to be designed to give a high gain level as well as a high degree of selectivity.

A superhet receiver can readily employ a circuit device known as *automatic gain control*, or *a.g.c.*, whereupon its operation can be made extremely simple. With automatic gain control, the amplification of the stages preceding the detector is controlled by a direct voltage derived from the signal at the detector, with the result that the detected signals have a fairly constant amplitude despite wide differences in level at the aerial. If a superhet is fitted with a.g.c. the only essential controls required are for tuning and volume. The volume control merely varies the gain of the a.f. amplifier stage following the detector.

Conventional valve superhets designed for domestic listening on long, medium and short waves employ the stage progression illustrated in Fig. 2, in which the aerial input signal is applied directly to the mixer stage via a tuned circuit. Superhets which are required to provide a higher performance incorporate an r.f. amplifier between the aerial and the mixer stage, with the consequence that there are two tuned circuits resonant at signal frequency before the mixer. See Fig. 3. In this case tuning is carried out by a 3-gang capacitor, two of whose sections control the signal frequency tuned circuits whilst the third controls oscillator frequency. Domestic superhets intended for reception on f.m. or television frequencies always have an r.f. stage, but alternative tuning methods are used. An f.m. receiver normally has the tuned circuit immediately following the aerial tuned to a fixed frequency at or near the centre of the f.m. band (Band II—87.5 to

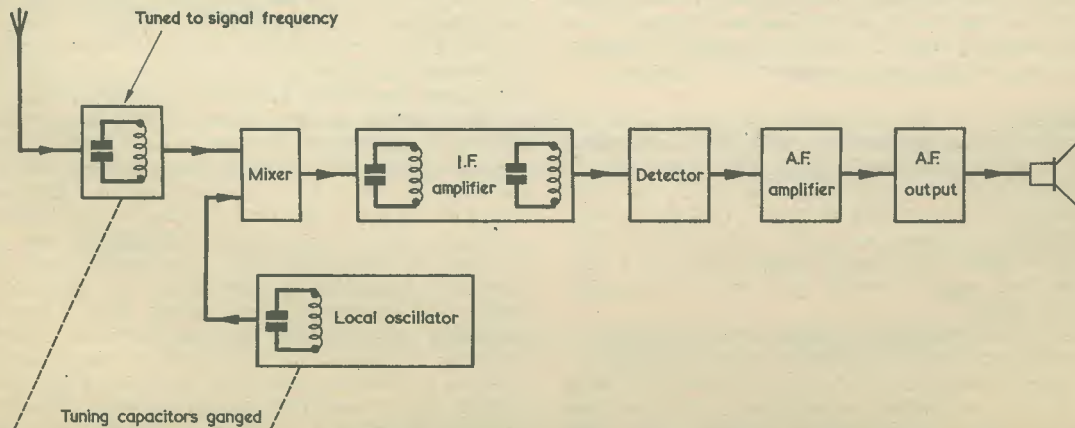


Fig. 2. A superhet suitable for long, medium and short waves. Although only two tuned circuits are shown in the i.f. amplifier "block", this amplifier will in practice normally have four or more

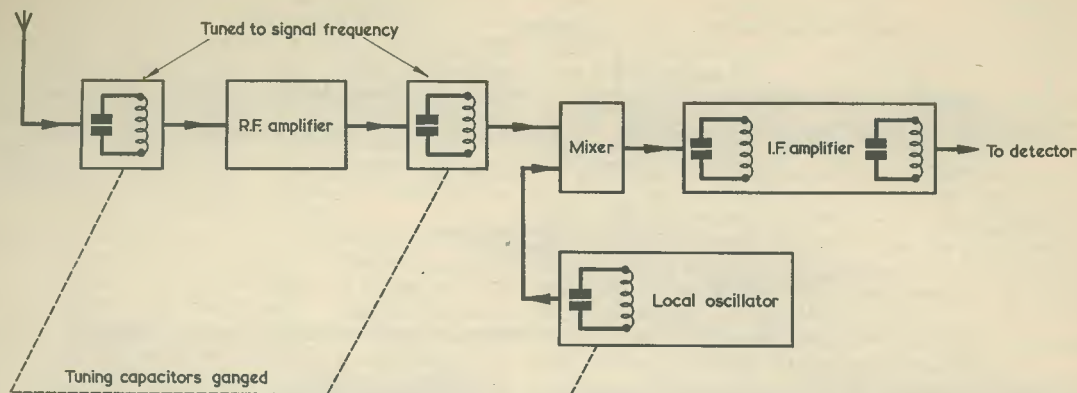


Fig. 3. Improved performance is given if an r.f. amplifier precedes the mixer and its input tuned circuit

100 Mc/s), the response of this tuned circuit being made sufficiently broad for it to accept signals over all the band. The following r.f. tuned circuit and the oscillator tuned circuit are then controlled by a 2-gang capacitor. In television receivers, tuning over Channels 1 to 13 is carried out by a system which switches different inductors into circuit for each channel. At the higher u.h.f. channels a 4-gang tuning capacitor is usually employed. The extra section is required because, in television receivers, there are two tuned circuits between the r.f. amplifier and mixer stages instead of one.*

A superhet intended for specialised work, such as long distance communications and the like, may have a considerably more complex stage "line-up" than those shown in Figs. 2 and 3. A typical instance is the *double superhet*. In the double superhet the output from the mixer is amplified at one intermediate frequency and is then fed to a second mixer and oscillator. The second oscillator runs at a fixed frequency and provides a second intermediate frequency which is again amplified before being finally passed to the detector. This technique is taken a step further in some receivers by having two mixers and three intermediate frequencies. High amplification is not always the primary reason for employing two or more intermediate frequencies in a superhet; nevertheless, superhets of this type can offer an exceptionally high overall gain because amplification is carried out at more than one frequency and the difficulties of instability due to unwanted feedback from output to input are correspondingly reduced.

Terminology

Some points of terminology need to be cleared up at this stage. In early texts, which dealt only with the more simple superhet, as in Fig. 2 or Fig. 3, the mixer was referred to as the "first detector", and the detector following the i.f. amplifier as the "second detector". These two terms have been discontinued for a considerable time but the reader may still, occasionally, encounter them.

Sets in which the detector works at signal frequency are described as *straight* receivers in order to differentiate them from the superhet. This applies whether the aerial is fed direct to the detector input tuned circuit or via

an r.f. amplifier, as in Fig. 1. A set in which one or more tuned r.f. amplifiers precede the detector may also be referred to as a *t.r.f.* (*tuned radio frequency*) receiver.

I.F. Response

As we have noted earlier in this series (in the May 1965 issue) the process of amplitude modulating a transmitted carrier causes *sideband* frequencies to be produced which are spaced from the carrier by the modulating frequency. Thus, if we have a 1,000 kc/s carrier modulated, at the transmitter, by a 1 kc/s a.f. tone, the signal broadcast by the transmitter consists of the 1,000 kc/s carrier plus sidebands of 999 kc/s and 1,001 kc/s. These sidebands *must* be applied to the detector at the receiver if this is to recover the original 1 kc/s modulation.

Let us see what occurs in a superhet when the 1,000 kc/s signal with its 1 kc/s modulation is applied, from the aerial, to the mixer input. For the sake of illustration we will assume that the intermediate frequency is 100 kc/s, whereupon the local oscillator may run either at 1,100 kc/s or 900 kc/s. For reasons which we shall discuss in a later article, it is usual to have the oscillator frequency higher than the signal frequency, and so we shall set our oscillator to 1,100 kc/s. In consequence, the 1,000 kc/s carrier produces a heterodyne at 100 kc/s. At the same time, the 999 kc/s sideband produces a heterodyne at 101 kc/s (1,100 minus 999) and the 1,001 kc/s sideband produces a heterodyne at 99 kc/s (1,100 minus 1,001). Thus, the output from the mixer consists of a 100 kc/s signal corresponding to the original carrier, plus sideband frequencies on either side spaced away from it by 1 kc/s. Detecting this i.f. signal with its sidebands produces the 1 kc/s modulating tone in just the same way as if the original signal at the aerial had been applied to the detector.

Because of the crowded conditions in the bands covered by domestic a.m. (amplitude modulation) receivers—including in particular the medium wave band—it is necessary for the tuned circuits in the i.f. amplifiers of domestic superhets to be sufficiently selective to cut out interference from transmitters working on frequencies close to that of the desired station. This necessitates designing the i.f. amplifiers of such superhets to have a response curve similar to the typical example shown in Fig. 4, and it will be noted that this offers heavy attenuation to frequencies

* A full description of the circuits and principles employed in television tuner units is given in "Understanding Television", published by Data Publications, Ltd.

spaced away from the centre frequency by some 4 kc/s or more. In consequence, the more widely spaced sidebands of the desired signal reach the detector at a considerably reduced level, whereupon the modulating audio frequencies to which they correspond appear, after detection, at a similarly low level. This effect is a common feature of the normal type of domestic a.m. superhet. The a.f. output of receivers of this nature rarely extends, at any significant strength, above some 4 kc/s or so.

It is usual to refer to a superhet intermediate frequency in terms of a single frequency. In the example just quoted, for instance, we said that the intermediate frequency was 100 kc/s. We can now see that the real situation is that the i.f. amplifier passes a *band* of frequencies, of which the stated frequency is the centre frequency.

In practice, the intermediate frequency chosen for domestic long, medium and short wave superhets lies between some 450 and 475 kc/s according to the specific design of the set. Specialised short wave receivers often use an intermediate frequency of 1.6 Mc/s (which may be changed to a lower frequency by a second mixer stage). The i.f. amplifiers of such receivers are, also, frequently designed to offer much lower bandwidths than are common in domestic superhets in order that a high degree of selectivity may be achieved. Domestic f.m. receivers have an intermediate frequency of 10.7 Mc/s with a relatively wide bandwidth (extending to more than 75 kc/s on either

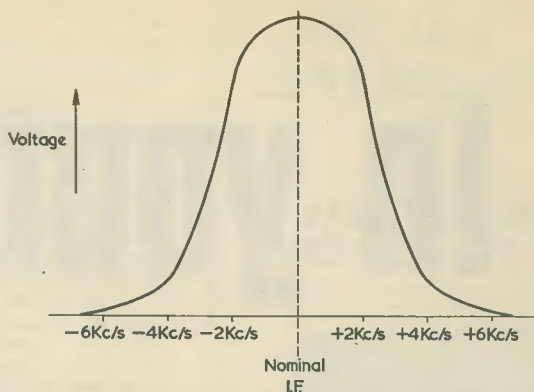


Fig. 4. A representative i.f. amplifier response curve for an a.m. domestic superhet

side of 10.7 Mc/s) to accept the frequency modulated signal after it has passed through the mixer.

Next Month

In next month's issue we shall examine the techniques which enable the signal and local oscillator tuned circuit frequencies to be adjusted by a common ganged capacitor. *

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Heathkit Division models on display (Stand No. 418) will include a wide range of instruments applicable to the many fields of Research, Design, Test and Servicing, as well as Industrial and Educational Training.

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A.P.T. Electronic Industries Ltd., manufacturers of Lektrokit electronic rack and chassis construction systems, have appointed Home Radio (Components) Ltd., 187 London Road, Mitcham, Surrey, as retail stockists of all Lektrokit components.

Over 150 individual items in the Lektrokit ranges will now be available "off the shelf" from the company and it is expected that this arrangement will help small order customers to enjoy a quicker delivery service.

In your

workshop



Anyone can wind a coil and get it to function at a desired frequency. But, as Smithy's assistant Dick soon discovers, it takes quite a lot of extra knowledge for that coil to be specified in a form suitable for mass-production

"I ended up," said Dick chattily, "by winding the aerial tuned coil with 8 turns of wire. The receiver I'd been building then covered the range I required exactly."

With a flourish, Dick popped the last crust of his lunch-time sandwiches into his mouth and chewed vigorously.

"And that," he concluded, somewhat indistinctly, "is how I built my latest short-wave receiver. It goes like a bomb, too!"

Mentally suppressing a sudden vision of Dick's street vanishing beneath a mushroom cloud, Smithy took a swig at his tea and cast an approving glance at his assistant.

"Very commendable, too," he remarked. "I always think it's an excellent idea if people who are coming up the servicing ladder carry out a few home-constructor projects of their own. These help considerably in demonstrating some of the problems

which the commercial set-designer has to tackle and they also give practical experience with components and their functioning. I'm glad to see that you've been winding a lot of your coils too, and that you've been playing around with the number of turns until you get them exactly right. A little experience in that direction is often worth pages of book-learning."

Winding Wire

"Oh, I'm a real gen-kiddy on coil winding now," boasted Dick. "After all the practice I've had winding my own coils I should be in the set-maker's lab *designing* receivers instead of being stuck here servicing them!"

A twinkle came into Smithy's eye. "Fair enough," he remarked. "Well, if you *did* happen to be working for a set-maker, how would you describe that tuned coil you designed in order that it could be put into production

on the shop-floor? For this particular exercise, we'll ignore any coupling windings it might also have had."

Dick considered for a moment.

"Well," he replied, "I'd say that it consisted of 8 turns of wire on a 2 inch diameter former."

"And the spacing between turns?"

"The coil was close-wound."

"Wire gauge?"

Dick opened his mouth, then faltered.

"I'm not entirely certain about that," he remarked, thoughtfully. "I would guess that the wire was around 18 s.w.g. or thereabouts."

"Blimey," remarked Smithy. "You wouldn't get very far! You can't ask a manufacturer's Purchasing Department to buy wire which is around 18 s.w.g. or thereabouts! You've got to state the exact gauge."

"In this case, that's easier said than done," replied Dick. "What I actually did was to use some wire from an old choke that I stripped down."

"O.K. then," said Smithy resignedly. "Let's assume for the sake of argument that the wire *is* 18 s.w.g. If you were working in a lab, you'd next have to state how much wire is needed for each coil made up to your design."

"There's no difficulty there," returned Dick confidently. "The coil consists of 8 turns on a 2 inch former,

which means that the wire length is 8 times the circumference of the former. Work that out from the old 2π bit, add a couple of inches for the lead-outs to the coil tags, and you're made, mate!"

"No you aren't," retorted Smithy. "You'd be out on your ear if you got up to tricks like that. A manufacturer doesn't buy winding wire by length, Dick, he buys it by weight."

"By weight?"

"By weight," repeated Smithy. "So, what you have to do is to find the weight of wire on your coil and quote it in your specification. In this instance you could wind a trial coil, strip the wire off again and then weigh it on a balance. In some factories you'd then quote that weight plus, say, 1% to 3%, to cover wastage, rejects and tolerances in the wire itself. In other factories you'd have to quote the exact weight."

"Gosh," said Dick. "This is getting a bit involved."

"We haven't even started yet," said Smithy cheerfully. "What sort of wire is it?"

"Why, copper of course."

"And the covering?"

"Covering?"

"The insulation," explained Smithy.

"Does it, for instance, have a textile covering?"

"What do you mean by textile covering?" Dick returned the question. "Do you mean silk or cotton covered?"

"That's right," confirmed Smithy.

"The normal textile coverings for winding wire are silk, cotton or rayon. Nowadays, rayon is used more frequently than the other two, and you get winding wire called up as 's.r.c.' for single rayon covered or 'd.r.c.' for double rayon covered. Some of the old hands call the rayon covering 'art silk', incidentally. And, of course, you can have any of these textile coverings on the bare copper wire or on enamelled copper wire."

Further Subdivisions

A light gleamed in Dick's eyes.

"At last," he remarked, "I'm on home ground. The wire I used didn't have any textile covering at all. It was just plain straightforward enamelled wire. And you can't have it any simpler than that!"

At that moment, Smithy drank the last of his tea, whereupon he held his disreputable mug up in the air with a gesture reminiscent of the Statue of Liberty. Wordlessly, Dick rose and replenished the mug at the Workshop sink, then returned it to Smithy's side. This long established practice had become, over the years, entirely automatic. Smithy drank deeply from his recharged mug.

"What," he asked, placing the mug carefully on his bench, "sort of enamel?"

"Enamel?"

"On the wire in your coil."

"Hell's teeth," replied Dick irritably. "It was just enamel, that's all. Either

copper wire is enamelled or it isn't enamelled. The wire I used was enamelled!"

"Yes," persisted Smithy, "but was the enamel oleo resinous, vinyl acetal, polyurethane or polyester?"

Dick's jaw sagged open.

"Smithy," he said eventually, "you've just got to be joking!"

"No, I'm not," grinned Smithy. "I've merely mentioned the four common enamel coverings which are used for winding wires. You'd have to know all about these if you were designing coils for commercial mass-production. Also, you'd have to specify the enamel thickness as well."

"Thickness?" repeated Dick incredulously. "Corluvaduk, if you've got to go through all this palaver to design a commercial coil, I'm sticking to servicing! Did you really say thickness?"

"I did," confirmed Smithy with a chuckle. "Actually, I've been pulling your leg a little bit over the last five minutes or so, but I did want to bring home to you the fact that winding wires form quite a detailed subject in themselves. For a home-constructed design the wire covering isn't terribly important because coils made up to the design are normally hand-wound one at a time, and it's quite O.K. in these circumstances to refer to a wire by its gauge and covering type only. Counting the various thicknesses as subdivisions, there are considerably more than a dozen standard enamel coverings for copper wire, but pretty well any of these would be all right in a home-wound do-it-yourself coil. So far as the textile coverings are concerned, you often find the wire for do-it-yourself coils described as s.s.c. or d.c.c. or something like that, when it would be quite in order to use single rayon covered or double rayon covered instead. The chap who designed the coil may well have used a wire with a rayon covering himself, but described it instead as silk or cotton!"

As Smithy spoke, an expression of gloom descended over Dick's face.

"Do you know what radio is like?" he asked morosely.

"No, what is it like?"

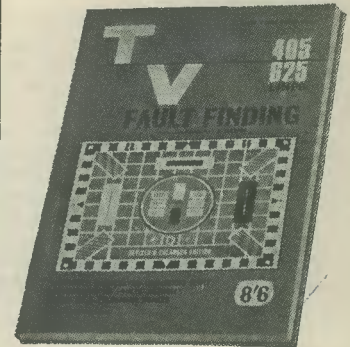
"It's like turning over stones in a meadow, mate," said Dick disgustedly. "Every time you turn over a fresh stone you encounter something new and horrible!"

"I don't follow you."

"Well, take this enamelled wire business," said Dick aggrievedly. "Up to now I've been pressing happily on through life in the innocent belief that you insulate copper wire by the simple process of putting enamel on it. I've now turned over the enamelled wire stone and what do I find? Ghastly things which have names like oleo resinous, poly-whatsit, poly-thingummybob, and goodness knows what else. Not only that, but all these horrors come in different thicknesses as well!"

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"Take it easy," laughed Smithy. "We're just encountering one of those fascinating things you always keep bumping into in electronics. Electronics embraces so many arts, sciences and practices that you enter a complete new field of endeavour whenever you start examining any single facet of it in detail. In this instance, we're looking into the field of enamelled winding wire in production and use. And what we're beginning to see is just a small part of the outcome of decades of research and development in a world-wide industry which employs many thousands of people."

"Making winding wire?"

"Of course," said Smithy. "Apart from the winding wire used in the coils of radio and TV sets, just think of the winding wire used in all the telephone circuits throughout the world and in all the electric motors. To say nothing of the wire in the coils which appear in automobiles and all the other devices and appliances we take for granted these days."

"Stap me," gasped Dick. "I'm just beginning to realise what you're getting at."

"Good," returned Smithy. "You may now also begin to realise why there are so many different types of enamel. These have all been developed for the large number of varying applications in which the wire is to be used. The four types of enamel I mentioned just now are those normally employed for small coils, such as are found in electronic equipment. So far as servicing is concerned it's not necessary to learn a great deal of detail about these, but it's certainly worthwhile knowing the basic types of enamel which exist and why they are used. A service engineer is always the better if he has a knowledge of the materials employed in the sets he fixes."

Different Enamels

"Okeydoke, Smithy," said Dick. "I'm converted! I hope that all these different types of enamel aren't going to be very complicated."

Included in
next month's issue

THE RADIO CONSTRUCTOR'S EASY VIEW DIARY

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"Don't worry," replied Smithy. "Actually, the whole subject, if you look at it in basic form, is quite simple. We'll start off with the first enamel I mentioned, the oleo resinous type."

"Simple, he says!"

"Don't allow yourself to be put off by long words," replied Smithy sternly. "The 'ol' bit in 'oleo resinous' comes from the Latin *oleum* which means 'oil', and you'll find it in lots of other words as well. As a simple example, the ointment for haemorrhoids which you buy at the chemist's is sold as 'Anusol'. With the enamel, 'oleo resinous' just means that this type is oil-based. It's occasionally called 'ordinary' enamel to distinguish it from the other enamels I mentioned just now."

Smithy took a sip from his mug.

"Oleo resinous enamel was pretty well the only enamel covering used for winding wires in radio before World War II," he resumed, "and it was made up mainly from oils obtained from natural sources, such as linseed and the like, plus some bitumen. Modern formulations may be slightly different but there should still be the same basic reliance on natural raw materials. Oleo resinous enamel comes in two thicknesses, these being known as Normal and Thick, or N and T for short. In the jargon of the trade, the thicknesses may be described also as 'Single' and 'Double' respectively."

"Does that mean," asked Dick, "that the wire has one coating of enamel for the Normal thickness and a second coating for the Thick?"

"Oh no," replied Smithy. "With oleo resinous enamel the winding wire passes through the enamel bath quite a few times before it acquires the required thickness of enamel. The words 'Single' and 'Double' have no real meaning in this respect. They're just loose terms which have grown up in the trade. Hang on a jiffy!"

Smithy got off his stool and rummaged around in the cupboard below his bench.

"Here we are," he called out triumphantly, as he emerged with a small booklet in his hand. "I *knew* I had some wire tables in there somewhere. Come over here and have a look at these."

Obediently, Dick walked over as Smithy opened the booklet and indicated one of the tables in it. (Fig. 1).

"This will give you an idea of the dimensions the wire manufacturers have to work to," said Smithy. "Let's take 26 s.w.g. as an example. The nominal diameter of the bare copper wire is 0.018 inch, with tolerances which allow a maximum of 0.0182 inch and a minimum of 0.0178 inch. If you put on a Normal thickness of oleo resinous enamel the increase in diameter must be at least 1.3 mils and the overall diameter must not exceed 0.0199 inch. You

get the same sort of approach in the figures for the Thick covering except, of course, that these apply to a heavier coating of enamel."

"What's a 'mil'?"

"A thousandth of an inch."

Dick surveyed Smithy's table with interest.

"Gosh," he remarked eventually, "those dimensions are tied up pretty tightly."

"They have to be," replied Smithy. "If the increase in diameter due to the enamel was lower than the figure in the table it could be weaker in mechanical and electrical strength. And, if the overall diameter were greater than the *maximum* figure the wire would take up too much room."

"Does that matter?"

"Of course it matters! Suppose you were designing a mains transformer with a certain number of turns of enamelled wire on each layer. If the wire was too thick the turns at the end would be forced over the edge of the space allotted to them."

"Why, of course," said Dick. "I never thought of that."

"It's just one of the reasons why you've got to put tolerances on the wire and the enamel covering. Anyway, let's continue. Now, oleo resinous enamel has very good electrical properties but it has low abrasion resistance and a low resistance to some of the solvents that are encountered in coil manufacture."

"What's 'abrasion resistance'?"

"Resistance to rubbing or chafing," explained Smithy. "Oleo resinous enamel is rubbed off the wire fairly easily if it is chafed during winding, with a consequent risk of short-circuits between turns. At the same time, it's an enamel which can be produced relatively cheaply and so it is an excellent choice for things like iron cored transformers and chokes with paper interleaving. The wire for these components is wound on in layers side by side and is treated quite gently in the process. These components are then later impregnated with a wax or a varnish which won't harm the enamel covering."

Smithy turned to another page of his wire tables.

"We next," he remarked, "leave oleo resinous enamel and turn to the other enamels I mentioned. The first of these is vinyl acetal enamel. This first appeared around the end of World War II under the American trade name Formvar, and is more in the nature of a plastic than is the oleo resinous enamel, which is dried off by heat. The advantages of vinyl acetal enamel are that it has a much higher abrasion resistance and can stand up to many more solvents than the oleo resinous type. So, for reasons of abrasion resistance alone, it's a better choice for coils where the wire has to be treated rather roughly in the winding process. If, for instance, you were going to make a smoothing choke with a scramble winding on a

| Size S.W.G. | Nominal dia. In | Maximum dia. In | Minimum dia. In | Normal covering (N) | | Thick covering (T) | |
|----------------|-----------------------|-----------------------|-----------------------|-------------------------------|---------------------------------------|-------------------------------|---------------------------------------|
| | | | | Maximum overall dia. In | Minimum increase in dia. Mil | Maximum overall dia. In | Minimum increase in dia. Mil |
| 24 | 0.022 | 0.0222 | 0.0218 | 0.0241 | 1.5 | 0.0251 | 2.2 |
| 26 | 0.018 | 0.0182 | 0.0178 | 0.0199 | 1.3 | 0.0208 | 2.0 |
| 28 | 0.0148 | 0.0149 | 0.0147 | 0.0164 | 1.1 | 0.0172 | 1.7 |
| 30 | 0.0124 | 0.0125 | 0.0123 | 0.0138 | 0.9 | 0.0145 | 1.5 |
| 32 | 0.0108 | 0.0109 | 0.0107 | 0.0121 | 0.8 | 0.0128 | 1.4 |
| 34 | 0.0092 | 0.0093 | 0.0091 | 0.0104 | 0.7 | 0.0110 | 1.2 |

Fig. 1. Enamelled copper winding wire is manufactured to close tolerances, as this table for some commonly encountered gauges illustrates. The three columns after the gauge column apply to the bare copper wire. The remaining four columns give tolerances for oleo resinous enamels

former with end cheeks, then there'd be far less risk of shorted turns with vinyl acetal enamel than with oleo resinous enamel. Since the vinyl acetal enamel isn't obtained direct from natural raw materials, it was described as 'synthetic' enamel when it first came out. Which explains why the oleo resinous enamel is also known as 'ordinary' enamel."

Smithy tapped his finger against the wire table in his booklet. (Fig. 2).

"If you look at this," he remarked, "you'll see that vinyl acetal enamel is available in four thicknesses. I won't go through the actual figures, but you'll note that these thicknesses are Fine or F, Medium or M, Thick or T, and Extra Thick or X. This gives the coil designer a great deal of variety to play with."

"The Fine thickness," remarked Dick, "seems to be thinner than the Normal thickness with the oleo resinous enamel."

"True enough," agreed Smithy. "And it can be used for applications where there is only a very low voltage between adjacent enamelled wires. Now, let's press on to the next enamel, which is polyurethane. This was developed some years after the appearance of vinyl acetal enamel. Again, it falls into the plastic category, and it is, indeed, very similar in all character-

istics to vinyl acetal enamel. But there is one important exception."

"What's that?"

"It melts at soldering iron temperatures," replied Smithy.

"Why, blow me," exclaimed Dick, "that must be what they call quick-soldering enamel!"

"That's exactly what it is," confirmed Smithy. "Polyurethane enamel is given a lot of other similar names as well, such as 'self-soldering', 'solder-through', and so on. The great advantage of polyurethane enamelled wire is that, after a coil has been wound with it, there's no necessity to strip the enamel off the ends to make connections. You merely fit each end of the wire to its connecting point, apply a soldering iron and Bob's your uncle! The enamel melts and you've got a solder joint to the copper straightaway. There's no necessity to scrape away the enamel first, as is required with the oleo resinous and vinyl acetal enamels. Polyurethane enamel provides some fluxing action as well and you can, if desired, tin the wire end by merely dipping it in a bath full of molten solder."

Polyester Enamel

"Blimey," said Dick, "that's labour-saving with a vengeance!"

"Just imagine," replied Smithy, "how much time it saves on a coil winding production line. Incidentally, and speaking in very general terms, polyurethane enamel is not, perhaps, quite as tough as vinyl acetal, but it has the terrific advantage of melting at soldering temperatures. Like vinyl acetal enamel, it comes in the four thicknesses, F to X, and these have exactly the same dimensions and tolerances as has the vinyl acetal enamel."

"That," said Dick thoughtfully, "clears up three of the different wire enamels. I seem to remember that, earlier on, you mentioned four."

"I did," confirmed Smithy. "And the fourth one is polyester enamel, which made a general appearance in the early 1960's. This, again, is made in the same four thicknesses as the last two enamels, and its main advantage is that it is very much tougher again. If you're making a coil in which the wire is treated very roughly indeed during winding, then polyester enamel is the type to use. Like vinyl acetal enamel, by the way, it doesn't melt at soldering temperatures."

Smithy put his tables to one side.

"Now I've only," he remarked, "given you a brief description of the different types of copper wire

| Size S.W.G. | Nominal dia. In | Fine covering (F) | | Medium covering (M) | | Thick covering (T) | | Extra thick covering (X) | |
|----------------|-----------------------|-------------------------------|---------------------------------------|-------------------------------|---------------------------------------|-------------------------------|---------------------------------------|-------------------------------|---------------------------------------|
| | | Maximum overall dia. In | Minimum increase in dia. Mil | Maximum overall dia. In | Minimum increase in dia. Mil | Maximum overall dia. In | Minimum increase in dia. Mil | Maximum overall dia. In | Minimum increase in dia. Mil |
| 24 | 0.022 | 0.0240 | 1.2 | 0.0249 | 1.9 | 0.0257 | 2.8 | 0.0273 | 3.6 |
| 26 | 0.018 | 0.0199 | 1.1 | 0.0207 | 1.8 | 0.0215 | 2.6 | 0.0229 | 3.4 |
| 28 | 0.0148 | 0.0164 | 1.0 | 0.0171 | 1.6 | 0.0178 | 2.3 | 0.0191 | 3.0 |
| 30 | 0.0124 | 0.0139 | 0.9 | 0.0146 | 1.5 | 0.0153 | 2.2 | 0.0164 | 2.9 |
| 32 | 0.0108 | 0.0122 | 0.8 | 0.0129 | 1.3 | 0.0136 | 2.1 | 0.0147 | 2.8 |
| 34 | 0.0092 | 0.0104 | 0.7 | 0.0111 | 1.2 | 0.0118 | 1.9 | — | — |

Fig. 2. The "synthetic" enamels (vinyl acetal, etc.) are produced in four thicknesses. Tolerances for the same wire sizes as in Fig. 1 are shown in this table. (The extra thick covering is not usually available for 34 s.w.g. and thinner wires)

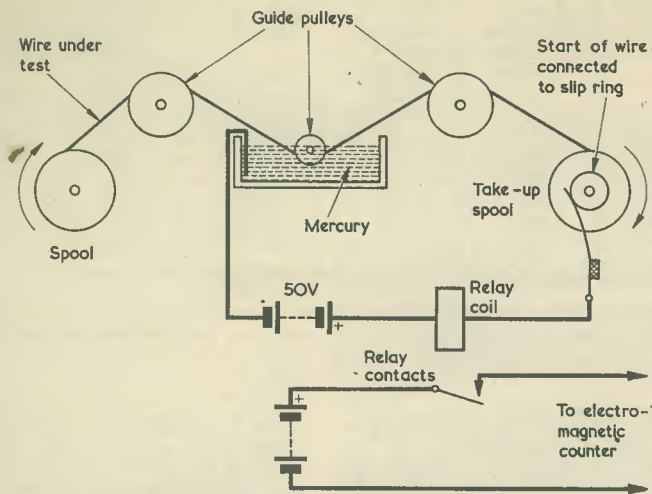


Fig. 3. A simplified diagram illustrating the apparatus used for testing for pinholes in wire enamel. When a pinhole passes through the mercury bath a circuit is completed between the mercury and the wire under test, causing the relay to energise

enamel here, but what I've told you should enable you to have a general idea of what goes on."

"I see," remarked Dick musingly. "Incidentally, how does the coil designer know what thickness of enamel to use for any particular coil?"

"To some extent," replied Smithy, "he relies on a certain amount of common sense, together with accumulated experience with similar coils in the past. Speaking in very approximate terms it is helpful to think about the enamel in terms of 'thicknesses'. I've already mentioned that Normal oleo resinous enamel can be thought of as 'Single' and the Thick variety as 'Double'. You can apply this line of thinking to the synthetic enamels as well, calling the F type 'single', the M type 'double', and so on. You then employ a few simple rule of thumb concepts. If there is negligible voltage between two touching turns in a coil it can be considered reasonably safe to put two 'thicknesses' of enamel between adjacent copper conductors. Thus, you could use Normal oleo resinous or Fine synthetic. Typical examples would be given by the turns of a layer-wound mains transformer where the potential between adjacent turns is about one-eighth of a volt, or in a receiver r.f. coil where the potential between turns is negligible. On the other hand, in a TV line output transformer you get something like 10 volts per turn, which is relatively high. Such a transformer, when layer-wound, would use vinyl acetal or polyurethane M enamel, or even T enamel. You have to remember that the cost of the wire goes up as the enamel thickness increases and

so the designer has to choose an enamel thickness which gives the desired reliability so far as preventing shorted turns is concerned, without being excessively expensive. There is, also, a random factor with the thinner gauges which causes the coil designer to rely rather heavily on previous experience."

"What random factor is that?"

"Pinholes."

"Pinholes?"

"Pinholes," confirmed Smithy.

"You see, it's very difficult to make the thinner gauges of enamelled wire without tiny pinholes appearing here and there. The copper is exposed at these pinholes."

"Blimey," said Dick. "I'd always thought the wire was completely covered by the enamel."

"Unfortunately not," replied Smithy. "Obviously, the number of pinholes to be expected in a length of wire decreases as the thickness of the enamel goes up, because the wire has been subjected to more enamel coating processes. Pinholes are only normally troublesome if two of them come alongside each other in adjacent turns of wire in a coil. A pinhole in one wire adjacent to an unbroken surface of enamel in the next can't cause a breakdown because there is still enamel between the two turns. The risk of having two pinholes side by side in adjacent turns is pretty remote in practice and it decreases as the enamel thickness goes up and the number of pinholes goes down. A careful designer bears this point in mind when working out the enamel thickness for a particular coil."

"Can't the wire manufacturer prevent the formation of pinholes?"

"Not entirely," said Smithy, pulling his note-pad towards him and making a quick sketch (Fig. 3). "Instead, he's allowed a maximum number of pinholes per unit length of wire according to gauge and thickness. Batches of the wire being made go through a test set-up in which the wire passes through a mercury bath. If there is a pinhole in the wire going through the bath a current passes through the wire and the mercury and closes a relay coupled to a counter. The counter then indicates the number of pinholes in the length of wire being tested. If this exceeds a certain number, the batch of wire is considered faulty. The permissible number, incidentally, is laid down in a British Standard applicable to the type of enamel."

"There's certainly far more to this wire enamel business," commented Dick, "than I'd ever even anticipated."

"It does get a little involved when you start looking into it," agreed Smithy cheerfully. "Another complication is that the wire manufacturers have a habit of referring to their enamelled winding wires by individual trade names instead of by the enamel formulation, although they do usually state the formulation as well. You can normally tell which enamel is which by the British Standard Specification quoted for the wire. Oleo resinous enamelled wires are covered by BSS156, vinyl acetal by BSS1844, polyurethane by BSS3188 and polyester by BSS3160. Incidentally, both the wire manufacturers and their customers stick rigidly to the appropriate British Standard."

Other Types

"Are there any other types of winding wire coverings that you haven't mentioned?"

"There are two main other types," replied Smithy. "One of these is self-bonding wire. This is covered with a standard synthetic enamel after which about 0.5 mil of a thermosetting glue is applied. A particularly common application for this sort of wire is in the flared self-supporting coils used in TV deflector yokes. The self-bonding wire is wound in a mandrel which gives it the final shape required. A current is then passed through the wire. This causes the wire to heat up and the thermosetting glue to melt and set in its final form. The coil is then taken out of the mandrel whereupon, because of the glue, it maintains the shape given in the mandrel."

"What's the other type of wire?"

"It's the old TNA stuff," grinned Smithy, "which I've mentioned on previous occasions."

"Oh, I know all about TNA wire," commented Dick quickly. "It consists of tinned copper wire covered with nylon fibre and an outer lapping of acetate fibre. It's used for single layer close-wound coils, these being brushed afterwards with acetone, whereupon the acetate dissolves and

becomes re-set as a continuous coating over all the coil."

"That's right," agreed Smithy. "The coil then becomes self-supporting."

"Also," cut in Dick eagerly, "the nylon and acetate melt at soldering iron temperatures, so there's no need to strip the coil ends before connecting it into circuit."

"Exactly," confirmed Smithy. "Those little self-supporting air-cored r.f. chokes you see in u.h.f. TV tuners use TNA wire, as also do the tuned coils in many Band I—Band III tuners. All these coils can be wound automatically with TNA wire on a machine which applies the acetone and dries it as well, whereupon it produces complete ready-made coils. A machine of this nature can also wind TNA wire coils on formers coated with acetate. The acetate on the former then bonds with that on the wire when acetone is applied, causing the whole assembly to be fully bonded together."

From The Earth

"Fascinating, isn't it?" remarked Dick. "All this winding wire business, I mean."

"What I find even more fascinating," replied Smithy, "is to think in terms of the raw materials from which the wires are made. The copper itself is, of course, mined as copper ore, the mineral in the ore being copper pyrites which is smelted and refined near the mining site. I've already referred to the natural sources for the oleo resinous enamels. The synthetic enamels derive from natural sources as well although, of course, considerable chemical changes take place before they emerge in the form we use them. For instance, the vinyl acetates can be derived from coal or crude petroleum, and so on."

"In other words," chimed in Dick, "all the materials used in these wires originally come from the earth itself."

"Plus," added Smithy, "oxygen from the air if this is needed for any

chemical processing. Go a bit further and consider an ordinary TV receiver. Now, this is a complex piece of equipment incorporating hundreds of different materials ranging from the wood of the cabinet to the mica in some of the capacitors. Funnily enough, both the wood and the mica are used in exactly the state that they are found in nature. But all the rest of the parts in the TV sets are the result of processing natural raw materials which, in their original condition, could be anything from mud to rocks. I think it's all *quite* marvellous."

With which pronouncement Smithy drained the last of his tea. This, it may be added, was processed from the natural tea leaf and was added to milk (obtained directly from the cow via United Dairies) and to water (courtesy of the local Water Board).



THE JET SET

Amateur Radio has a new Image

It is now fashionable to be a Radio Amateur. In fact it is very "with it". The "image" of amateur radio has changed beyond all recognition in the last decade or so. The early designation of "ham" to those who participated in amateur radio was indicative of the type of individual most frequently to be found associated with this particular activity in the early days. Often they were fanatics, completely absorbed in their hobby, burning the midnight oil, building haywire radio transmitters and receivers or contacting similar enthusiasts in distant parts of the world. They were sometimes oblivious of the niceties of communal living. Their elaborate aerial systems, an eyesore to neighbours for miles around, were the pride of their hearts. In spite of much serious scientific experimentation and development done by them, for the most part they were treated by friends and relations as cranks.

In recent times, however, the picture has completely changed. Amateur radio has become very respectable. Some say it is the influence of James Bond, or the "Man from UNCLE" or that we now live in a much more scientific age. But there may be a much more subtle reason. Is it, we wonder, due to the interest the women are now taking in amateur radio?

Since amateur radio went "mobile" and the "old man" emerged from his shack and reorganised himself and his hobby so that he could give the family a day out in the country or beside the sea, woman's attitude to the hobby has changed completely. This new mode was something quite different to her way of thinking! Instead of spending all his spare time in a little shed down the end of the garden, tinkering with his bits and pieces, his valves and wire; he now makes something he fits into the car and wants to take out to some quiet secluded place in the country to try out. Instead of having the husband's cronies calling at the house and sooner or later demanding tea and cakes, he now goes to quite attractive spots by car, to meet his cronies there. And there she meets other wives with whom she can talk kids, schools, the rising prices of everything and the apparent craziness of her husband. Amateur radio now provides her with a release from dull every day routine. Not only has it brought interest and comradeship to her old man, but it has given her social outings and contacts far and away above what she could otherwise have enjoyed. Thus did woman come into Amateur Radio. Under her tender hand, it has now escalated into sophistication. The gear is now commercially built and takes its place along with the Hi-Fi and Stereo; the colour TV and Tape Recorder in the lounge. It is all suitably encased and beautifully coloured. The antenna is a very "with-it" array outside in the centre of the lawn, around which the rest of the small garden is tastefully designed. It rotates and goes up and down at the push of a switch and completely eclipses the B.B.C. 1 and 2 and I.T.V. and F.M. aerials of the neighbours. And the amateur radio social occasions are no longer held on the beach at Southend or Mablethorpe. They are now in Knokke, Geneva, Malmo or Montreal. And you don't go by car, you go by plane. No longer is the Dx some distant ham shack in some exotic location in the sun, whose distance would suggest no possibility whatsoever of meeting its owner. Now, as likely as not, you'll meet him—or her—at the next Convention, and he like you will have come by plane. Yes, Amateur Radio too, now has its "Jet Set".

TRADE

NEWS . . .

NEW BLACK & DECKER D500 DRILL

The new Black & Decker Super D500 drill has been fitted with a larger chuck than any single-speed drill produced by the company in the past. Fitted with a $\frac{3}{8}$ in chuck, the drill will effectively deal with $\frac{1}{2}$ in steel, $\frac{1}{2}$ in masonry and $\frac{3}{4}$ in wood.

Capable of 2,400 revolutions per minute, this new drill has 20% more power than other single-speed drills in the range.

This drill, together with some of the accessories—such as the bench drill stand—would find a ready use in the radio enthusiasts workshop, making the onerous task of “chassis-bashing” a more pleasant occupation. The uses in the home for such a tool are, of course, legion.



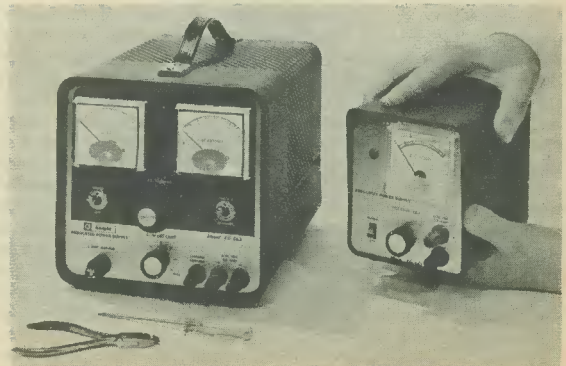
THE KNIGHT KG795 FM RADIO TUNER

The Knight KG795 solid state stereo FM Radio Tuner one of the many attractive sets which can be constructed from the wide range of “Knight-Kits” now being marketed in the UK and Europe exclusively by Electroniques (prop STC Ltd.). Easily built in four hours by anyone, regardless of their technical knowledge, the KG 795 utilises the latest electronic devices and circuit techniques (including silicon semiconductors and built-in automatic multiplex decoder) and is suitable for receiving the stereo broadcasting services of the BBC.



THE KNIGHT KG661 AND KG663 BENCH POWER UNITS

The Knight KG663 (left) and KG661 bench power units assembled—two of the many “Knight-Kit” construction kits now being marketed in the UK and Europe exclusively by Electroniques (prop STC Ltd.). “Knight-Kits” are easy to assemble kits which enable anyone, regardless of their technical knowledge to construct professional standard electronic equipment. The KG663 is a 0–40V 1.5A unit with continuously variable current limiting; the KG661 is a 0–25V 0.5A unit with overload current limiting at 0.7A.



Radio

Topics

By Recorder

JUDGING BY THE INTEREST SHOWN by readers, I think I'll have to change the title of this column to "Modulated Light Topics"!

You may recall that I devoted the whole of my space in the January issue to Mr. R. J. Ward's comprehensive modulated light transmission system, in which the light beam at the transmitting end is *frequency* modulated. Then, in the February issue we published the article "Long Range Light Modulator and Receiver" by J. P. Dakin, which employs quite a different method of operation. Mr. Dakin uses amplitude modulation with two balsa wood shutters in front of the transmitting light beam. One shutter is fixed and the other is secured to the voice coil of a loudspeaker coupled to the output of an a.f. amplifier. The shutters have parallel slots cut in them and are mutually arranged so that, when the voice coil moves in one direction a greater slot aperture area is presented to the source of light whilst, when it moves in the other direction the overall slot area decreases. Thus, the light is modulated *after* it leaves the source of illumination. In the previous systems described in this journal the

technique was to modulate the supply current to the lamp itself.

Alternative Shutters

Two readers have sent in suggested modifications for the shutter design, and I am happy to quote from their letters here.

The first letter, from J. M. Colles of Amersham, Bucks, puts forward the following idea for making up the shutters.

First, draw a number of black lines 0.1in wide and separated by the same distance on good cartridge paper. (Mr. Colles used a piece of cartridge paper measuring 13 by 16in with the lines parallel to the long side.) Then take two photographs of this, and use the negatives as shutters. The obvious advantages here are that no precision cutting out is required, as with the balsa wood shutters, and the moving shutter affixed to the loudspeaker voice coil is very light.

The second letter, from D. B. Pitt of Wollaton, Nottingham, refers to his experiences during the thirties when he used a similar type of loudspeaker-operated shutter system to modulate the light source in a 30-line

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television receiver. The shutters, or "grids" as Mr. Pitt prefers to call them, were photographic negatives also, these being obtained by photographing a striped tablecloth with a box camera. Three of these grids were then used in the following manner. One was mounted at the centre of the diaphragm of an otherwise unmodified loudspeaker, and it passed freely through a saw-cut in a length of wood straddling the loudspeaker frame. The two remaining grids were fixed, one on each side of the moving grid, at the sides of the saw-cut. The piece of wood was secured to the speaker frame using bolts and rubber washers under compression so that, by carefully adjusting the bolts, the grids could be aligned for the desired height and parallelism. The negatives forming the grids were arranged in a light frame to prevent curling, and the only limit to the usefulness of the arrangement seemed to be the ability of the negatives (at that time highly inflammable cellulose nitrate) to withstand the heat from the bulb without exploding into flames!

Mr. Pitt also raises an interesting question concerning systems of this nature. Why use an a.f. amplifier? Why not simply speak direct into the diaphragm of the loudspeaker?

"After all," concludes Mr. Pitt, "Edison's transmitter was only a thin mirror arranged at 45° to a beam of light!"

Pi and Coffee

"May I have a large container of coffee?"

This sentence represents a useful little mnemonic which, when I recently heard it included in a question in the B.B.C. sound radio quiz *Brain of Britain*, was new to me. Since it

may also be new to some readers as well, I quote it here.

The number of letters in each word of the sentence represents, in order, the first eight figures in our old friend, π , which looms so largely in electronic calculations.

M. G. Scroggie's excellent *Radio and Electronic Laboratory Handbook* (Iliffe) gives π to ten decimal places as:

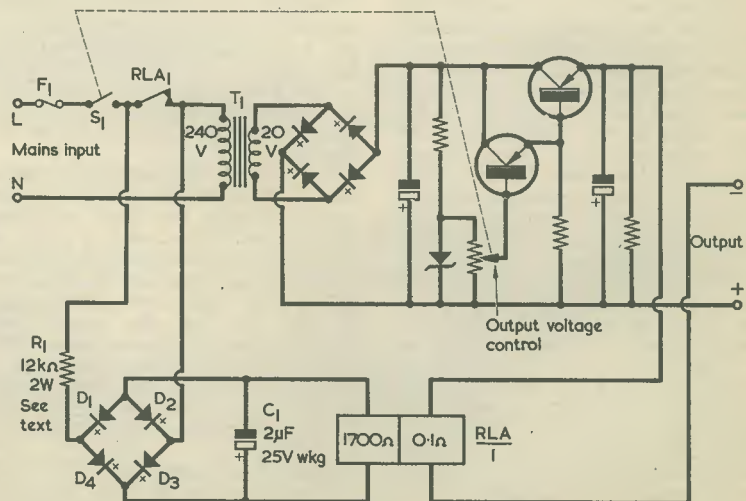
3.1415926535.

So it looks as though the mnemonic falls down a little on "coffee", which stands for 6, because when corrected to seven decimal places that last number should really be 7. Pedants may prefer to join me in a large container of Maderia or scrumpy according to their tastes.

Overload Trip Circuit

We have published several articles in recent issues on stabilised power supplies for transistor equipment, and these have prompted Mr. R. A. Jackson of Elmer Sands, Essex, to send us his design for a very neat overload trip circuit which, incorporated in a 20 volt 1 amp supply, has given him completely reliable service for over a year. The relay employed in the trip circuit was a surplus type (although I see that an equivalent new component is listed in the Henry's Radio 1967 catalogue) and requires some modification. The circuit should not be tackled, therefore, unless you feel competent to make the change required.

The circuit of the power supply with its trip relay appears in the accompanying diagram. The mains input is applied via F_1 , on-off switch S_1 , and the normally-closed relay contacts RLA_1 , to the primary of mains transformer T_1 . The 20 volt



The circuit of the overload trip, fitted to a 20 volt 1 amp supply. Using "detached" presentation, the relay coil is shown as a rectangle remote from its contact set

secondary of this transformer feeds a standard stabilised power supply circuit, incorporating the usual zener diode, two emitter followers and variable voltage control. Component values are not shown here because these vary with different power supply designs and do not influence the operation of the trip circuit proper. It will be seen that the output voltage control potentiometer is ganged with on-off switch S₁.

Relay RLA/1 requires only the normally-closed contact set RLAI, and the component employed by Mr. Jackson is a Siemens high speed relay available from surplus sources and much used for Radio Control work. It has two 1,700Ω coils and one change-over contact set.

One of the relay coils is removed, and is fully re-wound with 20 s.w.g. enamelled copper wire, giving a resistance of 0.1Ω. The leads of the new coil are then re-terminated at the relay base. It was found that the 20 s.w.g. coil caused the relay to operate satisfactorily at 1 amp, the moving contact having been slightly bent to give an equal gap at each pole face.

The trip circuit operates in the following manner. The 0.1Ω coil is in series with the output of the power supply and if, due to overload, the output current approaches or exceeds 1 amp the relay energises. Contact RLAI opens, whereupon the 12kΩ resistor R₁ and bridge rectifiers D₁ to D₄ are inserted in series with the mains input to T₁ primary. These components cause the output voltage to be reduced to a very low and safe value, whilst the a.c. flowing in the bridge rectifier is rectified and applied to the 1,700Ω coil of the relay. Thus, the relay remains energised, holding the trip condition. The 2μF capacitor, C₁, causes the trip to be effective should heavy loads cause an immediate collapse of output voltage, and it prevents relay chatter even on the most momentary output short-circuit.

The circuit is re-set by turning the voltage control potentiometer to zero volts. This causes switch S₁ to open, whereupon the relay de-energises. If the short-circuit has been removed, the switch may then be turned on again immediately and the output voltage control returned to the desired setting. In any case, the trip circuit is ready to operate if the overloads recur.

It should be noted that the phasing of the connections to the relay coils is important. Wrong phasing will cause relay chatter.

The rectifiers used by Mr. Jackson for D₁ to D₄ were S.T.C. type K8/15, which have a p.i.v. of 1,020 volts. Really, these are overrun, however, since they are rated at 5mA whilst the rectified current in the 1,700Ω relay winding is of the order of 8mA, and it would be preferable to use rectifiers with a current rating of at least 10mA. Provided that all rectifiers

are in circuit the bridge configuration keeps the p.i.v. applied to each diode at less than 100 volts, which means that a wide range of rectifiers could be employed for D₁ to D₄, including even such types as the OA81. Alternative types have not, incidentally, been tried in practice. Remember that the 1,700Ω relay winding load *must* be connected before applying power to the bridge, otherwise the p.i.v. and the voltage across C₁ will rise to an excessively high value.

The 12kΩ resistor, R₁ was found to cause the relay to remain reliably energised when contacts RLAI opened. However, the impedance offered by the mains transformer primary appears in the rectifier circuit when the relay trips and it may be necessary to alter the value of R₁ to accommodate different transformers. Different rectifiers may also necessitate a change in the value of this resistor. The value should be as high as is consistent with reliable circuit operation.

If it is desired to have the circuit trip at lower currents than 1 amp it will be necessary to use a thinner wire in the re-wound relay coil, and the gauge required here will have to be determined by experiment.

Finger Trouble

One of the most amusing servicing stories I have heard for ages appears in "The Serviceman" feature in the January issue of our Australian contemporary *Electronics Australia*. I am delighted to pass it on here with all due acknowledgement to source.

An engineer friend of "The Serviceman", whilst on a touring holiday in the outback of north Queensland, called in on a hospitable farmer during his travels for a drink and a chat. On learning that his visitor was in the electronics game the farmer asked him to have a look at his a.m. radio, which had never given a very good performance. When he checked, the engineer found that all that seemed to be wrong was that the set had never had an aerial wire connected to its aerial terminal.

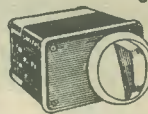
He then took the back off, to recoil from a horrible furry elongated mass which lay along the back of the chassis.

The farmer explained that, when the set had been originally put into operation some years earlier (similarly without aerial), a member of the family noticed that volume increased when he put his finger on the aerial terminal. Since it was inconvenient to keep touching the aerial terminal all the time and since, like a finger, a sausage is a cylinder of skin full of meat, it was decided to connect a sausage permanently to the aerial terminal. And it was the decomposed remains of that sausage which the engineer encountered.

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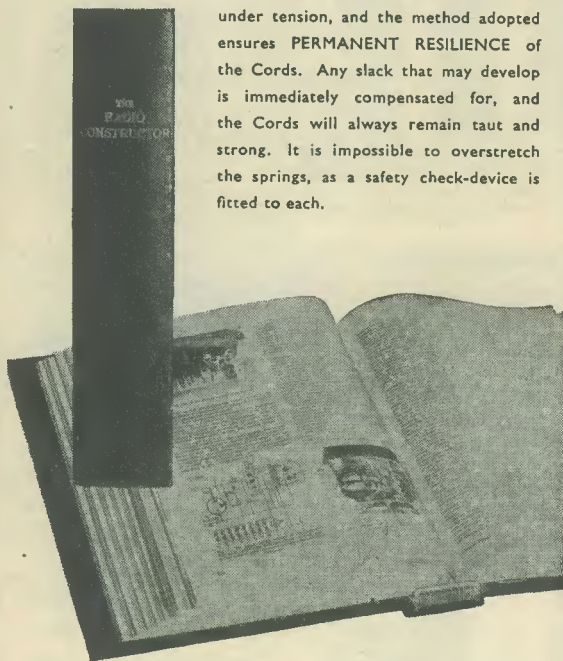
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continued on page 651

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continued from page 650

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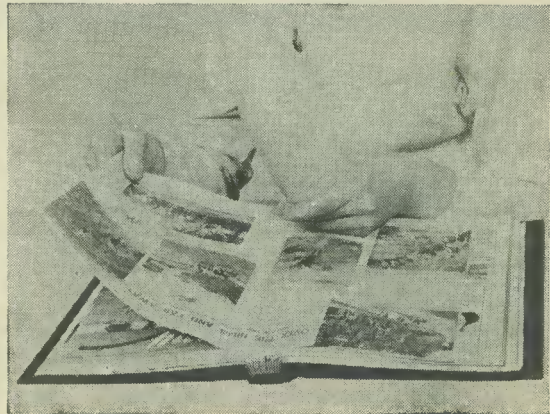
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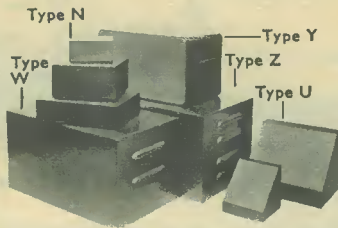
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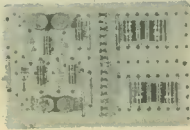
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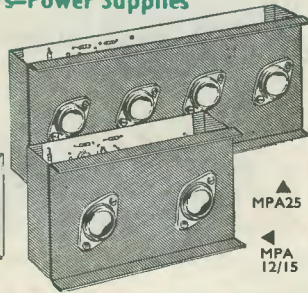
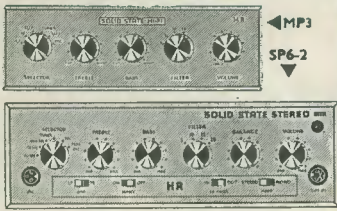
The old-established firm of printers who had printed the RADIO CONSTRUCTOR for nearly 20 years ceased business with only half this magazine printed and only giving 3 days notice, just prior to our publication date. Hence the delay in publishing this issue.

To have the magazine on sale within a reasonable time from the normal publication date has meant a mammoth operation by all concerned and we acknowledge the ready co-operation we have received from the staffs of the present and former printers.

We much regret the inconvenience caused to readers. We expect to publish the JUNE issue on Thursday, 6th June.

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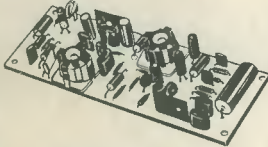
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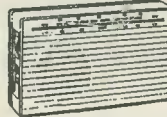
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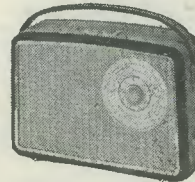
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