THE Radio Constructor

RADIO
TELEVISION
AUDIO
ELECTRONICS

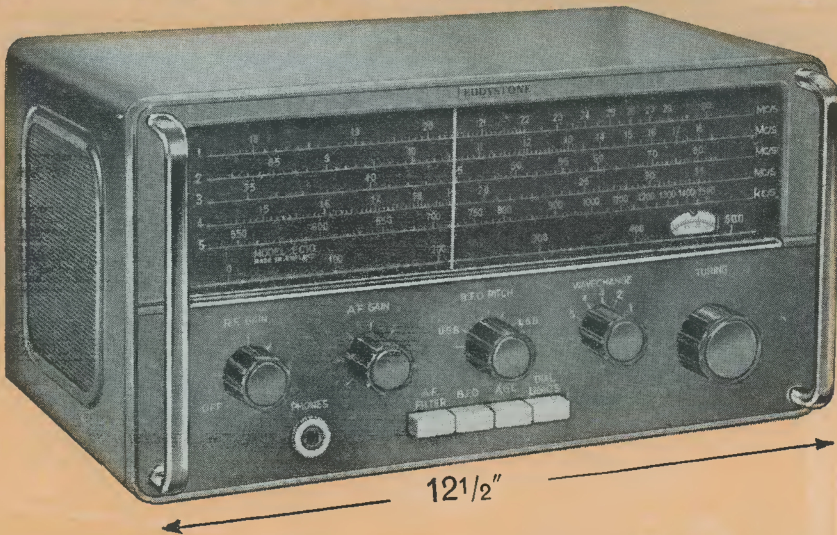
VOLUME 19 NUMBER 1
A DATA PUBLICATION
TWO SHILLINGS & THREEPENCE

August 1965

Phototransistor Sports Timer

THE EDDYSTONE MODEL "EC10"

TRANSISTORISED COMMUNICATIONS RECEIVER



RUGGED, LIGHT AND COMPACT FOR PROFESSIONAL AND AMATEUR USE

A most efficient transistorised receiver giving an excellent and consistent performance over the whole range from 550 kc/s to 30 Mc/s. Thirteen transistors and diodes, including stabilising Zener diode. Ample audio output to internal speaker, and panel jack also fitted for telephone headset. Precision slow-motion drive with 110 to 1 reduction ratio ensures delightfully easy tuning.

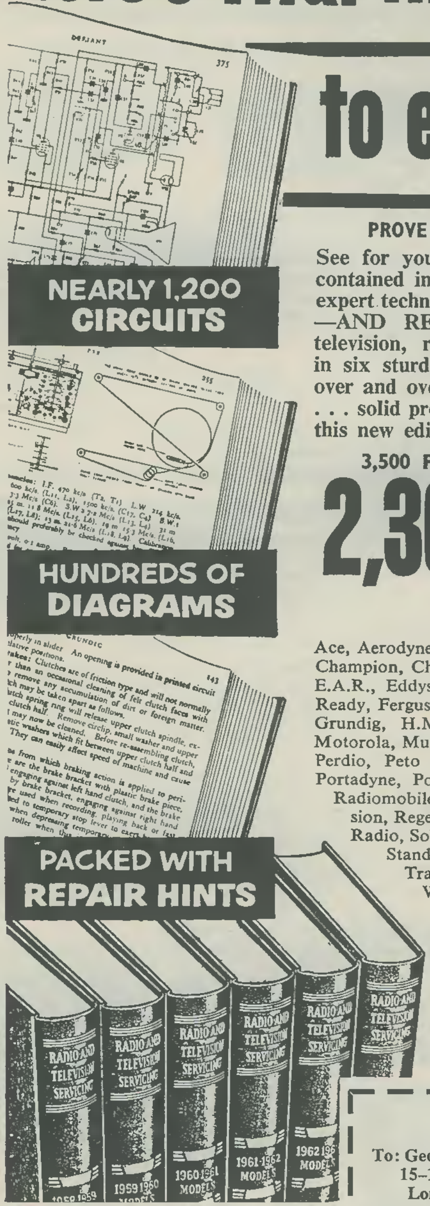
Self-contained battery unit holds long-life cells. Alternative aerial inputs for dipole, long wire and short wire aerials. Selective audio filter improves c.w. reception. Robust construction, modern styling, attractive two-tone grey finish. Dimensions are $12\frac{1}{2}$ inches wide, $6\frac{3}{8}$ inches high, 8 inches deep. Weight with batteries 14 lb.

List Price (in U.K.) **£48. 0s. 0d.**

EDDYSTONE RADIO LIMITED · Birmingham 31 · England

Here's vital time-saving data

to earn money for you!



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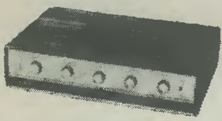
HI-FI AMPLIFIERS ~~~ TUNERS ~~~ RECORD PLAYERS

STEREO AMP. AA-22U



PLAYER AT-6

HI-FI 6W STEREO AMPLIFIER. Model S-33. 3 watts per channel 0.3% distortion at 2.5W/chnl., 20dB N.F.B. Inputs for Radio (or Tape) and Gram. Kit **£13.7.6** Assembled **£18.18.0**

20+20W TRANSISTOR STEREO AMPLIFIER. Model AA-22U. Outstanding performance. Handsome, walnut-veneered cabinet. Kit **£43.18.0** Assembled **£68.16.0**

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

HI-FI MONO AMPLIFIER. Model MA-5. A general purpose 5W Amplifier, with inputs for Gram., Radio. Presentation similar to S-33 Kit **£10.19.6** Assembled **£15.10.0**

PA AMPLIFIER, Model PA-1. 50W amplifier. The ideal, compact unit. Two heavy duty speakers. Variable tremolo. Legs optional extra 17/6 Kit **£54.15.0** Assembled **£74.0.0**

NEW MODEL!

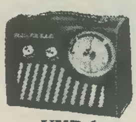
TRANSISTOR MIXER. - Model TM-1

A must for the tape enthusiast. 7 transistor circuit, battery operation allows unit to be used in or out of doors. Beautiful walnut-veneered cabinet.
Presentation similar to the AA-22U Amplifier.
Kit **£11.16.6** Assembled **£16.17.6**

TRANSISTOR RECEIVERS

UXR-2

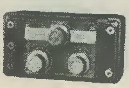
"OXFORD" LUXURY PORTABLE. Model UXR-2. Specially designed for use as a domestic, car or personal portable receiver. Many features, including solid leather case. Kit **£14.18.0** incl. P.T.



UXR-1

TRANSISTOR PORTABLE. Model UXR-1. Pre-aligned I.F. transformers, printed circuit. Covers L.W. and M.W. Has 7" x 4" loudspeaker. Real hide case. Kit **£12.11.0** incl. P.T.

JUNIOR EXPERIMENTAL WORKSHOP. Model EW-1. More than a toy! Will make over 20 exciting electronic devices, incl: Radios, Burglar Alarms, etc. 72 page Manual. The ideal present! Kit **£7.13.6** incl. P.T.



UJR-1

JUNIOR TRANSISTOR RADIO. Model UJR-1. Single transistor set. Excellent introduction to radio. Kit **£2.7.6** incl. P.T.

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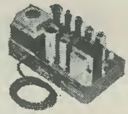
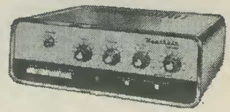
POWER AMP. MA-12



STEREO AMP. S-99



HI-FI MONO AMPLIFIER. Model MA-12. 10W output, wide freq. range, low distortion. Kit **£11.18.0** Assembled **£15.18.0**

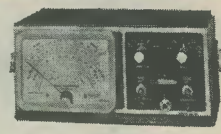
DE LUXE STEREO AMPLIFIER. Model S-33H. De luxe version of the S-33 with two-tone grey perspex panel, and higher sensitivity necessary to accept the Decca Deram pick-up. Kit **£15.17.6** Assembled **£21.7.6**

HI-FI STEREO AMPLIFIER. Model S-99. 9 + 9W output. Ganged controls. Stereo/Mono gram., radio and tape inputs. Push-button selection. Printed circuit construction. Kit **£28.9.6** Assembled **£38.9.6**

POWER SUPPLY UNIT. Model MGP-1. Input 100/120V, 200/250V, 40–60 c/s. Output 6.3V, 2.5A A.C. 200, 250, 270V, 120mA max. D.C. Kit **£5.2.6** Assembled **£6.12.6**

HI-FI CABINETS. A wide range available, prices from **£8.8.0** to **£46.4.0** incl. P.T. Assembled or in kit form.

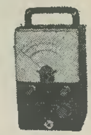
INSTRUMENTS



IM-13U

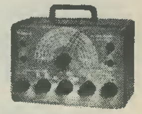
DE LUXE LARGE-SCALE VALVE VOLTMETER: Model IM-13U. Circuit and specification based on the well-known model V-7A but with many worth-while refinements. 6" Ernest Turner meter. Unique gimbal bracket allows operation of instrument in many positions. Modern styling. Kit **£18.18.0** Assembled **£26.18.0**

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. Kit **£22.10.0** Assembled **£30.10.0**



V-7A

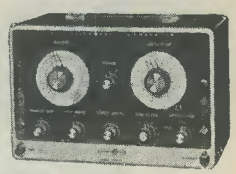
VALVE VOLTMETER. Model V-7A. 7 voltage ranges d.c. volts to 1,500. A.c. to 1,500 r.m.s. and 4,000 peak to peak. Resistance 0.1Ω to 1,000MΩ with internal battery. D.c. input resistance 11MΩ. dB measurement, has centre-zero scale. Complete with test prods, leads and standardising battery. Kit **£13.18.6** Assembled **£19.18.6**



RF-1U

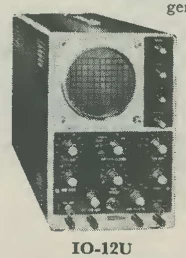
MULTIMETER. Model MM-1U. Ranges 0–1.5V to 1,500V a.c. and d.c.; 150μA to 15A d.c.; 0.2Ω to 20MΩ. 4½" 50μA meter. Kit **£12.18.0** Assembled **£18.11.6**

R.F. SIGNAL GENERATOR. Model RF-1U. Up to 100 Mc/s fundamental and 200 Mc/s on harmonics. Up to 100mV output. Kit **£13.8.0** Assembled **£19.18.0**



HFW-1

T.V. ALIGNMENT GENERATOR. Model HFW-1. Offers max performance at lowest cost. Covers 3.6 to 220 Mc/s fundamentals. Electronic sweep oscillators. Built in marker generators (5 Mc/s crystal). **£37.18.0** Kit **£47.10.0** Assembled



IO-12U

5" GENERAL-PURPOSE LABORATORY OSCILLOSCOPE. Model IO-12U. This outstanding oscilloscope, with its professional specification and styling, fulfils most laboratory and service requirements. Vertical frequency response 3 c/s to over 4.5 Mc/s, sensitivity 10mV r.m.s. per cm. at 1 kc/s. T/B covers 10 c/s–500 kc/s. Kit **£35.17.6** Assembled **£45.15.0**

2½" PORTABLE SERVICE 'SCOPE. Model OS-1. This is a light, compact oscilloscope, ideal for servicing, etc. Dimensions 5" x 8" x 14½" long. Wt. 10½lb. Fitted mu-metal CRT shield. Kit **£22.18.0** Assembled **£30.8.0**

ELECTRONIC SWITCH. Model S-3U. Converts a single beam 'scope to double beam operation at low cost. Kit **£12.18.0** Assembled **£18.10.0**

TRANSISTOR POWER SUPPLY Model IP-20U. Up to 50V, 1.5A output. Kit **£35.8.0** Assembled **£47.8.0**

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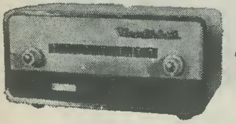
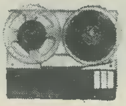
TAPE AMPLIFIERS ~~~ TAPE DECKS ~~~ CONTROL UNITS



FM TUNER FM-4U



MAGNAVOX NEW DECK

HI-FI FM TUNER. Model FM-4U. Also available in two units. R.F. tuning unit (£2.15.0 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). Total Kit **£16.8.0**

MAGNAVOX NEW TAPE DECK. The finest buy in its price range. Operating speeds: 1⅞", 3¾" and 7½" p.s. Two tracks, "wow" and "flutter" not greater than 0.15% at 7½" p.s. **£14.19.6**

HI-FI AM/FM TUNER: Model AFM-1. Available in two units which, for your convenience, are sold separately. Tuning heart (AFM-T1—£4.13.6 incl. P.T.) and I.F. amplifier (AFM-A1—£22.11.6). Printed circuit board, 8 valves. Covers L.W., M.W., S.W., and F.M. Built-in power supply. Total Kit **£27.5.0**

TRUVOX DECK

AM/FM TUNER

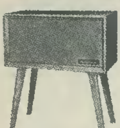
TRUVOX D-93 TAPE DECKS. High quality stereo/mono tape decks. **D93/2,** ½ track, **£36.15.0 D93/4,** ¼ track, **£36.15.0**

TAPE RECORDING/PLAYBACK AMPLIFIER. Thermometer type recording indicators, press-button speed compensation and input selection.
Mono Model TA-1M. Kit **£19.18.0** Assembled **£28.18.0**
Stereo Model TA-1S. Kit **£25.10.0** Assembled **£35.18.0**

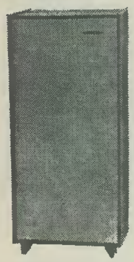
MONO CONTROL UNIT. Model UMC-1. Designed to work with the MA-12 or similar amplifier requiring 0.25V or less for full output. 5 inputs. Baxandall type controls. Kit **£8.12.6** Assembled **£13.12.6**

STEREO CONTROL UNIT. Model USC-1. Push-button selection, accurately matched ganged controls to ±1dB. Rumble and variable low-pass filters. Printed circuit boards. Kit **£19.10.0** Assembled **£26.10.0**

SPEAKER SYSTEMS



SSU-1



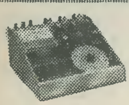
MFS

HI-FI SPEAKER SYSTEM. Model SSU-1. Ducted-port bass reflex cabinet "in the white". Two speakers. Vertical or horizontal models with legs, Kit **£12.12.0,** without legs, Kit **£11.17.6** incl. P.T.

COTSWOLD "MFS" SYSTEM. Designed to give best possible results where floor space is at a premium. This minimum floor space model is based on standard Cotswold. Size: 36" high x 16¼" wide x 14½" deep.
Kit **£25.12.0** Assembled **£33.17.0**

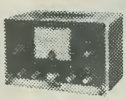
THE "COTSWOLD". This is an acoustically designed enclosure 26" x 23" x 15½" housing a 12" bass speaker with 2" speech coil, elliptical middle speaker together with a pressure unit to cover the full frequency range of 30–20,000 c/s. Capable of doing justice to the finest programme source, its polar distribution makes it ideal for really Hi-Fi Stereo.
Kit **£25.12.0** Assembled **£33.17.0**

NEW MODELS



IM-30U

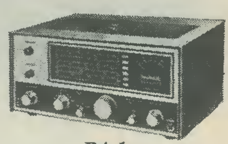
TRANSISTOR TESTER 1M-30U
Provides complete d.c. analysis of PNP and NPN transistors and diodes. Kit **£24.18.0** Assembled **£35.10.0**



IM-12U

HARMONIC DIST. METER IM-12U
Freq. coverage 20–20,000 c/s. Dist. ranges 1, 3, 10, 30, 100% f.s.d. VM ranges 0, 1, 3, 10, 30 volts f.s.d. Input Resistance 300kΩ. Kit **£24.15.0** Assembled **£34.0.0**

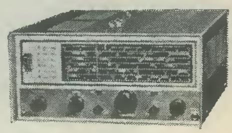
"AMATEUR" EQUIPMENT



RA-1

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

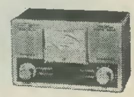
THE "MOHICAN" GENERAL COVERAGE RECEIVER. Model GC-1U. With 4 piezo-electric transfilters, variable tuned B.F.O. and Zener diode stabiliser, this is an excellent fully transistorised general purpose receiver for Amateur and Short wave listeners. Printed circuits, telescopic aerial, tuning meter and large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



RG-1

160-10M TRANSMITTER. Model DX-100U. Careful design has achieved high performance and stability. Completely self-contained.
Kit **£79.10.0** Assembled **£104.15.0**

COMMUNICATIONS TYPE RECEIVER. Model RG-1. A high performance, low cost receiver for the discriminating listener. Frequency coverage: 600 kc/s–1.5 Mc/s and 1.7 Mc/s–32 Mc/s.
Kit **£39.16.0** Assembled **£53.0.0**



HM-11U

REFLECTED POWER METER and SWR BRIDGE. Model HM-11U. Indicates reliably, but inexpensively, whether the RF power output of your TX is being transferred efficiently to radiating antenna.
Kit **£8.5.0** Assembled **£10.10.0**

AMERICAN HEATHKIT "AMATEUR" EQUIPMENT

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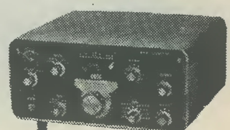
80-10M RECEIVER. Model SB-300E.



SB-300E

Of advanced design employing up-to-date construction techniques, its specification ensures unparalleled performance.
Kit **£133.14.0** (less speaker) + import levy

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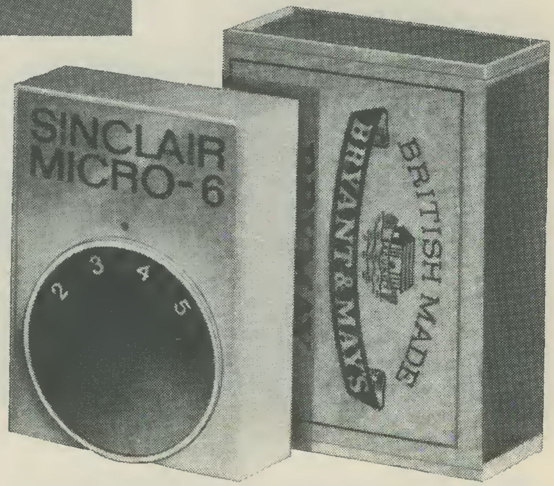
P.W.M. AMPLIFIERS
MICRO-RECEIVERS
MICRO-DESIGNS



Every constructor should build it

THE SMALLEST RADIO SET IN THE WORLD

SINCLAIR MICRO-6

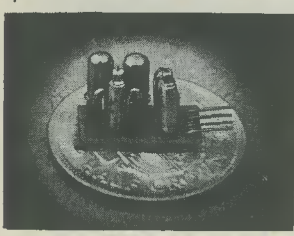
Fantastic range and power

No set in the history of radio has ever captured constructors' enthusiasm as has the world-famous Sinclair Micro-6. Never was a set so small, never so efficient and powerful. Smaller than a matchbox, the Micro-6 brings in stations from all over Europe and afar for your pleasure and entertainment. It performs with fantastic efficiency in cars, buses, trains as well as steel-framed buildings, yet everything to do with this set except the lightweight earpiece is contained in the minute white, gold and black case, size $1\frac{4}{5}'' \times 1\frac{3}{10}'' \times \frac{1}{2}''$. The many attractive features include a highly stable 6-stage circuit, powerful A.G.C., bandspread for easy Luxembourg reception, vernier-type tuning over the medium wave-band, and three special M.A.T. Transistors.

Build it in a single evening!

All parts including lightweight earpiece case and dial, and exceptionally well prepared 8-page instruction manual come to **59/6**

Mallory Mercury Cell Type ZM312 (2 required) each 1/11: Pack of 6, 10/6
Sinclair "Transrista" well-styled, strong black nylon wrist strap, 7/6



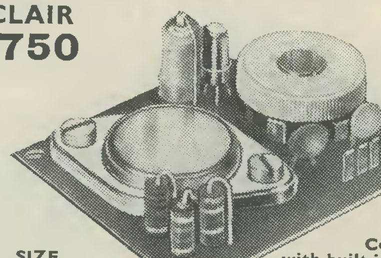
SINCLAIR MICRO-AMP

Smaller than a 3d. piece!

This fantastic amplifier has a frequency response from 30 to 50,000 c/s $\pm$ 1dB and power gain of 60dB (1,000,000 times) can be used as a broadband R.F. amplifier, A.F. quality amplifier or in a F.M. transmitter. Many other applications are given in the instructions included with set of parts. **28/6**

A POWER AMPLIFIER FOR YOUR MICRO-6

SINCLAIR TR750



SIZE 2" x 2"

Complete with built-in switch and volume control

Designed principally for use with the Micro-6, with which it will make a powerful and efficient car, portable or indoor domestic loudspeaker set, this amplifier will also make a mono or stereo record player, an intercom system, baby alarm, etc.
With built-in switch and volume control. Output 750mW for feeding into standard 25 to 35 ohm speaker. Input 10mV into 2kΩ. Operates from 9V d.c.

All parts and instructions come to **39/6** *Ready built and tested* **45/–**

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WITH INTEGRATED PRE-AMPLIFIER

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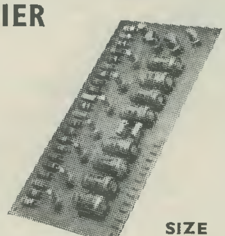

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Pulse Width Modulated High Fidelity Amplifiers

By J. BAGULEY, G. I. Mech. E., G. I. E. R. E.

Audio frequency amplifiers employing the pulse width modulation system are raising continually increasing interest. This article surveys the basic circuits and principles involved in amplifiers of this type

PULSE WIDTH MODULATED (P.W.M.) AMPLIFIERS offer great improvements over normal amplifiers, particularly from the aspects of efficiency and heat-dissipation in the output transistors. The maximum theoretically possible efficiency of a non-inductively coupled class A amplifier for a sine wave signal is 25%; for an inductively coupled class A amplifier this rises to 50%; and for a class B amplifier to 78.5%. None of these can be achieved in practice due to inevitable component power dissipation and biasing requirements.

Early Class A, AB and B transistor amplifiers were choke or transformer coupled, resulting in disadvantages such as bulk, weight, cost and poor low frequency response accompanied by distortion (unless large inductance was used).

In recent years an improved form of amplifier has become popular, this being the complementary driver class AB push-pull type. Here, problems of crossover distortion are largely eliminated by negative feedback and by biasing into class AB operation; also the pulsed current demanded of the power supply can be obviated by constant current mode operation.

Even this latter type of amplifier rarely has an efficiency as high as 70%, the remaining 30% or so of the supply input power being dissipated in bias resistors and, more important, in the output transistors. The implications of this are wasted power necessitating powerful (and sometimes expensive) output transistors, plus the designing of good thermal stability into the amplifier. It has, however, eliminated inductive coupling.

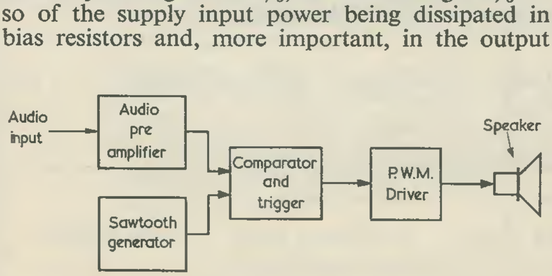


Fig. 1. Block diagram for a pulse width modulated amplifier

Basic Principle Of The Pulse Width Modulated Amplifier

If an amplifier could be designed using no inductors and small, less powerful, output transistors, it could be built on to a single printed circuit card and be tucked into an odd corner of a hi-fi system. Such an amplifier is the pulse width modulated amplifier. It has the great advantage that it can drive primarily inductive loads like speaker systems and motors with high efficiency and low output transistor dissipation. However, it is not normally useful as an instrument amplifier without prior filtering of the output waveform.

The block diagram of this type of amplifier is shown in Fig. 1 and the main waveforms are shown in Fig. 2.

The audio input at a suitably amplified level is compared with the sawtooth waveform. Whenever there is coincidence between the two a trigger circuit generates either a positive or a negative-going edge. Hence, a train of pulses results as shown. The driver applies this pulse modulated waveform to the speaker.

The train of pulses contains amplitude information by pulse width variations and frequency information by the rate of change of this width. When this waveform is applied to a speaker, what can we expect to hear? For the answer to this, consider the frequencies contained in the modulated waveform by referring to Fig. 3.

A square wave of 1:1 mark-space ratio and say 50 kc/s frequency (reasons for the use of 50 kc/s or more will become apparent from the following) is the result of the comparison of d.c. and a 50 kc/s sawtooth. It has the frequency distribution of Fig. 3 (*a*). These frequencies are the odd harmonics only and as with (*b*), (*c*) and (*d*) are not shown in their correct amplitude relationship for simplicity. Most mark-space ratios will contain the even harmonics of the 50 kc/s basic waveform as well, as shown in Fig. 3 (*b*). Note, however, that only harmonics of 50 kc/s can appear whatever the mark-space ratio. This result is given by comparison with d.c. which is not coincident with the mean level of the 50 kc/s sawtooth.

Suppose we now compare the sawtooth with a sine wave contained within the audio spectrum (say, 10 kc/s). The frequency distribution of Fig. 3 (*c*) will result. Here, 10 kc/s is present along with 50 kc/s and its harmonics, but there are also beat frequencies between 10 kc/s and 50 kc/s plus its harmonics.

Extension of this to the full audio spectrum of 15 kc/s (which is as high as most people can hear) results in the frequency distribution of Fig. 3 (*d*). In fact the distribution is a little more complex than shown by Fig. 3 (*d*) as a full analysis reveals. However, Fig. 3 (*d*) is sufficient for our purpose.

This shows that we are applying a waveform to the speaker which contains the desired audio, and other frequencies of 35 kc/s or more (unless harmonic distortion of audio beating with 50 kc/s throws spurious frequencies into the 15 kc/s audio band).

The audio produces the required result, but, what of the other frequencies? Firstly, they are not audible. Secondly, a 15Ω speaker may well have a reactive impedance of several hundred ohms at 35 kc/s so that the power dissipated by this frequency and by higher frequencies in the speaker will be negligible. Hence, although the voltage waveform we are applying to the speaker is the modulated 50 kc/s square wave shown in Fig. 2 the current waveform is very nearly the original audio waveform. This, of course, ignores the changing impedance of the speaker through the audio band which applies to any amplifier whose load is a speaker.

The Individual Circuits

Audio Pre-Amplifier

This can be a normal pre-amplifier. It has only to amplify the audio input to the required level with a minimum of distortion. It may include equalisation and tone control circuits, and filtering to remove higher frequencies than audio to prevent the appearance of distorting intermodulation frequencies produced by beating with 50 kc/s.

Sawtooth Generator

This must provide a waveform with linear rise and fall otherwise distortion will result. As drawn in Fig. 2 the "flyback" should not be fast as with c.r.t. deflection circuits, and it is in fact better if it is equal in time to the rise. Care should be taken if circuits with fast flyback are used (as described later) that the basic multivibrator frequency is high, otherwise frequencies resulting from the

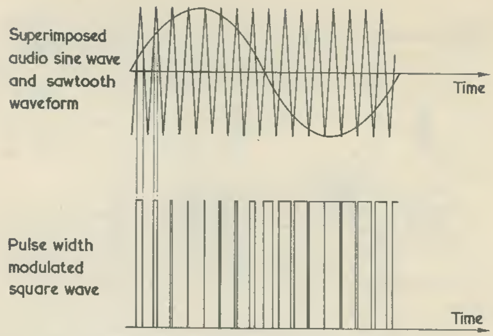


Fig. 2. Main waveforms occurring in the amplifier

modulation are more likely to fall in the audio band.

Most sawtooth waveforms are generated by the linearised charging and discharging of a capacitor due to an applied square wave. The generation of the square wave is considered first. The RC coupled multivibrator is shown in Fig. 4, and explanation of it is not felt necessary. In this application its frequency need not be very precise but it must provide a good waveform so that the integrator which may follow it is able to create a linear sawtooth.

Now consider the generation of a sawtooth from this square wave. Pure mathematical integra-

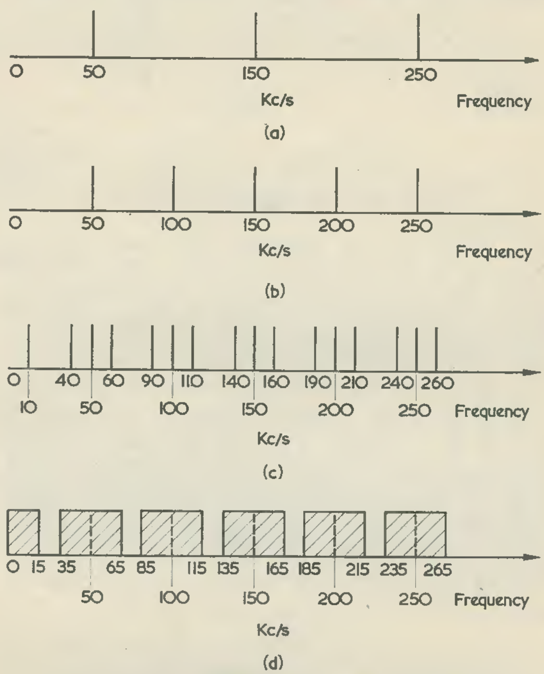


Fig. 3. Frequencies contained in various modulated and unmodulated 50 kc/s waveforms. (a) 1:1 mark-space ratio square wave. (b) Square waves with other mark-space ratios. (c) Waveform pulse width modulated by 10 kc/s sine wave. (d) Waveform pulse width modulated by 15 kc/s audio spectrum

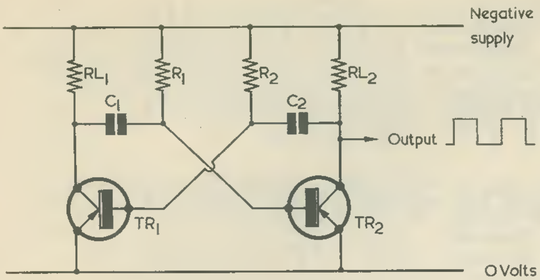


Fig. 4. RC coupled multivibrator

tion is ideal since the integral of a constant "level" is a ramp function:

i.e. $\int_0^t k\,dt = (kt)\Big|_0^t$ where k is a constant voltage step or pulse of length t. A square waveform when integrated results in the waveform of Fig. 5. Note that the amplitude of the resulting waveform at any time is proportional to the area under the input waveform up to that point in time.

We must have either an approximation to this mathematical integration, such as is given by a Miller integrator, or linearised charge and discharge

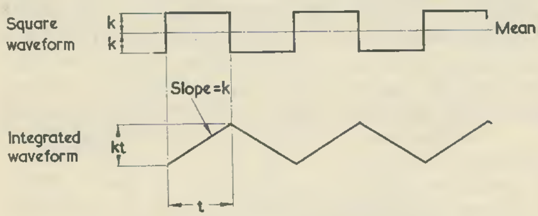


Fig. 5. An integrated square waveform

of a capacitor to generate the linear voltage sawtooth from the input square wave. Fig. 6 shows the block schematic of a Miller integrator. If the amplifier gain A is large the output voltage is related to the input voltage by:

$$V_{out} \propto -\frac{I}{CR}\int V_{in}\,dt$$

A simple form of Miller Integrator is shown in Fig. 7. In this RB_1, RB_2 and R_L must be large compared with R, and R_e is unbypassed by a capacitor to give a high input impedance. Better linearity could be achieved by using a direct coupled amplifier having several stages to make gain A larger.

A circuit using the alternative approach of linear capacitor discharge is shown in Fig. 8. The

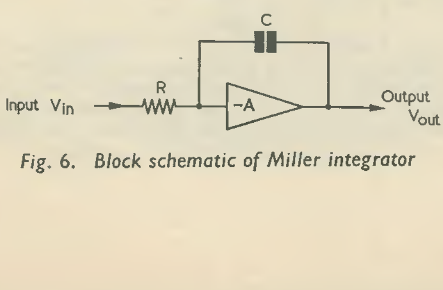


Fig. 6. Block schematic of Miller integrator

reset pulse initially charges C_1 to a negative voltage through D_1. The base bias on TR_1, set by R_2 and R_3 and bypassed by C_2 to eliminate transients, causes a constant emitter current and hence a constant collector current to flow. Thus C_1 is discharged linearly while D_1 is back-biased. If the reset pulse is recurrent and the charging time of C_1 through the forward resistance of D_1 is short compared with the discharging time of C_1, a sawtooth waveform of fast fall and slow linear rise is generated.

A more linear sweep can be generated using the bootstrap sawtooth generator which is shown in Fig. 9. In this circuit, the voltage to which the capacitor is charging rises as the capacitor voltage rises so that their difference, and hence the charging current, is constant giving a very linear sawtooth waveform. Initially TR_1 is turned on by the reset pulse so that C_1 is discharged. TR_2 is also turned on by this reset pulse so that C_2 is charged through TR_2 and D_1 to the full negative supply voltage. During sweep, TR_1 is turned off so that C_1 can charge through R_1. C_1 charges towards the voltage to which C_2 is charged plus the voltage at the emitter of TR_3. As the charge on C_1 rises, the base of TR_3 is taken more negative and the emitter

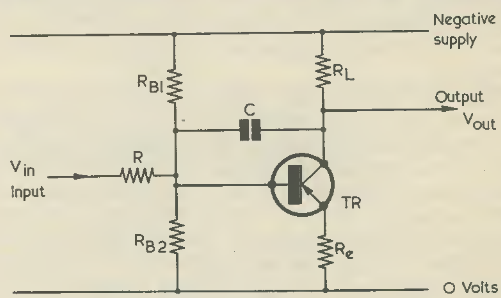


Fig. 7. Simple Miller integrator circuit

of TR_3 and C_2 follow, taking the positive end of C_2 more negative. Thus, assuming that C_2 is sufficiently large for the voltage across it to be considered constant, a fixed charging current is maintained into C_1. To compensate for the slight discharge of C_2 during each sweep it is recharged by each reset pulse. This was achieved as mentioned at the beginning of this description by turning TR_2 on. C_2 cannot discharge back into the negative supply during sweep since it is taken negatively and reverse-biases D_1.

Note that both of these circuits (Figs. 8 and 9) have fast flyback and the precaution already discussed should be observed if using them, i.e. modulation frequencies falling into the audio band.

Comparator and Trigger

This compares the audio and sawtooth waveforms, and triggers the driver with very little delay when they are coincident, otherwise distortion will result. The Summing Operational Amplifier can be a very precise comparator and is shown in Fig. 10

as a block schematic. If the amplifier gain A is large and $R_{i1} = R_{i2} = R_f$, V_{out} is the sum of V_{1in} and V_{2in}. Scaling can be accomplished by using R_{i1} and R_{i2} of different value from R_f. A simple form of this circuit is shown in Fig. 11. As with the simple Miller integrator of Fig. 7, a better circuit would result from using several stages of amplification. R_b and R_L must be large compared with R_f, R_{i1} and R_{i2}, and R_e is unbypassed by a capacitor to give a high input impedance.

A triggering circuit, the Schmitt trigger, is shown in Fig. 12. If the input is initially in the positive direction TR_1 is cut off and R_{L1} has only the current of the R_{L1}, R_2, R_3 divider chain flowing through it. The resulting negative voltage at the junction of R_2, R_3 and the base of TR_2 turns TR_2 on.

If the input is taken negatively, a point is reached where the base of TR_1 approaches the negative emitter voltage shared by both transistors (negative because of the emitter current of TR_2 through R_e). TR_1 will then begin to turn on, causing an increase of current through R_e to very slightly lower the shared emitter voltage. It also causes additional current to flow through R_{L1} which raises the base voltage of TR_2 tending to turn it off. This in turn

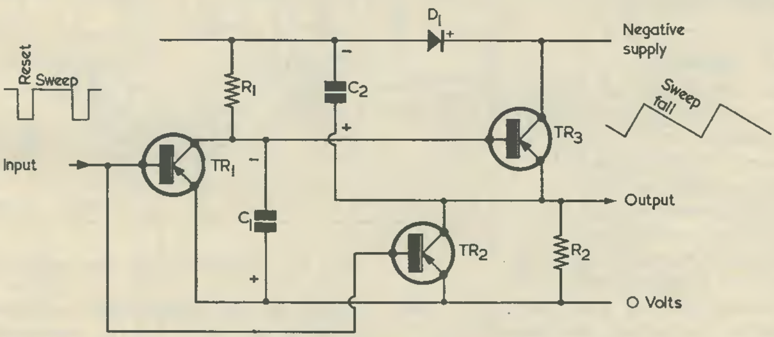


Fig. 9. Bootstrap sawtooth generator

increases the allocation of current allowed to TR_1 in R_e and the effect becomes regenerative, giving rapid switching from a slowly changing input.

Similar reasoning can be applied to the reverse, which occurs at a slightly more positive voltage (backlash). The circuit inevitably becomes a compromise between switching speed and backlash, which should be kept to a minimum in this application to avoid distortion.

An alternative circuit which is a combined comparator and trigger and was first proposed by D. R. Birt in *Wireless World* is shown in Fig. 13.[1] At the most negative point of the sawtooth TR_1 is on and the current it causes to flow in R_e cuts TR_2 off by taking the emitter of TR_2 more negative than its base. As the sawtooth rises positively on its sweep, a point is reached where TR_1 is turned off and TR_2 comes on. TR_2 remains on

[1] D. R. Birt, "Modulated Pulse A.F. Amplifiers", *Wireless World*, February 1963.

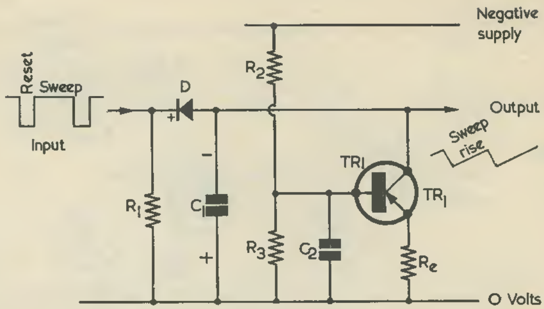


Fig. 8. A circuit utilising constant current capacitor discharge

until the negative-going flyback once more turns on TR_1.

An audio input at the base of TR_2, superimposed on its d.c. bias potential, will alter the point at which it switches and hence change the mark-space ratio of the output waveform, resulting in pulse width modulation.

Driver

This is required to drive the speaker with the 50 kc/s p.w.m. waveform, maintaining fast rise and fall times otherwise distortion and excessive dissipation in the output transistors for more than an instant will result and may destroy them. The orthodox complementary emitter follower of Fig. 14 (*a*) provides a low impedance output but, without a blocking capacitor, allows nett d.c. to flow in the speaker, resulting in distortion. A large capacitor would be needed and a neater solution which is able to give twice the output voltage is shown in Fig. 14 (*b*). The improved version causes a voltage to be applied to the speaker in both directions

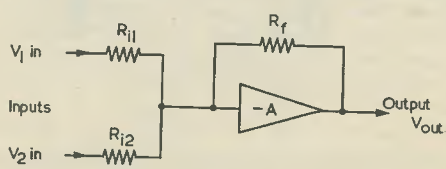


Fig. 10. Block schematic of summing amplifier

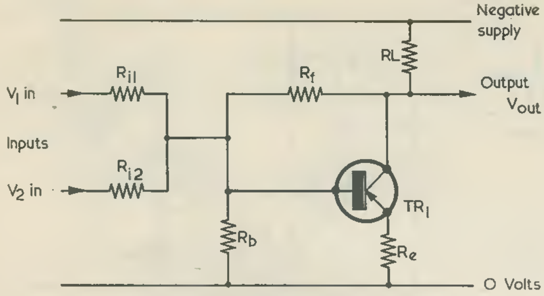


Fig. 11. Simple summing amplifier circuit

with no nett direct current. It is necessary to provide both phases of driving pulse train for this circuit, but these are readily available from both Schmitt trigger and long tailed pair comparator circuits. Since no voltage transient occurs, as does when an established direct current is stopped flowing through a relay coil, no transistor protecting diodes are necessary. The transistors must be fast-switching types to maintain the rapid voltage transitions which are necessary to keep their dissipation low and to minimise distortion.

The Sinclair X10 Amplifier

As first in the field with an unorthodox and successful departure from typical products of a highly competitive market, Messrs. Sinclair Radionics deserve especial mention.

Their amplifier is shown in Fig. 15 connected for a typical crystal pick-up arrangement but many more facilities are described in the leaflet which is supplied with the amplifier, e.g. comprehensive tone control arrangement and stereo connection.

C_1 and R_6 decouple the pre-amplifier from the power amplifier. TR_1 is a pre-amplifier of approximate voltage gain $\frac{R_2}{R_1}$; R_1 providing the necessary input impedance for the crystal pick-up instead of the low input impedance to TR_1 itself. RV_1 is a gain control. RV_2 is a bass control where C_3 is a fairly small capacitor whose increasing reactance with decreasing frequency causes frequency-selective loss of gain. RV_3 is a treble control which shunts the input to TR_2, the reactance of C_5 decreasing with increasing frequency and causing frequency-selective loss of gain. TR_2 is a further audio pre-amplifier whose output is applied via C_{10} to the Schmitt trigger.

The multivibrator consists of TR_3, TR_4 and associated components, and its output of several tens of kilocycles per second is passed to the Miller integrator. The resulting sawtooth is applied via R_{13} and C_9 as a current input to the Schmitt trigger, to be compared with the audio input and, hence, provide a pulse width modulated waveform at the output of the Schmitt trigger.

The two anti-phase outputs of the Schmitt trigger are applied via C_{11} and C_{12} to the Twin Complementary Emitter-Follower Driver.

Note that excellent results have been achieved using very simple circuits, this demonstrating that some of the refinements considered earlier in this article are not strictly necessary. For example, simple Miller integrator and summing are used, and the backlash versus triggering speed compromise of the Schmitt trigger has been optimised.

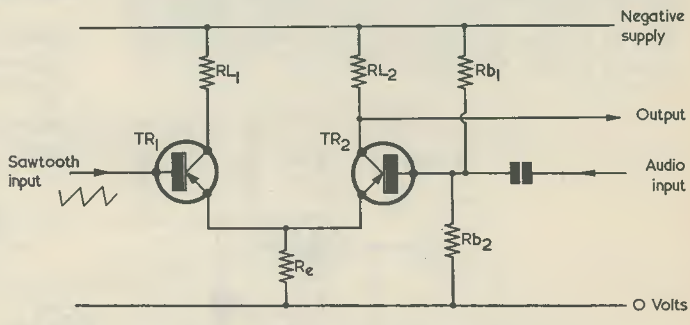


Fig. 13. Long tailed pair comparator and trigger

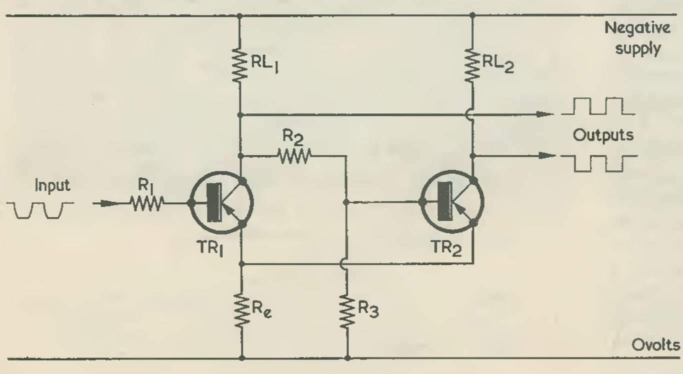


Fig. 12. A Schmitt trigger

Further Developments

Further developments are being pursued by Messrs. Sinclair Radionics Ltd., who are now marketing a series of amplifiers capable of up to 100 watt output for applications such as public address systems, pop groups, etc. A 15 watt amplifier should be generally available shortly. They are further improving the comparator circuit which remains a low input impedance type like the Schmitt trigger, but is fed by resistors (current feed) from both sawtooth and audio inputs. It has become an over-driven 2-stage amplifier with diode clamps to settle the mean input level and prevent saturation of the first transistor, thereby avoiding hole storage effects and consequent

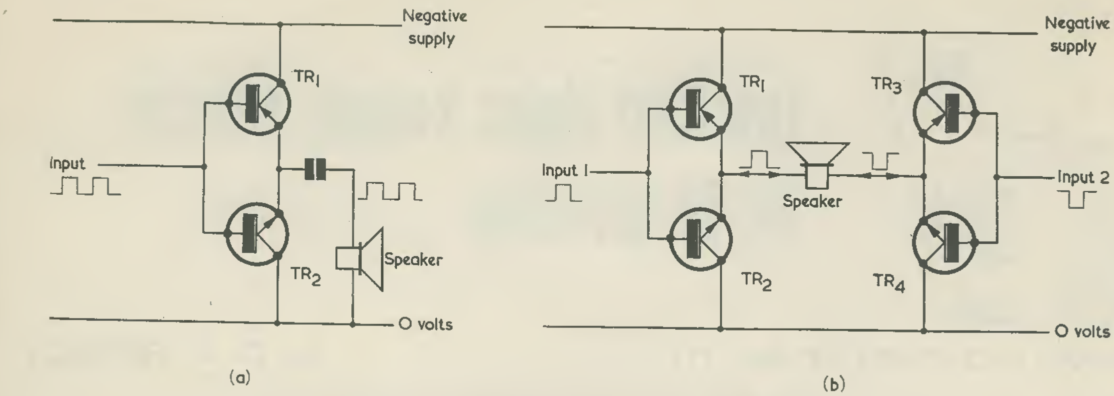


Fig. 14. Two complementary emitter-follower driver circuits

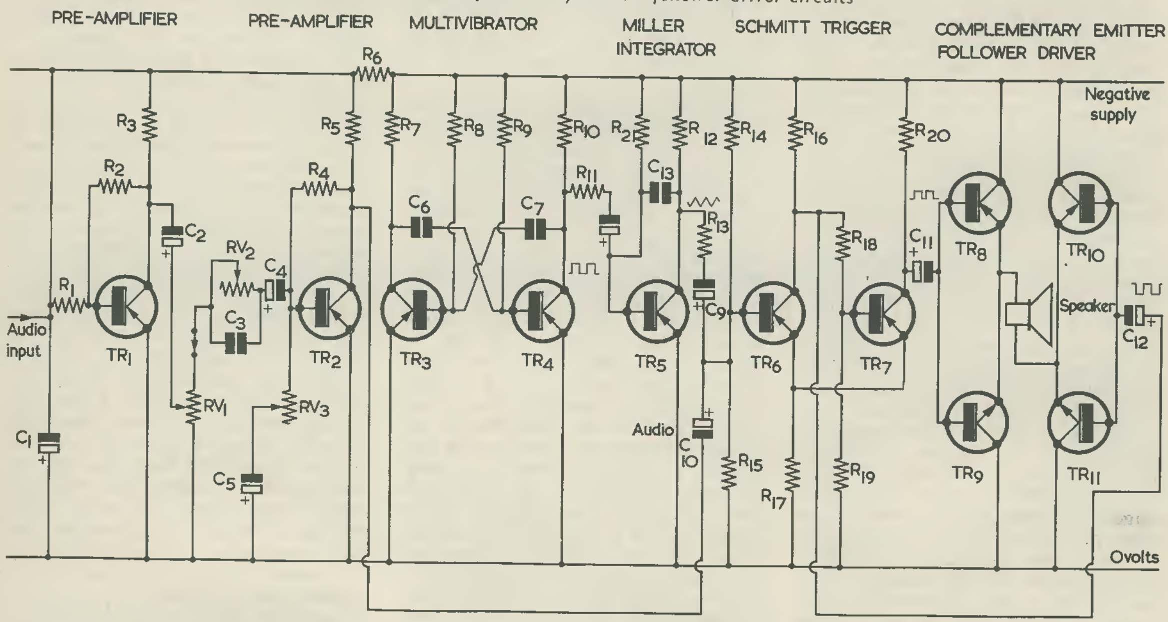
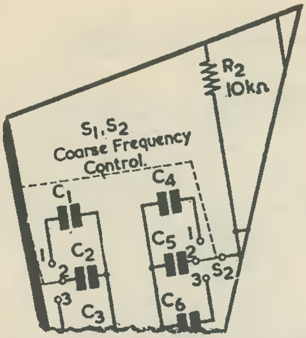


Fig. 15. The Sinclair X10 amplifier

switching delay. They also tend to favour the two-transistor driver of Fig. 14 (*a*), particularly with high output powers which necessitate more expensive transistors, and they emphasise the care needed in designing this part of the circuit if distortion at high voltage levels is to be avoided. Feedback from output to input has been considered but is not felt necessary as the circuits from the output of the pre-amplifier onwards are inherently linear if designed correctly.

Another extremely cleverly designed amplifier of this type by Turnbull and Townsend of Manchester University has also been published in *Wireless World*, although it is of lower power than those marketed by Sinclair Radionics.[2] This amplifier has audio summing and square wave integration performed in one Miller integrator which acts as an integrator to the higher frequency square wave and an amplifier to the audio input. A closed loop development also eliminates the multivibrator by negative feedback from the speaker drive circuit to the input at the combined summer and integrator. It does this by using the property of phase shift through the several transistors adding up to 180° at some frequency, turning the negative feedback into positive feedback and, hence, changing the whole system into an oscillator at the frequency at which the multivibrator would otherwise have operated. A further advantageous by-product of this idea is that negative feedback is provided at the audio frequency, resulting in further reduction of distortion. It also uses the over-driven amplifier switch which Sinclair are likely to favour.

[2] G. F. Turnbull and J. M. Townsend, "A Feedback Pulse Width Modulated Audio Amplifier", *Wireless World*, April 1965.



Low-Cost Mains Voltage Adjuster for TV Servicing

SUGGESTED CIRCUIT No. 177

By G. A. FRENCH

As is well-known, one of the more irritating features of a service engineer's work is the clearing of intermittent faults. It is necessary to wait for an intermittent fault to appear before it can be recognised and located, and this process frequently entails running the equipment for long periods of time whilst other work is proceeded with. It can be helpful, under these conditions, to run the faulty equipment with a slightly increased power supply voltage, provided that this does not significantly exceed that for which the equipment was designed. The increased power supply voltage can often cause the intermittent fault to appear earlier than would be the case under normal conditions.

Television receivers are especially susceptible to changes in mains supply voltage, the most critical circuits appearing in the line output stage. Because of this point, it is often desirable to check a television receiver, after repair, at a slightly *reduced* mains supply voltage, since this will allow any potential troubles from this cause to show up whilst the receiver is on the test bench. Low domestic mains supply voltages often occur in some districts, of course, and it is preferable that the television receiver should be capable of giving an acceptable performance with such voltages.

It follows from what has been said that a useful adjunct to the servicing bench would be a supply circuit which causes a small increase or decrease in mains voltage to be achieved by means of a simple switch operation, and which is capable of use with television receivers. Unfortunately, television receivers require a relatively high power, typical figures ranging from some 130 to 180 watts. So far as reduction in voltage for TV receivers is concerned, another factor is that it is generally undesirable to attempt to obtain this by such devices as inserting resistance in series with the supply, as the h.t. circuits in most TV sets are designed for operation from a low impedance supply. With some TV sets it is possible to obtain small effective increases or decreases in supply voltage by suitably adjusting the mains voltage selector fitted to the receiver itself, but this is often quite a fiddling operation. Other receivers have somewhat coarse mains voltage selector circuits which do not, in any case, permit small effective increases or decreases.

If, therefore, a convenient means of providing small increases or decreases in mains voltage is to be employed, it should be external to the equipment being tested and it has to incorporate a transformer. Also, the transformer must be capable of supplying the relatively high mains currents required by television receivers. From the power figures just mentioned it might seem that what is required is an autotransformer with suitable tappings rated at some 200 watts, but such a component is likely to be large, bulky and expensive. A much easier and cheaper solution is described in this month's article, which shows how advantage may be taken of a low-cost transformer introduced fairly recently to the general home-constructor market and which offers the same final results as would be given by the autotransformer. The circuit itself is extremely simple. (The writer has found, however, that very simple "Suggested Circuits" appear to be just as popular amongst readers as are the more complicated ones!)

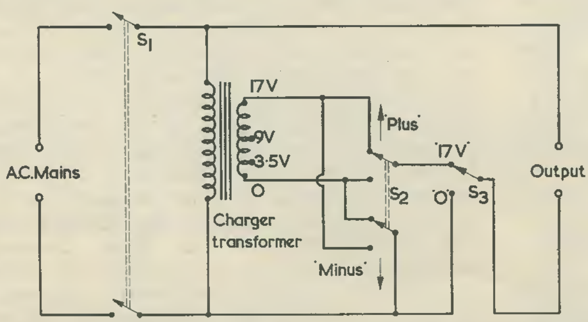


Fig. 1. Switching circuit which allows mains voltage to be increased or decreased by 17 volts. The secondary of the transformer has a current rating of 1 amp, and the circuit is suitable for supplying television receivers and similar equipment up to some 200 watts

The Circuit

The circuit of the mains voltage adjuster is given in Fig. 1. In this, the a.c. mains supply is applied to on-off switch S_1, and, thence, to the primary of the transformer. The transformer secondary, which is rated at 1 amp, offers 17 volts, and this may be reversed in phase by the "Plus"-"Minus" switch S_2. Switch S_3 selects either "0" or "17V". In the "0" position, S_3 connects the a.c. mains direct to the output terminals whilst, in the "17V" position, it causes the transformer secondary to be inserted in series. When S_2 is in the "Plus" position, 17 volts is then added to the input voltage and, when it is in the

"Minus" position, 17 volts is subtracted. Thus, the circuit is capable of offering an increase or decrease in mains voltage for the testing of television receivers and other equipment having similar, or lower, power requirements.

The important component in the circuit is the transformer. This is a "charger transformer" with a 1 amp secondary intended for accumulator charging use and is available from several home-constructor suppliers.* Secondary taps are given at 3.5 and 9 volts, but these are unused in Fig. 1. Since the secondary current rating is 1 amp, it can cope quite comfortably with the current drawn by equipment rated at 200 watts.

In the circuit, the secondary is connected by S_2 so that it is either series-aiding or series-opposing the applied mains voltage. S_2 merely reverses its phase. In some cases, where the available mains voltage is close to the maximum figure specified for the majority of television receivers likely to be serviced, it may be thought that an increase of 17 volts for testing purposes would be excessive. In this instance the switching circuit shown in Fig. 2 can be used, in which the increase is 9 volts and the decrease is 17 volts.

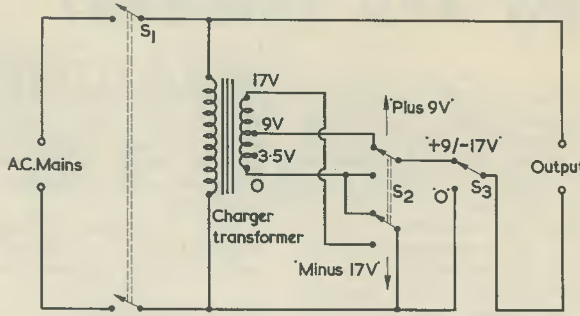


Fig. 2. An alternative circuit, which offers an increase of 9 volts instead of 15 volts

Components and Construction

We have already dealt with the transformer employed in the circuit, and the only components remaining are the three switches. These should all be toggle switches suitable for mains switching, S_1 being d.p.s.t., S_2 d.p.d.t., and S_3 s.p.d.t. Operation could be made a little easier by employing a single rotary switch to carry out the functions performed by S_2 and S_3, but rotary switches suitable for mains circuits are not readily available whereas toggle switches are.

The circuit may be fitted as a permanent installation to the work bench, the output terminals connecting to sockets suitable for the equipment under test. Alternatively, the components may be fitted in a small portable box fitted with a flexible mains lead and plug, thus providing a unit which may be connected to the mains only when required. In the latter instance it would be possible to dispense with S_1, at a small saving in cost.

A very useful addition would be an a.c. voltmeter connected across the output terminals, since this would show the mains voltage fed to the equipment under test at any time. Alternatively, the service engineer may prefer to check the output voltage with the bench multi-testmeter.

A final word is required in connection with phase. After the circuit has been assembled it will be necessary to connect a voltmeter across the output terminals to check whether an increase in output voltage is given when S_2 is set to the "Plus" position, and a decrease in voltage when S_2 is set to the "Minus" position. If the reverse occurs then, with Fig. 1, the connections to either the primary or the secondary of the transformer should be reversed. With Fig. 2, the connections to the primary only should be reversed.

* The transformer appears, for instance, in the Henry's Radio catalogue as type CT1, and is listed, at the time of writing, at 10s. 6d plus 1s. 6d. postage and packing.

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NEWS AND COMMENT . . .

U.S.A. Radio Amateur Regulations

The Amateur Radio transmitting fraternity in the U.S.A. is undergoing one of its most severe furores for many a long year, due to new licensing proposals put forward by their licensing authority.

Basically, it is suggested that a series of graded technical examinations should be introduced starting with a minimum standard, just sufficient to know how to operate a station efficiently, and ending with a top class at almost a professional level. This in itself may not seem a very revolutionary suggestion but, coupled with it, is the proposal that all existing licences should be withdrawn and new ones issued indicating the standard at which the holder passed. The mind boggles at the magnitude of the administration effort such a procedure will involve, but no doubt in this day of punched tape and computers this is not the problem it would have been in the past.

An interesting feature of the proposals is that it originated from within the ranks of Amateur Radio, the American Radio Relay League —the official body representing radio amateurs in the States— itself proposing such a scheme to the licensing authority. Apparently, the great increase in commercially made amateur equipment has seen a real drop in technical "know-how" amongst American radio enthusiasts, many of whom mostly use the hobby as a sort of private radio telephone.

In this country, the existing examination requirements for an amateur radio "ticket" do ensure that all new recruits to the hobby are competent before they are allowed on the air. Amateur Radio is essentially a technical hobby and we should never lose sight of this fact and standards should be kept as high as is reasonable for a hobby.

Slice of Life

We reprint, without comment, the following amusing anecdote recently reported in the London *Evening News*.

Television has cured four New York Zoo gorillas of bad temper.

They were bored, edgy and nervous, and were continually wrangling.

Then a television set was placed just outside their cage. Now, when the set is turned on, the gorillas stare at it, transfixed. Boredom and fighting are bad memories.

Only 15-year-old Mambo occasionally reverts to his old bullying habits—during commercials.

The Unseen Viewer

Many readers will have seen on TV the demonstrations of the use of CCTV by the Liverpool Police. So successful were the experiments using closed circuit television in crime detection and prevention that an order has been placed for a further four television channels with EMI Electronics Ltd.

The cameras will be used by the Police Commando Force to observe places where crime is likely to occur, such as unattended car parks and storage areas.

As they are fitted with zoom lenses, the cameras can be located some distance from the areas being observed. Once set up they require little attention and their outline can be disguised to blend with the local architecture.

When a suspect is picked up on the screen a detective sends information by radio to Police Headquarters, or to the nearest member of the Commando Force in the area.

A year or two ago some friends of the writer watching the Lawn Tennis championships at Wimbledon on TV, suddenly saw me talking animatedly to a beautiful young lady, not my wife, and much amusement was caused thereby. It is not difficult to visualise some much less innocent incident being picked up by television cameras and, although not disagreeing with their use by the police, there are obviously "Big Brother" implications.

Package Deals for the Constructor

The International Rectifier Company, of Oxted, Surrey, are selling pre-packaged products to radio constructors through various retail centres which are being opened in the United Kingdom. Its new commercial product distribution programme is to market a comprehensive range of semiconductor components through I.R. authorised semiconductor centres.

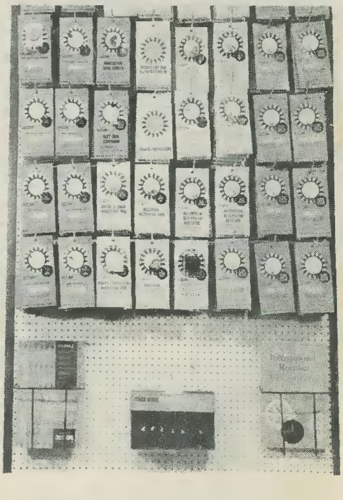
The I.R. semiconductor centre is a free-standing, display rack which carries 83 different types of components, which include solar cells, transistors, rectifier diodes, zener diodes, silicon controlled rectifiers, selenium photocells and experimenter kits. All the products are pre-packaged and most include instruction manuals aimed at assisting the novice or experienced engineer alike.

The many applications for which these products can be used range from audio amplifiers and photoelectric alarms to solid state motor speed control.

Each product is type marked and performance details are guaranteed. For example, International Rectifier's range of ten transistors, ranging from r.f. to 25 watt power types, has a listing showing over 1,000 American and European equivalents.

Detailed text books on several groups of products are available, listing circuits and many applications. A catalogue giving complete details, including prices, is available at each centre. Mail order selling will be developed by several of the authorised centres.

International Rectifier Company is primarily aiming its programme at the younger enthusiasts, and hopes to stimulate and satisfy the expanding public interest in semiconductor devices.



Part of the I.R. semiconductor centre free-standing display rack

Part 1

By
P. Vernon

Beginner's A.F./R.F. Signal Tracer

The unit described in this article, which has been specially written for the beginner, is probably the most versatile equipment in the workshop and one that usually heads the list of requirements when planning test gear construction. In addition to its use as an a.f./r.f. signal tracer, it may also be put into service as a simple a.f. amplifier and as a spare power supply for other ancillary units

THE UNIT DESCRIBED HERE MAKES AN IDEAL constructional project for the beginner who requires to commence building ancillary and test equipment in order to equip the workshop or shack. The construction is fully described and illustrated so that the beginner may successfully bring the venture to completion without hidden snags and consequent failure.

All the components specified are currently available, and should be obtained without substituting other types having differing ratings or, just as important, differing colour codes—as would occur with the mains transformer, for example. The three valves may be obtained cheaply on the "surplus" market but the remainder of the components should be purchased new.

The unit described here can operate as a standby audio amplifier, bench power supply, or as an audio frequency and radio frequency signal tracer for testing purposes—these tests being described in the concluding instalment next month.

In order to operate as an a.f. signal tracer, an a.f. test probe must be used with the basic amplifier of Fig. 1. Additionally, for service as an r.f. signal tracer, an r.f. probe unit comprising a simple untuned detector circuit, with probe, has to be constructed. Both of these are described next month.

The amplifier and power supply circuit is shown in Fig. 1. The audio output from the amplifier is approximately four watts, more than enough for the average workshop. The available power supply, given when the unit is used as a power pack only with switch $S_{1(a)(b)}$ in the open position, is 280 volts d.c. at 75mA and 6.3V a.c. at 3A—sufficient to run a 4 or 5 valve receiver or other ancillary equipment. It should be pointed out here however, that it would be unwise to operate the unit as a power supply for external equipment *together* with the amplifier section by omitting the switch $S_{1(a)(b)}$ from the circuit. It should also be brought to notice that it would be equally unwise to run the power supply section for periods of time without being connected either to the amplifier *or* to other external equipment.

Low-cost octal based valves have been chosen for this design. To the beginner, the smaller type valves (B7G or B9A) have the valve pins close together and present some difficulty when wielding the still unfamiliar soldering iron, and this is avoided with the larger octal valves.

Circuit

The circuit is shown in Fig. 1. The input to the first stage (V_1) is via a coaxial socket and cable, the braiding of which must be earthed to the chassis, and the potentiometer R_1. The slider of R_1 is connected to the grid (pin 5) of the 6J5G triode. The switch $S_{2(a)(b)}$ shown in the a.c. mains input is ganged with potentiometer R_1.

Resistor R_2 and bypass capacitor C_1 decouple the anode load resistor, R_3, from the h.t. positive line. Cathode bias for V_1 is provided by the components C_3, R_4.

The amplified audio signal given by V_1 is passed, via coupling capacitor C_2, to the grid (pin 5) of the power output valve, V_2 (6V6G). Resistor R_5 is the grid leak whilst cathode bias is provided by the components C_4, R_6. The anode (pin 3) is connected to the h.t. line via the primary winding of the output transformer T_1, the audio signals appearing across this winding being induced into the secondary winding and the speaker.

It will be noted from the foregoing description, and from the circuit diagram, that the amplifier

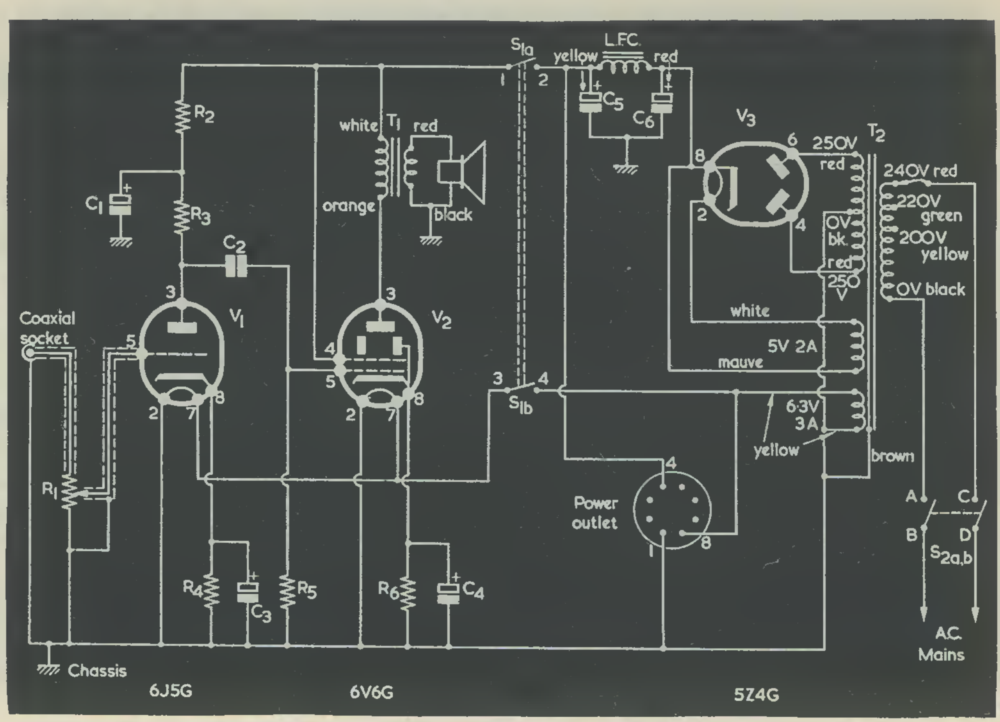


Fig. 1. Circuit diagram of the amplifier/power supply

Components List
(Fig. 1)

Resistors
(All fixed values ½ watt 10%, unless otherwise stated)

R_1 1MΩ potentiometer, log. with d.p.s.t. switch)
R_2 47kΩ
R_3 100kΩ
R_4 2.2kΩ
R_5 470kΩ
R_6 270Ω 1 watt

Output Transformer
T_1 Type 117E (H. L. Smith & Co. Ltd.)

Mains Transformer
Pri: 0–200–220–240V.
Secs: 250–0–250V, 75mA;
6.3V CT, 3A; 0–5–6.3V, 2A. Type 3104A. (H. L. Smith & Co. Ltd.)

Chassis and Panel
8 x 10 x 2½in; 8 x 10in. (H. L. Smith & Co. Ltd.)

L.F. Choke
10H, 120mA, 200Ω. Type M101. (H. L. Smith & Co. Ltd.)

Tagstrips
4-way, end tags earthed, ⅜in, 2 required

Capacitors
C_1 2μF, electrolytic, 350V wkg.
C_2 0.1μF, tubular (Mullard)
C_3 25μF, electrolytic, 12V wkg.
C_4 25μF, electrolytic, 25V wkg.
*C_5 32μF, electrolytic, 350V wkg.
*C_6 16μF, electrolytic, 350V wkg. (reservoir)
*Contained in single can with earthing clip

Valves
V_1 6J5G
V_2 6V6G
V_3 5Z4G

Switches
$S_{1(a)(b)}$ d.p.s.t. Type S300/PD (A. F. Bulgin Ltd.)
$S_{2(a)(b)}$ d.p.s.t. integral with R_1

Speaker
5in round, 15Ω

Valveholders
International Octal (4)

Miscellaneous
Mains lead (see text); coaxial cable (75Ω); coaxial socket; nuts & bolts, wire, solder, rubber grommets, etc.

section has been kept as simple as possible and uses the minimum of components consistent with satisfactory results and reasonable quality. Frills such as tone controls, negative feedback, etc., have been omitted initially in order (*a*) to simplify construction for the beginner and (*b*) to keep the cost of the project within bounds.

The power supply section, like that of the amplifier, is perfectly straightforward, the stipulation here being that a double-wound mains transformer with its consequent isolation from the a.c. mains, together with a good quality l.f. choke must be included, as shown. The rectifier (V_3) is a 5Z4G full-wave type capable of delivering the required h.t. potential. All the components specified for this section are used well within their ratings in order that they will not over-heat or burn out when supplying the full rated output previously mentioned. It is far better for the beginner to purchase, in the first instance, components that will last for many years than to specify and obtain under-rated components which will sooner or later emit smoke!

The rectifier has a 5 volt a.c. heater supply, whilst the heater supply for V_1 and V_2 is 6.3 volts. These voltages are provided from separate secondary windings on the mains transformer.

With the switch $S_{1(a),(b)}$ in the open position, as shown in the circuit diagram, power is supplied to the power outlet socket—an international octal valveholder mounted on the rear apron of the chassis—and thence to any external unit which may be connected. With the switch closed, power is provided for the amplifier section of the unit. No external equipment should, in this instance, be connected.

The circuit diagram has been reproduced here in such a form that the white circuit symbols may be "blacked-out" with a ball-point pen as construction proceeds and in this manner the beginner may relate the circuit symbols to constructional practice.

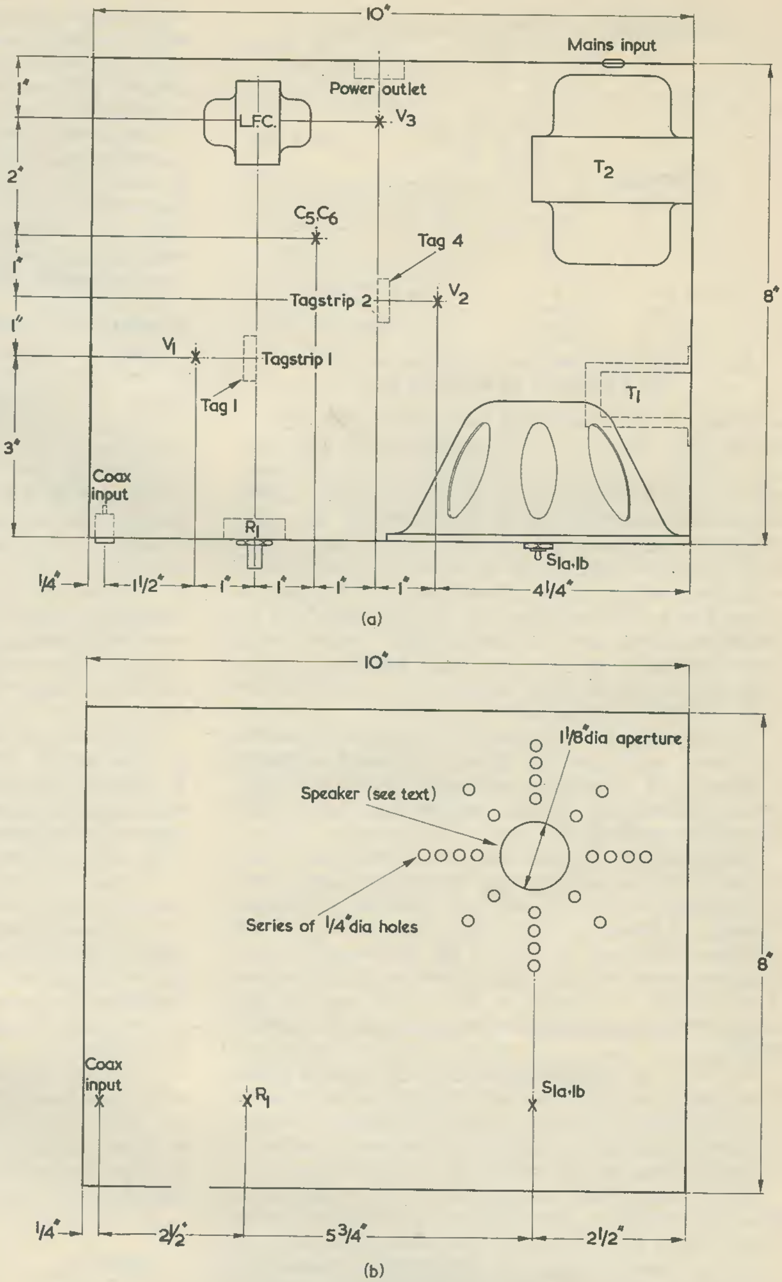


Fig. 2 (a). Chassis measurement details showing positions of the main components and (b) panel details

Construction

Figs. 2 (*a*) and (*b*) show the layout and measurements of the chassis and front panel respectively. For those who wish to cut the cost of the unit a little, the front panel could be omitted from the design, the speaker then being mounted to the chassis deck by means of two L-section brackets.

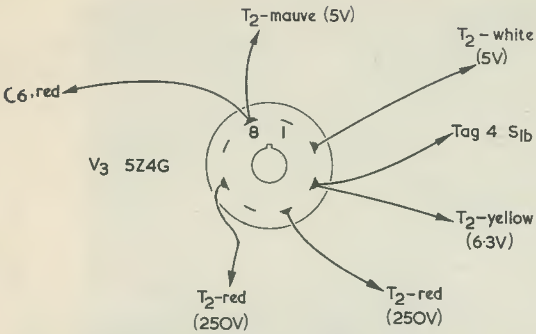


Fig. 3. The connections to V_3 valveholder. Note that pin 3 is used as an anchoring point

A panel is specified here for the reason that it makes the unit a more professional-looking job and also so that it may be used to accommodate various additional controls at a later date. These additional controls will be described in the concluding instalment next month. The front panel and chassis should now be drilled in accordance with the measurement details shown in Figs. 2 (*a*) and (*b*). The valveholder for V_1 should be so positioned that pin 5 is nearest the coaxial input socket mounted on the front panel and the orientation of V_2 valveholder should be such that pin 5 is nearest V_1 valveholder.

The output transformer T_1 is mounted under the chassis and is bolted to the chassis side-member as shown. A ⅜in rubber grommet should be fitted to the chassis rear apron and through this is fed the mains input lead.

The speaker aperture on the front panel may be made by first cutting a hole with an octal sized valveholder cutter (1⅛in), and following this by drilling a series of concentric ¼in holes in the pattern suggested in Fig. 2 (*b*) or in any other pattern favoured by the individual constructor. Alternatively, of course, a full circle may be cut out to suit the speaker, this being backed by speaker fabric.

The two smoothing capacitors C_5 and C_6 are contained in a single can and this should be secured to the chassis by means of the mounting clip, so that it is vertical with the tags below the chassis, and with the red tag nearest V_3 valveholder.

The power outlet socket should be mounted to the rear apron of the chassis, a solder tag being fitted under one of the securing nuts.

Two four-way tagstrips, with end tags used for mounting, are employed in the design, one of each being positioned alongside, and about 1in away from, the respective valveholders for V_1 and V_2. They appear below the chassis, as indicated in Fig. 2 (*a*).

It should be noted that two ⅜in rubber grommets will be required to take the leads of the mains transformer T_2 through the chassis. One ⅜in grommet will also be required for the l.f. choke leads and a further ⅜in grommet for the speaker leads. These grommets are all inserted into the chassis deck alongside the respective components and the requisite holes will need to be drilled. Also, an earthed solder tag will be required on the chassis deck adjacent to the speaker for later connection to one of the speaker tags.

The actual securing into position of the main components and drilling details will not be described in detail here, as reference to Figs. 2 (*a*) and (*b*) makes this task clear. The wiring-up details which follow are, however, described in detail so that the beginner may bring the electrical half of the project to a successful conclusion.

Wiring-up the Design

When wiring-up this design, the best plan is to deal first with the power supply section and to follow this by dealing with the circuits for V_1 and V_2 in that order. In this manner, the heater leads may be routed clear of the grid and anode leads of the two amplifier valves, this considerably assisting with the reduction of a.c. hum. A further reason for wiring-up the power supply section first is the fact that, to the beginner, the "high" voltages present may cause some trepidation in the construction of this stage. When no other components are fitted, less confusion is liable to arise with power supply wiring.

Fig. 3 shows the wiring diagram for the rectifier (5Z4G) valveholder and this should now be wired-up.

To pin 2 of the valveholder connect one end of the white wire from the mains transformer T_2. This wire should be suitably shortened, the end bared and the enamelled covering of the wire removed by scraping with a penknife. Tin this wire with solder prior to connection to pin 2.

To pin 3 of the valveholder similarly deal with, and connect, the end of the yellow wire from T_2. The other yellow wire from T_2 should also be dealt with in the same manner and soldered to tag 4 of tagstrip 2 (that associated with V_2 valveholder and shown in Fig. 10). To the same tag of this tagstrip should now be secured the brown wire from T_2.

To pin 3 of the V_3 valveholder solder one end of a short length of p.v.c. covered wire and connect the other end to tag 4 of the switch $S_{1(b)}$ shown in Fig. 4. Pin 3 of this valveholder is only used here as an anchoring point—there is no internal connection to the valve itself.

To pin 4 of V_3 connect one end of the red wire

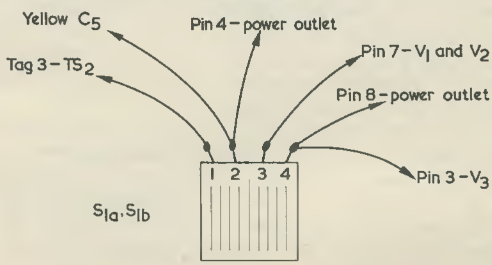


Fig. 4. Switch $S_{1(a), (b)}$ and the required connections

(250V) from T_2, suitably shortening this wire prior to soldering. Similarly deal with the remaining red wire from T_2, soldering the end to pin 6 of V_3. To pin 8 of the valveholder connect one end of a short length of p.v.c. covered wire, the other end of which now connects to the red tag of the smoothing capacitor C_6. To pin 8 also connect the mauve wire from T_2 (5V heater supply), preparing this in the same way as the white lead at tag 2.

To tag 4 of tagstrip 2 connect the end of the black (OV) wire from T_2 (see Fig. 10).

A single wire, coloured yellow/black, also comes from T_2. This must be taped such that its end does not make contact with the chassis. This wire is for the 6.3V heater centre-tap which is not required in the present design, and it is not, therefore, shown in the circuit diagram of Fig. 1.

Refer now to Fig. 4 (switch $S_{1(a), (b)}$). To tag 1 of $S_{1(a)}$ solder one end of a length of p.v.c. covered wire, the other end of which connects to tag 3 of tagstrip 2 (see Fig. 10). To tag 2 of the switch connect a length of p.v.c. covered wire and solder the other end to pin 4 of the power outlet socket mounted on the rear apron of the chassis. Also to tag 2 connect a further length of p.v.c. covered wire and solder the other end to C_5 yellow tag—see Fig. 5. To tag 3 of the switch connect a length of p.v.c. covered wire and solder the other end to pin 7 of V_2. To this latter point also solder a further length of p.v.c. covered wire and connect the other end to pin 7 of V_1. These last two connections are for the 6.3V heater supply and the wires should be routed close to the chassis deck and as far away from the other valveholder tags as possible.

To tag 4 of the switch (one connection has already been made here) solder one end of a length of p.v.c. covered wire and connect the other end of this wire to pin 8 of the power outlet socket.

Pin 1 of the power outlet socket should now be connected, by means of a short length of bare wire, to the solder tag mounted under one of the holding nuts of this valveholder.

Refer next to Fig. 5. To the red tag (C_6 16μF), to which one connection has already been made, solder one wire from the l.f. choke. Connect the other wire from the l.f. choke to the yellow tag (C_5 32μF). It does not matter which way round the l.f. choke is connected.

To complete the power supply section, we must now deal with the a.c. mains input via the switch

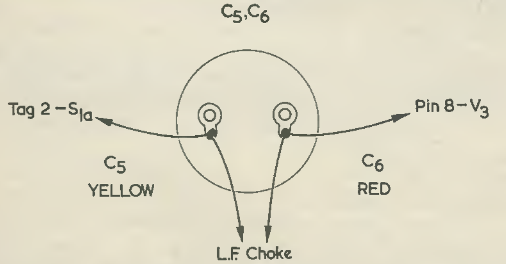


Fig. 5. Connections to the capacitors C_5 and C_6, the earth return being via the metal mounting clip

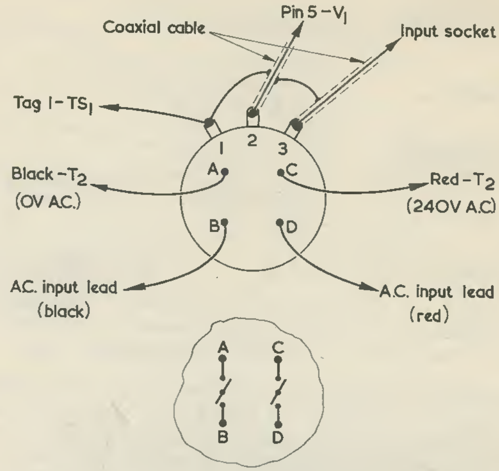


Fig. 6. The volume control R_1 with its integral switch $S_{2(a), (b)}$ (see text)

$S_{2(a), (b)}$ which is an integral part of the volume control R_1. Ensure firstly that the switching circuit is as shown in the inset in Fig. 6 (i.e. tag A connects to B and tag C to D) with the potentiometer you have obtained. This may be checked either with a continuity reading on the meter or, if a meter is not available, by connecting up a small battery and bulb to give an indication of continuity across the tags. Some potentiometers tend to differ in the positions in which the switch tags appear.

To tag A, connect the black wire from T_2 primary winding (0V a.c.) and to tag B solder the black wire of the mains input lead. It is assumed here that a plastic covered cable containing two leads, one red and one black, has been obtained for the a.c. input to the switch. This cable should first be fed through the rubber grommet on the rear apron of the chassis and an anchoring knot tied in it, having first allowed sufficient length to reach the switch tags.

To tag C of the switch solder the red lead from T_2 primary winding (240V a.c.) and to tag D connect the red a.c. mains input lead.

It is assumed that a 240 volt mains supply is available, whereupon the green and yellow wires of the T_2 primary winding will not be required. These two wires should be taped *separately* and tucked away to one side of the chassis. If mains voltages other than 240 are available locally, then either the 220 volt (green) or the 200 volt (yellow) should be connected to tag C of the switch as applicable, the remaining two wires being taped. This completes the power wiring stage.

To complete the wiring to R_1, connect tag 1 to tag 1 of tagstrip 1 (see Fig. 8) with a short length of bare wire. To tag 2 of R_1 solder one end of a coaxial cable inner conductor, the other end of which connects to pin 5 of V_1. The outer metal braiding of this length of coaxial cable should now be connected to tag 1 of the potentiometer as shown in Fig. 6. To tag 3 of R_1 should next be connected

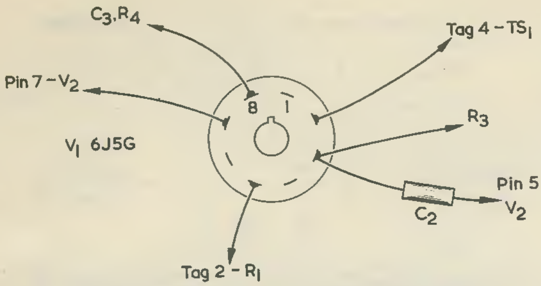


Fig. 7. Wiring details of V_1 valveholder. Where a component is shown designated within a rectangle, it should be fitted in position at that stage of construction

the inner conductor of a further length of coaxial cable, the other end of which is soldered to the centre tag of the coaxial input socket. The outer metal braiding of this length of coaxial cable should now be connected either to the braiding of the first cable or to tag 1 of the potentiometer by using a short length of p.v.c. covered wire. This completes the wiring to the volume control R_1.

Wiring-up V_1 Stage

Solder a length of p.v.c. covered wire to pin 2 of V_1 valveholder (see Fig. 7) and connect the other end to tag 4 of tagstrip 1 (see Fig. 8).

To pin 3 of V_1 connect one end of C_2 (0.1μF) the other end of which connects to pin 5 of V_2. (See Fig. 9.) The connections to pins 5 and 7 of V_1 have already been made.

Refer now to Fig. 8. To tag 1 of the tagstrip connect the negative end of C_3 (25μF, 12V wkg.) taking care to observe the correct polarity, and one end of R_4 (2.2kΩ red, red, red). The other ends of C_3 and R_4 connect to pin 8 of V_1. The other connection to tag 1 of tagstrip 1 has already been made.

To tag 2 of tagstrip 1 connect one end of R_3 (100kΩ brown, black, yellow) the other end of which connects to pin 3 of V_1. Also to tag 2 connect the positive end of C_1 (2μF 350V wkg.), and one end of R_2 (47kΩ yellow, violet, orange). The other end of R_2 connects to tag 3 of the tagstrip and that of C_1 to tag 4, the other connection to this latter tag having already been made. To tag 3 of the tagstrip solder a length of p.v.c. covered wire, the other end of which connects to tag 2 of tagstrip 2. (See Fig. 10.) This latter connection point is the h.t. positive supply to the V_1 stage. It should be noted that both tags 1 and 4 must be securely bolted to the chassis. This completes the wiring-up of the V_1 stage.

Wiring-up V_2 Stage

Refer to both Figs. 9 and 10. Fig. 9 shows the connections to the V_2 valveholder. To pin 2 solder a length of p.v.c. covered wire and connect the other end to tag 4 of tagstrip 2 (see Fig. 10). Also to this same pin of the valveholder solder one end of R_5 (470kΩ yellow, violet, yellow) the other end of this resistor being connected to pin 5 of the

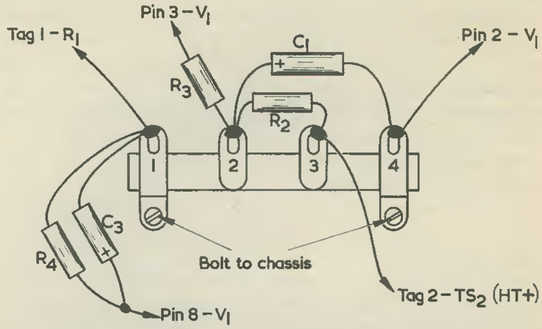


Fig. 8. Wiring details of tagstrip 1. Note the polarity of both C_1 and C_3. Tags 1 and 4 must be bolted to the chassis

valveholder. To pin 3 connect the orange wire from the output transformer T_1. The yellow and green wires from this transformer should now be joined together, soldered, and the join taped so that it does not make contact with the chassis. These two wires should now be tucked away to one side of the chassis.

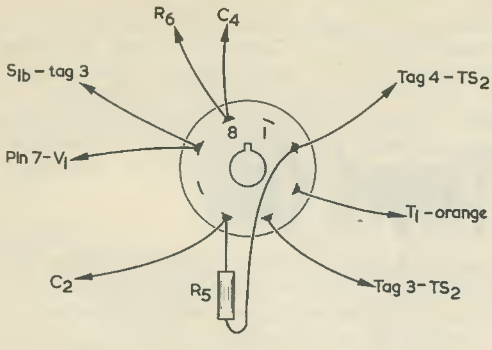
To pin 4 of V_2 solder a length of p.v.c. covered wire and connect the other end to tag 3 of tagstrip 2. Apart from pin 8, the other connections to the valveholder have already been made.

Completing the wiring to tagstrip 2, to tag 1 connect the negative end of C_4 (25μF, 25V wkg.) and one end of R_6 (270Ω red, violet, brown). The other ends of these two components now connect to pin 8 of V_2. To tag 2 of the tagstrip solder the white wire from T_1 and join tags 2 and 3 of the tagstrip together by means of a short length of bare wire. The other connections to tags 2, 3 and 4 have already been made. This completes the wiring of the V_2 stage, except for the speaker output connections. The black wire from the secondary winding of the output transformer T_1 should now be fed through the rubber grommet associated with the speaker and connected to one of the speaker tags (that nearest the earth tag mounted on the chassis deck) and via p.v.c. covered wire, the earth tag itself. It does not matter which way round the speaker is connected. The red wire from T_1 should now also be fed through the rubber grommet and soldered to the remaining speaker tag.

The wiring-up of the unit is now complete and a check should be made of all the connections described, both with the circuit diagram of Fig. 1 and the various point-to-point diagrams, to ascertain that all are correct, and that all connections are reliably soldered.

Testing the Amplifier

For the beginner who has access to a meter, the first essential prior to inserting the valves into their respective holders, is to make a continuity test between the h.t. positive line and the chassis without the mains connected; this being done by



V_2 6V6G

Fig. 9. Wiring details of V_2 valveholder

TAGSTRIP 2 (TS_2)

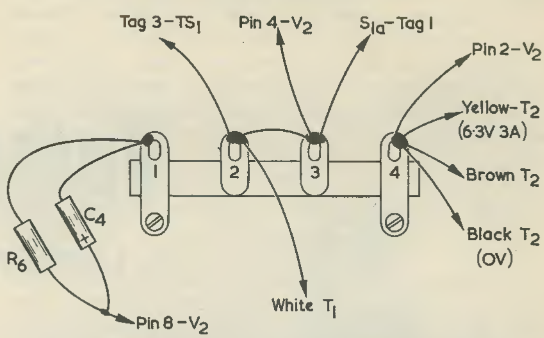


Fig. 10. Tagstrip 2 and the required connections. Note the polarity of C_4. Tags 2 and 3 must be joined together and tags 1 and 4 must be bolted to the chassis

inserting a meter switched to read resistance between tag 1 of the switch $S_{1(a)}$ and chassis with the switch in the closed position. Should a reading be obtained (apart from an initial "kick" due to the electrolytic capacitors) then a short-circuit exists and must be cleared before proceeding further.

Plug the valves into their respective holders, insert the a.c. mains plug and switch on, whereupon the valve heaters will be seen to light up. Turn the volume control R_1 to a position near maximum and place a finger on the centre conductor of the coaxial input socket. A loud hum should then be heard, and this denotes that the amplifier is working correctly.

For those beginners who do not have access to a meter, the following procedure should be adopted. Insert the valves and the a.c. mains plug and switch on. Ensure that the valve heaters light-up and then switch off. Stand the chassis on one edge so that the mains transformer is against the bench surface, whereupon the components beneath the chassis become clearly visible. Switch on and carefully watch for signs of over-heating for a period of some 10 minutes or so. Should a resistor (such as R_2 or R_3) show signs of over-heating, this will be in the form of "bubbling"—in which case the outer coating of the component will literally bubble and emit smoke. Should such a symptom exist, then a short circuit is prevalent in the anode circuit of V_1 and must be traced and corrected immediately.

(*To be concluded*)

CAN ANYONE HELP?

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

Receiver R-4/ARR-2 and Receiver 78.—D. Bowers, 95 Grenfell Avenue, Saltash, Cornwall—any information and details of modifications.

* * *

Cossor 339 Oscilloscope.—R. F. Morgan, 24 Lynton Avenue, West Ealing, London, W.13—loan or purchase of circuit diagram.

* * *

U.H.F. Tuner.—A. Bonnage, 10 Colvers Close, Matching Green, Harlow, Essex, circuit required, valve or transistor, 12V wet battery supply.

Trixette Everest Tape Recorder Amplifier.—F. Kenyon, 28 Mason Avenue, Bidston, Birkenhead, Cheshire—circuit diagram, loan or purchase.

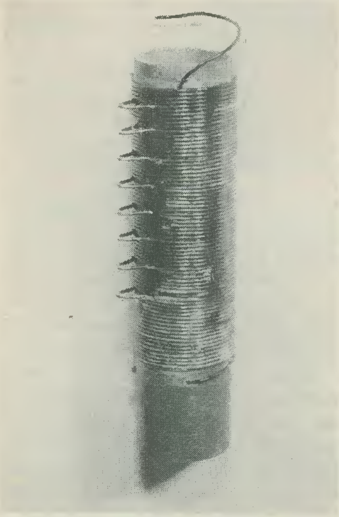
* * *

Wire Recorder, Disc Cutter, Antenna Tuner.—Mohamed J. Daya, P.O. Box 1187, Dar-Es-Salaam, Tanzania—any information, circuits, etc., on the following: wire recorder Agafon type 399155–3; direct disc cutting instrument Emidicta model 2400E and antenna tuner type BC939A.

Winding Tapped Coils

E. LAWRENCE

A simple and very neat method of introducing tapping points in single layer home-wound coils



The appearance of a typical coil with tappings formed in the manner described in this article

Continued dissatisfaction with the results obtained when winding tapped coils on plain cylindrical formers stimulated the author to search for a more satisfactory method. If, for instance, one attempts to solder a connecting wire to the edge of a single turn in a close-wound coil, the resulting joint may be of doubtful quality, this being especially true where it is necessary to prepare the wire by scraping off the insulating enamel. The possibility of bridging several turns is another hazard.

It is common practice to form a "pig-tail" at the required lapping point by twisting the wire, but this usually displaces the adjacent turns. The result is an untidy appearance, whilst the resulting wire deformation renders it difficult to remove the enamel to the required degree for soldering.

An Alternative Approach

The simple idea proposed by the author can be clearly seen in the first picture. The only thing needed in addition to the coil former and wire is a short length of ¼in wooden dowel which is slipped under the selected turn during the winding operation. An extension to the turn is thus formed. As the coil winding progresses the dowel is advanced with a screwing motion until the last loop is formed, after which the coil can be finished off with a coat of polystyrene cement or shellac and then allowed to dry. Providing the cement is kept away from the immediate vicinity of the dowel this may be withdrawn easily, and the loops should then be squeezed slightly so that they conform more closely to the curve of the former. A further application of cement in the area previously occupied by the dowel will ensure complete security of the turns.

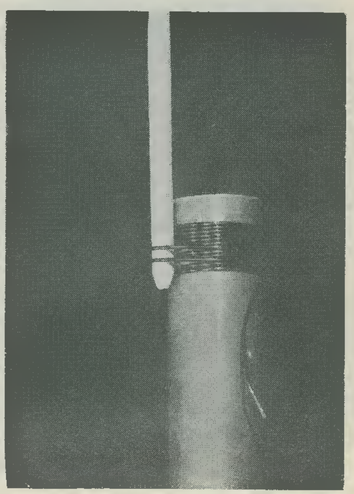
Paint stripper applied to the tips of each loop with a small water colour brush will facilitate removal of the insulating enamel, which then responds readily to the scouring effect of steel wool to produce an excellent tinning surface.

The coil, as seen in the second photograph, is now ready for use and connections can be made either by soldering or with crocodile clips. It is possible to apply the technique to the usual wire gauges employed for single-layer coils and tapping points may be introduced as close as alternate turns.

The coils produced in this manner perform excellently from the electrical point of view while possessing a neat appearance, and it is hoped that this idea will be of interest to all constructors who like to combine a good appearance with efficiency.

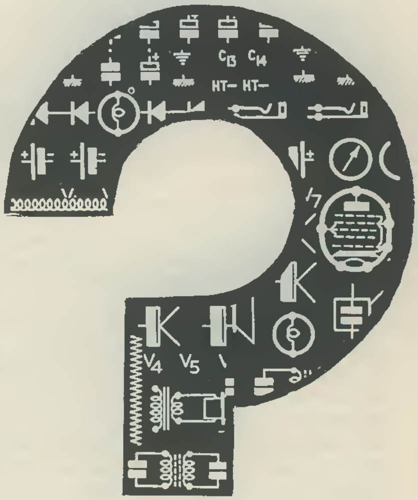
Editor's Note

The enamel stripping operation described above is not needed if the wire enamel happens to be of the "self-soldering" variety. "Self-soldering" enamel melts at soldering temperatures and enables a good joint to be made to the wire underneath without any preliminary stripping. The presence of "self-soldering" enamel may be readily verified by applying an iron and cored solder to a sample length of the wire.



How the dowel is introduced, during coil winding, to form an extension at the required tapping point

understanding radio



THE TRIODE AS VOLTAGE AMPLIFIER

By W. G. Morley

In last month's issue we introduced the I_aV_a (anode current–anode voltage) characteristic curve for the diode, and we saw that anode current was always limited either by the space charge or by saturation. We then touched briefly on "contact potential", after which we examined anode a.c. resistance. This completed our discussion on the diode and we shall now turn our attention to the triode.

The Triode

In the triode a third electrode, the *grid*, is inserted between the cathode and the anode. In passing, it is worth remarking that the step of adding the grid to the diode valve was made by Lee De Forest in 1907, and that it represents what is probably the most significant advance in the whole history of what is now known as electronics. This is because the introduction of the grid resulted in a device capable of *amplification*, whereas previously no such device was in existence.

The grid may, in practice, consist of a spiral of fine wire, as shown in Fig. 297. In this diagram the turns of wire which make up the grid are welded to two stout support wires on either side, the external connection to the grid being made by way of either of these support wires. Other types of grid construction are also used, these employing wire mesh or similar materials, and they all have the basic feature that apertures, or gaps, are provided to allow the passage of electrons from the cathode to the anode.

The three-electrode assembly of cathode, grid and anode in an evacuated envelope constitutes a *triode*, or *triode valve*, and it is represented in circuit diagrams by one of the symbols shown in Fig. 298. Fig. 298 (*a*) gives the symbol for a directly-heated triode (i.e. one in which the filament acts also as the cathode), whilst Fig. 298 (*b*) shows the symbol for an indirectly-heated triode (in which the cathode is heated by a separate filament or heater). The dashed line between the cathode and the anode represents the grid.

In Fig. 299 we connect a triode such that its cathode connects to the negative terminal of a high tension battery whilst its anode connects, via a current reading meter, to the positive terminal. At the same time, we apply to the grid a voltage obtained from a potentiometer connected across two batteries in series. These batteries are so connected that, when the slider of the potentiometer is at the top end of its track the potential applied to the grid is positive of the cathode, and when the slider is at the bottom end of the track the potential applied to the grid is negative of the cathode. A voltmeter connected between grid and cathode indicates the grid potential. As was pointed out last month, valve electrode potentials are always, unless otherwise stated, assumed as being with respect to cathode. Since the voltmeter has to measure both positive and negative voltage it may conveniently be an instrument having a centre-zero scale. A second voltmeter indicates the voltage from the h.t. battery. It is assumed that the cathode is heated by having the heater connected to a suitable source of supply.

Let us now see what happens when we vary the potential on the grid of the triode. If we adjust the potentiometer so that the slider is at the top end of the track, the grid becomes positive of the cathode and attracts electrons from the space charge. In doing so it partly neutralises the space charge, whereupon a large number of electrons are able to travel from the cathode to the anode, these passing through the apertures in the grid. If the potentiometer slider is now moved down towards the position corresponding to zero potential, the positive potential on the grid reduces, as also does the neutralising effect exerted on the space charge.

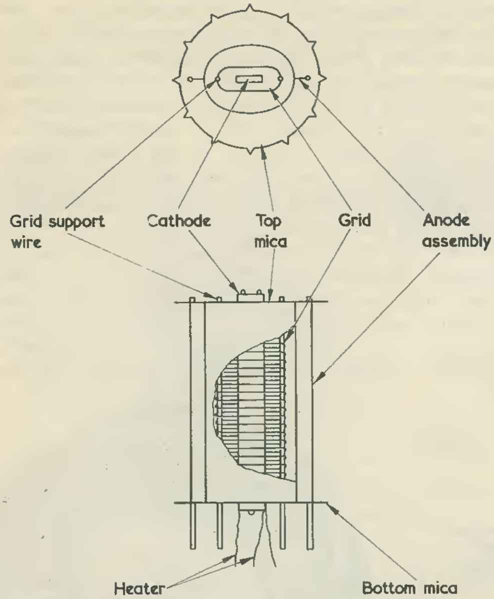


Fig. 297. In the triode, a grid is interposed between cathode and anode. In this diagram, which illustrates an indirectly-heated triode, the grid consists of a spiral of fine wire

The latter then imposes increased limitation on electron flow and the flow of electrons from cathode to anode decreases. When the potentiometer slider is moved further downwards it brings the grid negative of the cathode, with the result that the limiting effect due to the space charge is augmented by the negative grid. Electron flow is, therefore, decreased further. As the grid potential is made continually more negative, the flow of electrons continues to decrease until a negative grid potential is reached at which electron flow ceases altogether. This negative potential is known as the *cut-off potential* for the valve. It varies for different values of anode voltage because, as we saw last month, the latter also has a neutralising effect on the space charge and therefore affects the electron flow limitation given by negative grid-plus-space charge.

We may therefore see that, with a positive potential on the grid, a large number of electrons may pass through the grid apertures to the anode.

Fig. 298 (a). The circuit symbol for a directly-heated triode
(b). The symbol for an indirectly-heated triode

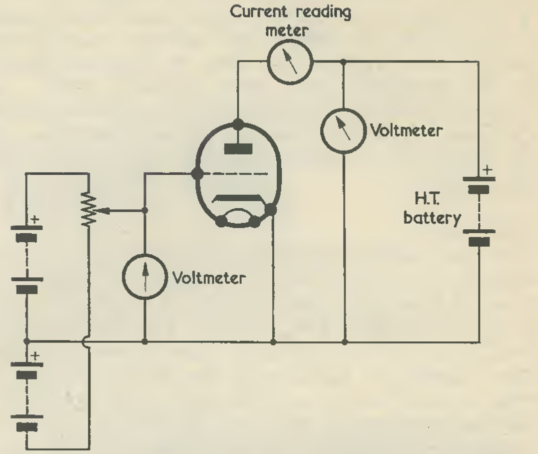


Fig. 299. A circuit which may be employed to obtain I_a V_g curves for a triode valve

Thus, a positive grid potential corresponds to a large anode current. As the positive potential on the grid reduces to zero the electron flow and, hence, anode current, reduces. The process continues after the grid passes through zero potential and goes negative, the anode current continually reducing as the grid becomes more negative until we reach the cut-off potential at which anode current ceases completely.

A set of typical I_a V_g (anode current–grid voltage) characteristic curves, as may be obtained from the circuit of Fig. 299, are shown in Fig. 300, and these demonstrate the fact that anode current decreases as grid voltage goes negative. Three curves are given, these corresponding to anode voltages of 100, 150 and 200.

An important point which we have not yet discussed is that, when the grid is positive of the cathode, some of the electrons from the cathode flow to it. This occurs because the positive grid acts as though it were the anode of a diode. On the other hand when the grid is negative of the cathode no electrons flow towards it, since it then offers repulsion to such electrons. Thus, there is a flow of *grid current* when the grid is positive, and none when it is negative. The consequence is that, if we keep the grid of the valve always negative of the cathode, we can control anode current by grid *voltage* only, since no current need flow in the grid circuit at all. Apart from any other factors, this is an extremely useful condition because it means that high impedance circuits[1] may be connected to the grid without risk of loss of voltage due to grid current. In practice, it is customary to operate a triode such that its grid is always negative of the cathode, and it is only in certain specialised circuits that the grid is allowed to go positive and, thereby, allow the flow of grid current.[2] Even in these circuits, however, the flow of grid current has to

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[1] That is, circuits which can be represented by a generator having a high internal impedance.

be kept at a low level, because excessive grid current may cause overheating of the grid and consequent damage to it. Valve manufacturers' published I_aV_g curves normally cover grid voltages from the negative cut-off potential to zero voltage only, these being similar to the curves to the left of the zero grid voltage point in Fig. 300.

The Triode as Voltage Amplifier

We have seen that we may vary the anode current of a triode by varying its grid voltage. Let us take this a stage further by applying an *alternating* voltage to the triode grid. The resultant effect on anode current is illustrated graphically in Fig. 301 (which reproduces the "150 volt" I_aV_g curve from Fig. 300). In Fig. 301 the alternating voltage is applied at the -3 volt point on the V_g axis, so that it causes the grid to swing by equal amounts positive and negative of -3 volts. The resultant anode current (produced on the right by drawing vertical lines from the alternating voltage up to the curve then, horizontally, to the right) also has an alternating waveform. Thus, by applying an alternating voltage to the grid we have caused an alternating current to flow at the anode. We can, in consequence, look upon the valve as a "generator" of alternating current, in which case it needs a load. Such a load can be provided by a resistor or by an impedance, and we shall now examine the case where the load is a resistor.

A resistive load is shown in Fig. 302 and it consists buite simply of a resistor connected between the anode of the triode and the positive terminal of the h.t. supply. It is referred to as the *anode load.*

[2] It is possible for a small current, due to effects inside the valve which have not yet been mentioned, to flow in the grid circuit even when the grid is negative of cathode. However, such currents are, proportionately, very low. For many applications, and in the present discussion, they can be considered as being negligible.

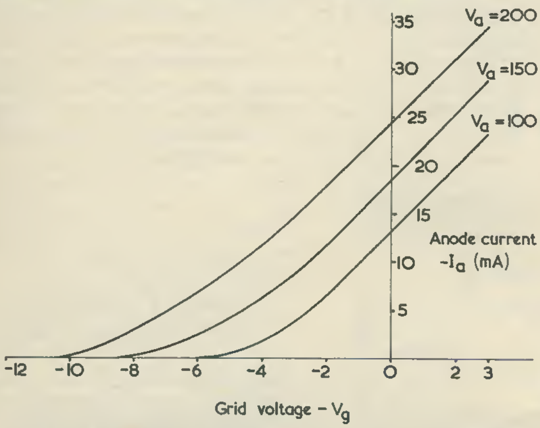


Fig. 300. Representative I_a V_g curves for a triode at anode voltages of 100, 150 and 200. For the purpose of explanation these curves show anode current for positive grid voltage, but it should be pointed out that it is normally desirable to operate triodes with negative grid voltage only, and that it is possible for a valve to suffer damage if excessive positive voltage is applied to its grid

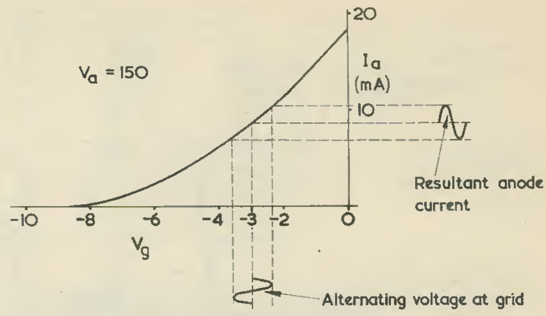


Fig. 301. Applying an alternating grid voltage to the V_a=150 curve of Fig. 300

Applied to the grid of the triode is an alternating voltage generator whose output is the same as the alternating voltage shown in Fig. 301. In Fig. 301 we positioned the alternating voltage at the -3 volt point along the V_g axis. In Fig. 302 we do the same in practice by inserting a 3 volt battery between the negative h.t. supply line and the lower terminal of the alternating voltage generator, this battery making the lower generator terminal 3 volts negative of the cathode.

The alternating voltage generator of Fig. 302 causes, as is to be expecied, corresponding changes in anode current. But the anode current now flows through the anode load resistor, with the result that the voltage dropped *across* this resistor varies according to the current which flows through it. In consequence an alternating *voltage* appears at the anode. Assuming that a satisfactory value of resistor has been chosen for the anode load, the alternating voltage at the anode may be many times greater than the alternating voltage applied to the grid; which means that the valve has caused the alternating voltage applied to the grid to be *amplified.* A circuit of the type shown in Fig. 302, whose function is to produce an amplified version of an alternating voltage, is described as a *voltage amplifier* circuit.

Although the grid circuit of Fig. 302 corresponds to the grid voltage conditions of Fig. 301, there are

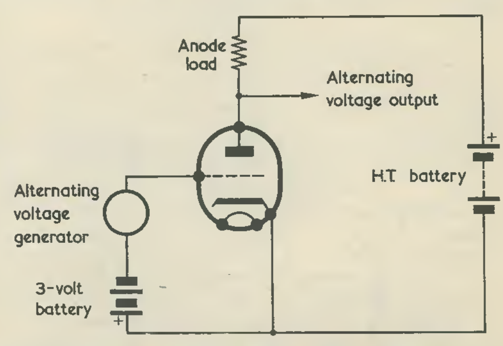


Fig. 302. Connecting an alternating voltage generator to a triode voltage amplifier. The 3 volt battery ensures that the alternating voltage is applied to the V_g axis at the same position as occurred in Fig. 301

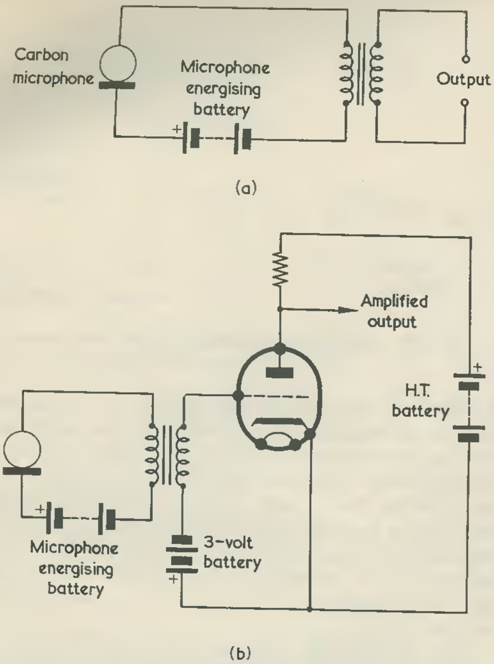


Fig. 303 (a). Obtaining electrical signals from a carbon microphone
(b). Applying the microphone output to the voltage amplifier of Fig. 302

no further points of similarity between the two diagrams. This is due to the fact that the curve in Fig. 301 defines anode current when *anode voltage is constant.* Anode voltage is quite patently *not* constant in Fig. 302 because we have purposely inserted a resistor in series with the anode to obtain an alternating voltage output. It would seem from this that there is little point in drawing characteristic curves for a triode with a fixed anode voltage because, when we want to use the triode as a voltage amplifier, the first thing we require is a *varying* anode voltage! As we shall see later, however, it is possible to find the alternating voltage appearing at the triode anode of Fig. 302 from curves which give much the same information as is given by Fig. 300.

In Fig. 302 we positioned the alternating voltage at the -3 volt point along the V_g axis by the simple expedient of inserting a 3 volt battery in series with the alternating voltage generator. This battery provides a *grid bias* of -3 volts and may be referred to as a *grid bias battery.* Alternative circuit devices can be employed to position the alternating voltage at a desired point along the V_g axis, and these are also described as applying *bias.*[3]

A further point in the circuit of Fig. 302 is that the current which causes the amplified alternating voltage to appear at the anode is provided by the h.t. battery. The grid may be considered as a controlling device which "turns on" more anode current as it goes positive, or vice versa, and which consumes no power[4] in the process provided that it does not go positive of the cathode. It should be remembered that, in the circuit under consideration, anode current is always present, and the alternating voltage only appears because this anode current is made to vary by the alternating voltage at the grid.

We have, up to now, looked upon the alternating voltage applied to the grid of the triode as being provided by a generator. In radio work we handle a number of alternating voltages, these including the electrical signals which correspond to sound. We have seen, for instance[5], that if we connect up a carbon microphone in the manner shown in Fig. 303 (*a*) we obtain, from the secondary of the transformer, electrical signals corresponding to the sound which reaches the microphone diaphragm. The secondary of the microphone transformer can replace the alternating voltage generator of Fig. 302, giving us the circuit shown in Fig. 303 (*b*). In this circuit, *amplified* electrical signals corresponding to the original sound appear at the anode of the triode. It should be noted, in passing, that the microphone transformer of Fig. 303 (*b*) could, in the present instance, have quite a high step-up ratio, this being of the order of 1:100. A practical carbon microphone is a low impedance instrument, whereas the grid input circuit of the valve presents a high impedance. The step-up transformer helps to match these two impedances to each other.[6]

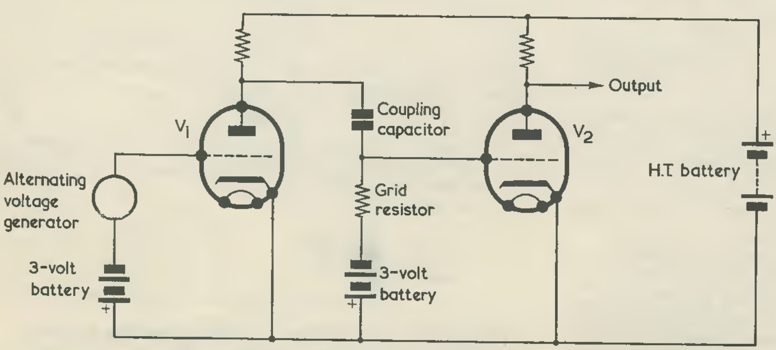


Fig. 304. Two triode voltage amplifiers in cascade. Resistance-capacitance coupling is employed between the two valves

[3] In American terminology, grid bias voltage is referred to as the "C voltage". The 3 volt battery of Fig. 302 then becomes a "C battery". The letter "C" differentiates the grid bias supply from the "A supply" (the supply for the filament or heater) and the "B supply" (that for the anode, and which is described in this country as the high tension or anode supply).

[4] To be exact, negligible power in the present context.

[5] In "Understanding Radio" in the February 1964 issue.

[6] See "Understanding Radio" in the July 1963 issue.

Voltage Amplifiers in Cascade

It frequently happens that a particular item of equipment requires more voltage amplification than a single triode can provide. This requirement may be met by adding a second triode to amplify the alternating voltage at the anode of the first. How may these two triodes be coupled together?

The simplest method of providing the coupling is shown in Fig. 304. In this diagram the alternating voltage is applied to the first triode, now designated V_1, in the same manner as occurred previously. It is only the alternating voltage at the anode of V_1 which needs to be fed to the second triode, V_2, and this alternating voltage is transferred by way of a capacitor whose value is such that it presents a low impedance at the frequencies being handled. If (as is usually the case in radio circuits employing triodes) these are audio frequencies, the value of the coupling capacitor would be of the order of 0.01μF to 0.1μF. The second triode has a grid bias battery (which, we may assume for the purpose of explanation, is also 3 volts), and this is coupled to the grid via a high value resistor referred to as the *grid resistor*. The grid resistor normally has a value of some 250kΩ to 1MΩ. The output alternating voltage is then taken from the anode of the second triode.

To fully appreciate the manner in which the capacitive coupling functions it is helpful to commence with the condition where the a.c. generator offers zero output (as would occur if the alternating voltage were obtained from a microphone on which no sound impinged). The voltage on the grid of V_1 will then be a steady -3 volts, and V_1 anode will take up a steady voltage which corresponds to this grid voltage. The capacitor has its upper plate connected to V_1 anode and its lower plate connected, via the grid resistor of V_2, to the negative terminal of the second grid bias battery. The capacitor thus holds a charge in which its plates are maintained at these two potentials and no current

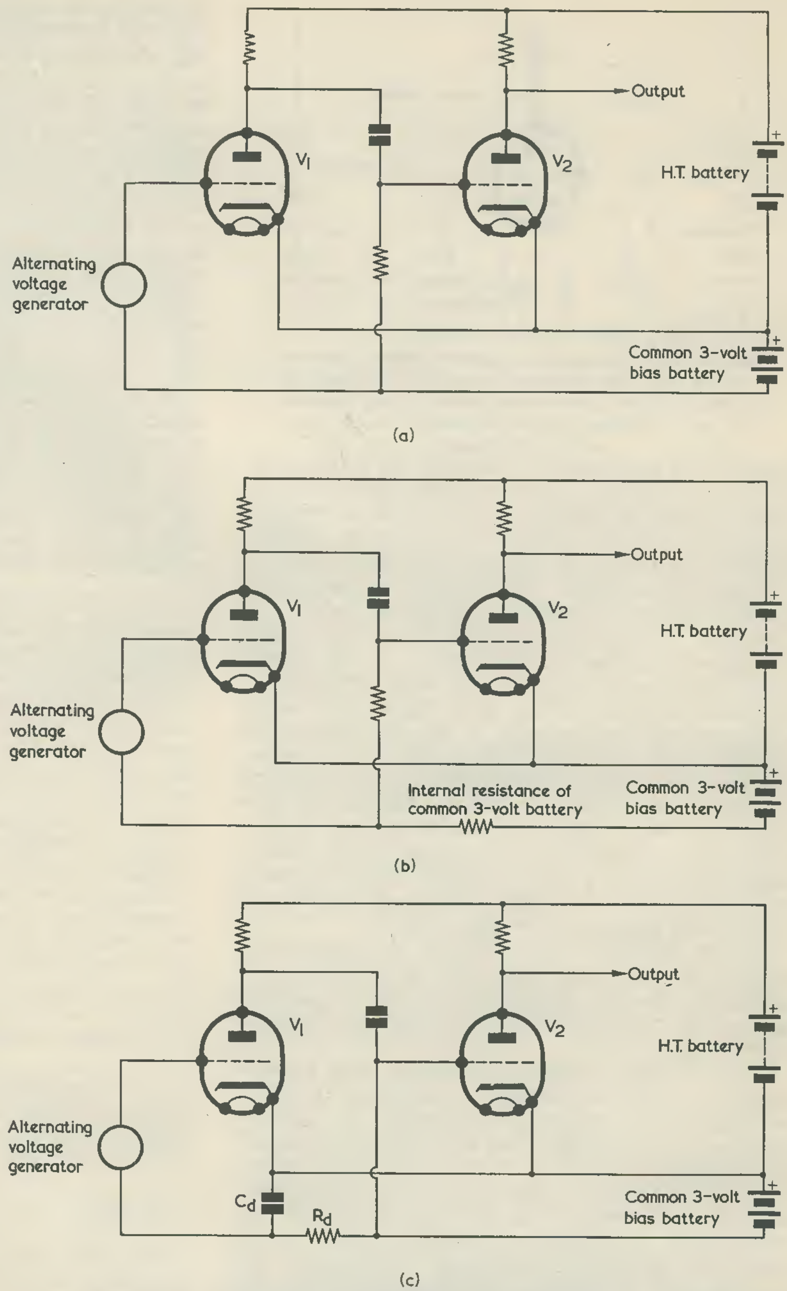


Fig. 305 (a). Employing a common source of grid bias voltage instead of the two batteries in Fig. 304
(b). If the internal resistance of the battery is high, part of the alternating voltage applied to the grid of V_2 becomes fed back to the grid of V_1
(c). The situation in (b) may be obviated by inserting a decoupling circuit, given by R_d and C_d, in the bias supply to V_1

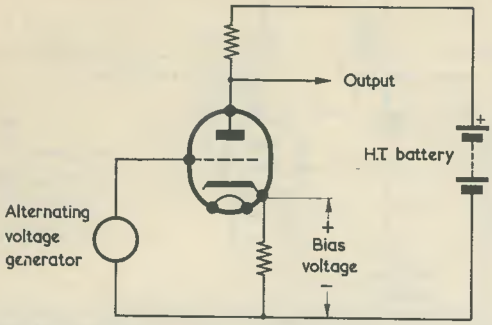


Fig. 306. If a resistor of the requisite value is inserted in series with the cathode of the triode, the cathode becomes positive of the lower terminal of the generator by the required bias voltage

flows in the grid resistor (although, of course, the charging current needed to bring the capacitor to its present condition would have flowed when the h.t. supply was initially switched on). Since no current flows through the grid resistor there is no voltage drop across it, and the −3 volts bias from the second grid bias battery is applied to the grid of V_2.

If, now, the generator produces an alternating voltage, the voltage on the grid of V_1 will swing positive and negative of the −3 volts provided by its grid bias battery. The anode of V_1 will, also, swing positive and negative of its previous steady voltage by an amount depending upon the amplification provided. The amplified positive and negative excursions at the anode of V_1 are passed via the capacitor, which tends to retain its charge, to the grid of V_2 which similarly swings positive and negative of the −3 volts provided by the second grid bias battery. A twice-amplified alternating voltage then appears at the anode of V_2.

As may be seen, the situation at the grid of V_2 is, so far as bias is concerned, just the same as if an alternating voltage generator had been inserted between the negative terminal of the bias battery and the grid.

When a valve amplifies the output from a preceding valve, the two valves are described as being *in cascade*. If a third valve amplified the output of the second, the three valves would also be referred to as being in cascade, and so on. The term "cascade" similarly applies when amplifying valves other than triodes are used or when other methods of intervalve coupling are employed. (Alternative inter-valve coupling circuits will be discussed in later issues.) The method of coupling shown in Fig. 304 is described as *resistance-capacitance* coupling, or *RC coupling*, because it is achieved with the aid of an anode resistor and a coupling capacitor.

Other Bias Circuits

In Fig. 304 grid bias for the two triodes was provided by two grid bias batteries. In practice it would be a little expensive and inconvenient to have a grid bias battery for each valve in an amplifier, and one method of simplification could consist of employing a single battery instead, as shown in Fig. 305 (*a*). This arrangement is quite practicable but, for correct operation, it is important that the internal resistance of the common grid bias battery be low. If its internal resistance were high, the situation shown in Fig. 305 (*b*) could arise. In this diagram, part of the alternating voltage applied to the grid of V_2 appears across the internal resistance of the common battery and is, therefore, applied to the grid of V_1. This is not a desirable state of affairs, and will not offer results corresponding to those given by the circuit of Fig. 304. In more complicated types of radio equipment the use of a source of grid bias offering a high common resistance (or impedance) to several grid circuits may give rise to quite serious faults, such as instability.[7] The difficulty may be overcome by inserting a resistor and capacitor in one of the grid bias supply circuits, as is shown in Fig. 305 (*c*). In this diagram R_d has a high resistance and C_d a low reactance at the frequencies being handled so that, even if part of the alternating voltage applied to the grid of V_2 appears across the grid bias battery, only an extremely small proportion of this unwanted voltage

[7] "Instability" defines the tendency of an amplifier to break into oscillation, and may be caused by an unwanted coupling between an output point and an input point (i.e. two circuit points between which amplification occurs). Oscillation has not yet been dealt with in these articles, but will be discussed shortly.

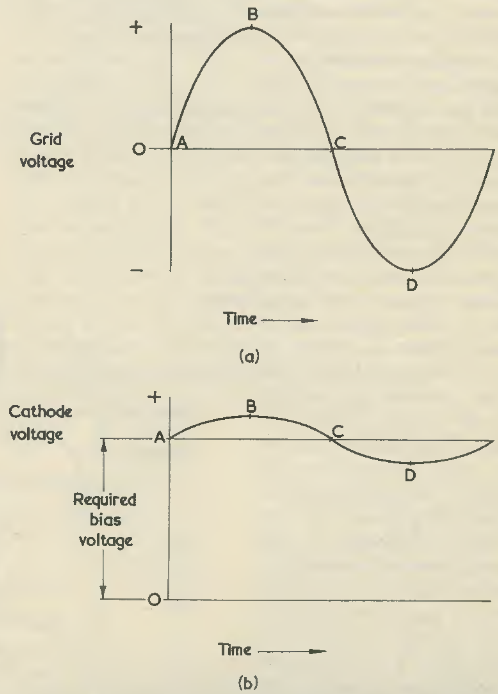


Fig. 307. The disadvantage with the cathode resistor of Fig. 306 is that the cathode tends to "follow" the alternating voltage on the grid. The grid voltage for a single cycle is shown in (a) and the corresponding cathode voltage in (b). Both voltages are with respect to the h.t. negative line

is actually applied back to the grid of V_1. R_d and C_d are known as *decoupling* components because they de-couple (i.e. break the coupling) between two circuit points.

Some radio circuits have a common bias supply which is not derived from a battery but from an alternative source. Decoupling circuits similar to those of Fig. 305 (*c*) are, then, frequently employed to prevent unwanted couplings between stages. A decoupling circuit may, indeed, be inserted in each grid circuit.

An alternative method of providing bias for a valve dispenses with the grid bias battery concept, but it may only be employed with indirectly-heated valves in which the cathode is insulated from the heater. As we have already seen, the alternating voltage at the anode of a voltage amplifier is caused by changes in its anode current, this current being provided by the h.t. battery. If we look upon the current in terms of a flow of electrons, we can say that electrons leave the negative terminal of the h.t. battery, pass to the cathode, are emitted to the anode, then flow back to the positive terminal of the battery. Clearly, therefore, the anode current flows, also, through the cathode circuit.

In Fig. 306 we insert a resistor in series with the cathode of a voltage amplifier triode. We also apply our alternating voltage generator, but in this case its lower terminal is connected to the negative h.t. line. No bias voltage is, in consequence, applied to the grid at all. The anode current flows through the resistor in the cathode circuit, causing a voltage to be dropped across it, with the result that the cathode goes positive of the h.t. negative line and the lower terminal of the alternating voltage generator, by that voltage. The cathode going positive of the lower generator terminal is exactly the same as the lower generator terminal going negative of the cathode, as occurred previously when we employed the grid bias battery. If, therefore, we give the cathode resistor a value which causes the required grid bias voltage to be dropped across it, then we will achieve the same result, so far as direct voltage is concerned, as was given previously by the grid bias battery.

Unfortunately, the cathode resistor, on its own, does not completely meet the requirement for a bias circuit. This point may be readily understood if we examine circuit operation over a cycle of the alternating voltage offered by the generator.

Fig. 307 (*a*) illustrates a single cycle as provided by the generator, whilst Fig. 307 (*b*) shows the voltage appearing at the cathode of the valve when connected as in Fig. 306. Both voltages are shown with respect to the h.t. negative line. At point A, the generator voltage is zero, whereupon the grid of the valve is at the same potential as the h.t. negative line and the lower terminal of the generator. As is shown in Fig. 307 (*b*), the required bias voltage is then dropped across the cathode resistor. At point B, the generator output is at its peak positive potential. This results in an increase in anode current and, in consequence, in cathode current. A greater current flows through the cathode resistor and a greater voltage is dropped across it. The cathode, therefore, goes more positive. At point C of Fig. 307 (*a*) the alternating voltage at the grid is zero and the voltage dropped across the cathode resistor is the same as for point A. At D, the generator voltage reaches its maximum negative excursion. This causes a reduction in anode current and in cathode current, with less voltage dropped across the cathode resistor. The cathode goes, therefore, negative of the potential it held at points A and C.

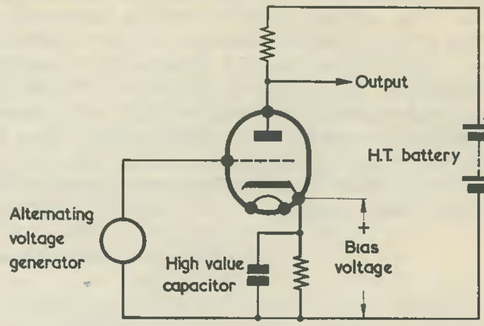


Fig. 308. Adding a capacitor having a very low reactance (at the frequencies handled) in parallel with the cathode resistor maintains the cathode at a steady potential and prevents the effect shown in Fig. 307 from taking place

We have examined cathode voltage at the peaks B and D but, as is shown in Fig. 307 (*b*), this voltage will similarly change, by corresponding amounts, for grid voltages between zero and the peak values. A low-amplitude version of the grid alternating voltage appears, in consequence, at the cathode of the valve, this going positive when the grid goes positive and negative when the grid goes negative. Now, the voltage which controls the flow of electrons in the valve is that between grid and *cathode*, and it may be seen from inspection of Fig. 307 that the grid-cathode alternating voltage is *less* than that provided by the generator. The cathode voltage changes in sympathy with the grid voltage and the actual grid-cathode alternating voltage is that provided by the generator less the alternating voltage appearing on the cathode.

By inserting the cathode resistor we have obtained a useful bias voltage but we have caused the overall amplification provided by the circuit to be reduced. The solution consists of connecting across the cathode resistor a high-value capacitor having a very low reactance at the frequencies being handled. (See Fig. 308.) The added capacitor prevents the cathode voltage from "following" the alternating voltage on the grid, whereupon the circuit provides the requisite bias for the valve and behaves, when alternating voltage is applied to the grid, in the same way as did the previous circuits using grid bias batteries.

The circuit of Fig. 308 is, in practice, a very convenient one, because it enables the bias requirements for the valve to be met by means of two simple components—a resistor and a capacitor.

The bias applied in Fig. 308 is described as *cathode bias*, and it may be employed with amplifying valves other than triodes. For audio frequency amplification, it is usual to give the cathode bias capacitor a value of the order of 25μF. An electrolytic capacitor can be employed here and, since the voltage dropped across the bias resistor is normally low, it can be a small component having a low working voltage rating.

As a point of terminology, the loss of overall amplification which results when the cathode resistor is employed on its own, as in Fig. 306, is referred to as *cathode degeneration.*

Next Month

In next month's issue we shall continue to discuss the triode.

Radio Control for Models

A Survey of Current Practice

By F. C. JUDD, A. Inst. E., G2BCX

Our contributor, well-known for his activities in the field of model control by radio and author of Radio Control For Models *(No. 16 in the Data Book series) outlines the recent developments which have taken place in this fascinating branch of home-construction*

DURING THE COURSE OF THE PAST TEN TO FIFTEEN years, radio control for models has not only developed rapidly and with tremendous technical improvements, it has also become an industry of considerable size. Gone are the days of elastic-driven escapements and gas filled valves, and of unreliable receivers and indifferent sensitive relays. Today the transistor has taken pride of place, and it appears in crystal controlled transmitters and receivers and in servo circuitry, doing away almost completely with large batteries and the many other problems which previously beset the radio control enthusiast. Nowadays, precision servo systems ensure completely reliable steering and engine control, and even the aerials used for transmitters and receivers are no longer "bits of wire" but items to be carefully designed and constructed. Despite all this development, the amateur who likes to construct his own equipment has been somewhat left out of the picture, and it has become common practice to buy equipment ready made. In addition very little has been published in the popular technical press to encourage the keen constructor.

Commercial concerns have been quick to take advantage of the situation and one can pay up to £300 for comprehensive radio control outfits comprising transmitter, receiver, servos, batteries, in fact everything except the controlled model itself. I hasten to add however, that it is not my intention to survey the vast range of radio control equipment available today but rather to discuss some of the techniques and circuitry; to bring readers up to date, as it were, with current practice. On the other hand, we cannot ignore the many precision made servos now available, most of which would be quite beyond the constructional ability of all but the few with well-equipped workshops. The same comments apply to models and as one who makes no claim to being proficient at model making and who builds mainly from kits, these too must of necessity be mentioned. It will not be out of order therefore to include a few words

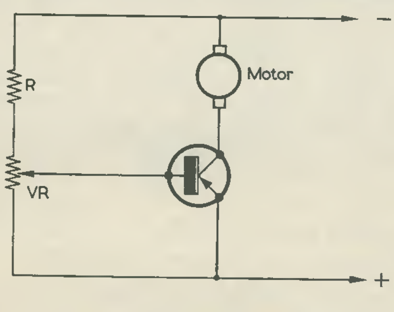
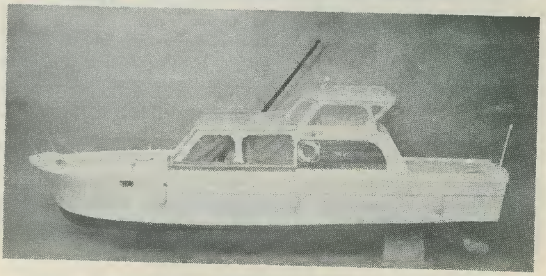
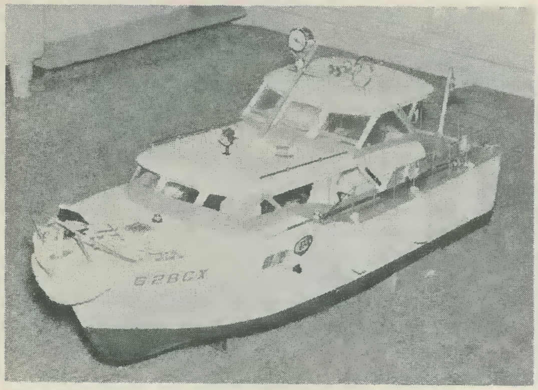


Fig. 1. A basic servo motor circuit



The Chris Craft "Constellation", a 25in model launch for radio control



The "Constructor I", a 4ft launch built by the author to function as a floating radio control "test bed". Top speed is 15 knots

about model boats and aeroplanes suitable for radio control because without the model there is no point in making or buying radio control equipment.

Models for Radio Control

Those who are already experienced model makers may be excused for ignoring the next few paragraphs altogether. Like myself, the "electronics fraternity" will regard the actual model as a means to an end, a floating or flying test bed for one's prowess with a soldering iron and a handful of transistors! Here I suggest a model boat, particularly for those without knowledge of aeronautics. There is nothing more soul-destroying than to have a model aircraft smash itself and its radio gear to bits because of a dry soldered joint or a loose wire, or just plain lack of flying experience.

Among the many kits available for boat models the 25 inch model Chris Craft Constellation by Graupner is an attractive proposition for those who just want to dabble with the more simple radio control techniques—simple engine and steering or what is popularly known as the bang-bang system! That is, engine off or engine on and rudder (bang) over to left or (bang) neutral or (bang) right, etc. All of this can be done with a composite servo like the Kinematic and a single radio channel, i.e., transmitter and receiver with a carrier-on/carrier-off sequence. My own version of the Chris Craft launch complete with a control system as outlined above is shown in the illustrations. This is an outfit you can go and buy outright because even the transmitter and receiver are built from printed circuit kits. In other words you get a "packaged deal" that requires only a soldering iron and a few small tools. For those with a more serious interest who would like to tackle the radio part "the hard way" there are numerous boat and aircraft kits which can be purchased in almost any shop specialising in models. Perhaps it would be better if I simply list a few of these and go on to the equipment.

Radio Control Models

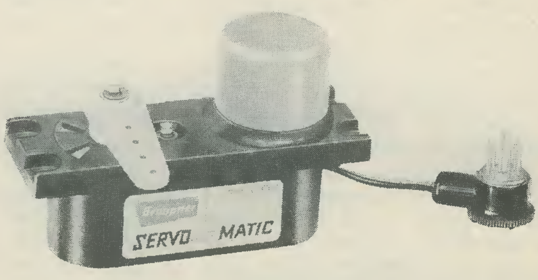
Chris Craft Constellation launch, 25in model—Graupner (Ripmax Ltd.) as Fig. 1.
Theodor Heuss Rescue Launch, 39in model—Graupner (Ripmax Ltd.)
Aerokit R.A.F. Tender, 34in model—Keil Kraft Ltd.
Fairey Huntsman, 42in model—Veron Ltd.
Consul Monoplane, 40in wing span—Graupner (Ripmax Ltd.)
School Boy, 29in wing span—Topflite Models Ltd.
Super 60 Trainer, 60in wing span—Keil Kraft Ltd.
Tauri Multi Trainer, 57in wing span—Topflite Models Ltd.
(the larger models are more suitable for multi-channel operation and experimental work).

Control Systems

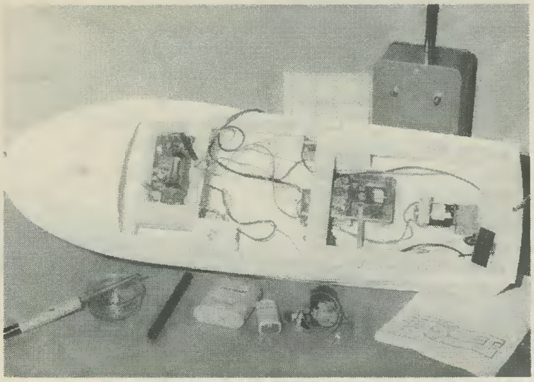
It is beyond the scope of this article to deal with the hundreds of different circuits in current use. Control systems generally can be broken down into three or four categories and of these the single channel carrier-on/carrier-off system (i.e., the bang-bang system referred to earlier) is still the most popular for simple radio control. The self-excited oscillator transmitter is also still fairly widely used but many enthusiasts are turning to crystal control to ensure frequency stability and to provide for some sort of "channel occupation". This would be difficult with self-excited oscillators, which are inclined to wander in frequency.

A variation of the carrier-on/carrier-off system is the use of single audio tone modulation whereby the tone is keyed on or off and superimposed on the carrier. This gives greater protection from interference. In more advanced "multi-channel" systems several modulating tones are used and up to twelve channels are practicable.

The carrier is demodulated at the receiver and the tones then used to operate "tuned reeds" or filters. The "reed" is electro-mechanically vibrated at the tone frequency and provides a "contact" for supplying a servo via a transistor or relay. Filters work in a similar manner but are essentially electrical as opposed to electro-mechanical and thus there are no moving parts to go wrong or be adjusted. The common practice with reed or filter systems is to use the channels in pairs, i.e. two for steering, two for engine control, and so on.



A Graupner steering servo. This can be driven by a single OC81 transistor



Layout of control equipment in the Chris Craft launch. The receiver is to the left, immediately after the bows. A Kinematic engine and steering servo is fitted just to the right of amidships, whilst the drive motor with integrated rudder and propeller is visible at the stern

Some enthusiasts favour the so called pulsing system which provides a form of proportional control whereby the rudder, for instance, can be moved "gradually" in either direction and held as required. This usually requires two channels (i.e. one for left and one for right rudder) and the general arrangement is to divide the pulse, frequency- or amplitude-wise, between the two channels. When the pulse mark-space ratio is 50–50 the signal is equal in both channels and the rudder is neutral. A ratio of 100 to 0 will therefore provide a rudder position to the limit in one direction whilst a ratio of 0 to 100 will provide a position to the limit in the opposite direction. Other ratios will provide intermediate positions.

The really true proportional system is also available but requires extremely complex circuitry and as such is at present very expensive. A true proportional system requires considerable power since the rudder must be held in any position or moved in either direction, and follow exactly the movement of the "steering" control at the transmitter. As in driving a car power must be provided to hold the steering whilst taking a corner or going round in a circle. With a model some form of "fail safe" operation is required (e.g. steering automatically restored to neutral if the radio or control system fails) and this is incorporated in most proportional systems.

Modern Servos

Servos are in many instances the stumbling block of all radio control enthusiasts for in most cases precision mechanics are called for if one is to enjoy reliable operation. Except in special cases it is not worth the time and effort called for to successfully turn out a steering servo like the one in the photograph shown here, particularly for model aircraft where compactness and light weight is of prime importance. Most servos now available can be directly controlled by transistors. In the main they consist of a miniature permanent magnet reversible electric motor (reversible by reversing the polarity of the supply) coupled to a built-in gear train with a ratio of some 300 or 400 to 1, thus allowing for slow and gradual movement of rudders, etc.

A considerable amount of power is developed through the gear train. The general method of control is by a low power transistor such as an OC81 whereby the motor is connected directly in the collector circuit. With one transistor the direction of rotation would of course be one way and a relay would have to be employed to reverse the connections to the motor in order to reverse direction. This can be overcome by using two transistors, each with its own h.t. supply, or by using a p.n.p.-n.p.n. arrangement whereby the direction of current depends on which transistor is being driven by the control signals. It is hoped to give more detailed circuitry for servo control in a later article but, to show the basic function, Fig. 1 is included here. In this diagram the motor is connected in series with the transistor which, normally, will be non-conducting. When the base is taken negative via the potentiometer (or a negative-going signal is applied) the transistor conducts and the motor turns. This type of circuitry can be applied in dozens of different ways and to many different forms of control. If all goes well, this and other techniques including receivers and transmitters, etc., will be the subject of more articles, all of which will be based on work now in progress and for which the "test bed" is a 4-foot long high speed motor cruiser. (See illustration.)

Receiving

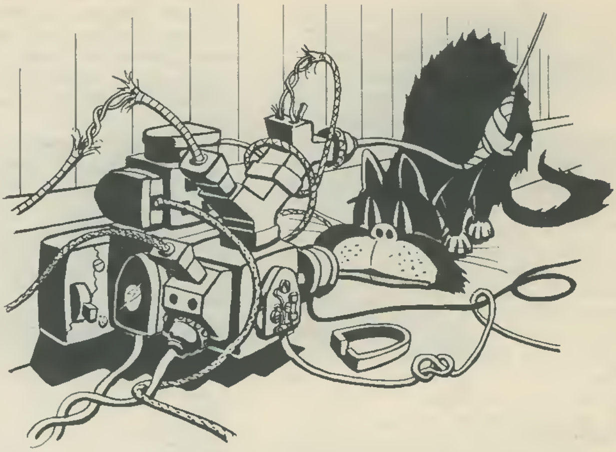
Finally, a few words about receivers. Among these the simple single channel types still employ a squegging valve oscillator-cum-detector, but they do at least make use of transistor d.c. amplifiers which in many instances do away with relays. For instance a transistor like the OC81 will happily drive a midget permanent magnet motor (current about 40–60mA for 4.5V h.t.). The Macgregor receiver used in the Chris Craft launch has an output transistor which will pass up to 500mA at 4.5V, more than sufficient to operate the Kinematic combined engine and steering servo.

The more advanced receivers, used mainly for multi-channel work, are superhets with crystal controlled local oscillators, to match the transmitter. These receivers are very expensive and an outfit including a 10 channel crystal controlled transmitter and superhet receiver can cost up to £125—whilst proportional can be double this figure, and in both cases servos are extra! Such equipments, however, are not beyond the scope of an experienced constructor.

Editor's Note

All the components and kits referred to in this article are available via retailers, and may be obtained at your local Model Shop.

In Your Workshop



When there's very little work to do and the August sun shines invitingly outside, what can be more understandable than the desire to take an afternoon off and go for a picnic in the country? This is exactly what Smithy the Serviceman, accompanied as always by his able assistant, Dick, sets out to do, although he finds it necessary to square his conscience by devoting at least part of the time to readers' hints!

"Ah, here it is," said Smithy. "Excellent!"

Emerging from the darkness of the trees, Smithy the Serviceman stopped and blinked in the bright August sunshine. In front of him lay a flat stretch of vivid green grassland, lightly shimmering as the air above it danced in the afternoon heat. There was the faint drone of bees and a lone butterfly, its wings a fluttering kaleidoscope of yellow, blue and scarlet, hovered over a cluster of Heart's Ease, or Love in Idleness.

"*Yet mark'd I where the bolt of Cupid fell:*
It fell upon a little western flower,
Before milk white, now purple with love's wound,
And maidens call it Love-in-idleness."

Thus, in "A Midsummer Night's Dream" spoke Oberon, as he planned to do the dirty by Titania. But Smithy's thoughts were not so vengeful, and he gazed ecstatically at his unsullied corner of the pastoral world.

A sound of heavy stumbling came from the wood, and Smithy suddenly remembered his companion.

"Hurry up, Dick," he called out. "This is an absolutely marvellous place. It's a bit of pure Nature, mate!"

The sound of crashing, of breaking twigs and of undergrowth being swept aside became louder.

"Where," came a despairing voice from the fastnesses of the wood, "the blooming heck are you?"

"Over here," shouted Smithy. "In a spot of the *real* countryside. Just like I told you."

There was silence for a moment as the denizen of the forest took an aural bearing on Smithy's voice, and then the sound of rending, splintering wood recommenced. It grew louder as Dick advanced and, after a while, an undercurrent of muttered comment, punctuated by abrupt inspirations of breath became clearly perceptible. "Cor blimey, talk about darkest Africa"—*puff, puff*—"you need a blooming tank to get through this lot"—*puff, puff*—"it's all right for *him*"—*puff, puff, splash*—"a flaming great ditch now; it'll be a ruddy tiger-trap next"—*puff, puff*—"let's take the afternoon off and have a picnic in the country, he says"—*puff, puff*—"I'd like to show *him* a bit of the country"—*puff, puff* . . .

It occurred to Smithy that all might not be entirely well with his assistant.

"Do you," he called out, "want any help?"

But Smithy's offer was too late, and a perspiring, bedraggled and mud-besmirched Dick came tottering out of the wood, staggering under the weight of two large suitcases. Dick dropped his twin burdens, collapsed heavily on the grass and turned a baleful eye upon the Serviceman.

A Few Tips

Smithy waited until his assistant had regained his breath.

"Now, just look around you," he said, an ostentatious sweep of his arm taking in the entire surroundings up to the horizon. "Wasn't it worth a bit of trouble getting to a really beautiful place like this?"

But Dick had no eyes for beauty.

"Two minutes' walk, you said," he snarled furiously. "It would just be two minutes' walk through the wood. *That's* what you said."

"Well," said Smithy soothingly. "It might have been a bit longer than that. Still, *I* got through in about a quarter of an hour."

"Of course you did," fumed Dick, "after you'd conned me into carrying these two great heavy suitcases for you."

"I brought the cases down *to* the wood."

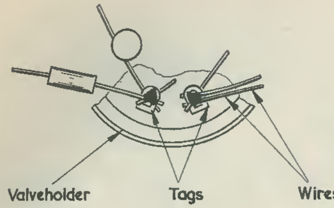
"Ye gods," snorted Dick. "I should jolly well hope so, seeing that all you had to do was to put them in the boot of the car. What's in them, anyway?"

"It's the stuff for the picnic," replied Smithy. "Food and that."

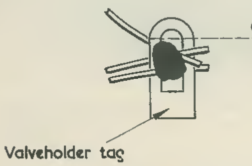
"*Food?*" queried Dick. "Are you sure you haven't got half the mains transformer stock from the Workshop in them as well?"

"Funnily enough," said Smithy, "there *are* a few things from the Workshop in them."

Under the glowering eye of his



(a)



(b)

Fig. 1 (a). Valveholder tags frequently have rectangular apertures, as shown here (b). When stripping down equipment having such valveholders, it is helpful to cut off the top of the tag. Slight upward pressure from the soldering iron then causes the wires to slide out quickly and easily

assistant, Smithy sat down on the grass, pulled one of the suitcases towards him, opened it and produced a cardboard portfolio.

"And what," asked Dick belligerently, "have you got there?"

"Something," replied Smithy, "that you've been pestering me about for ages. Readers' hints! At the last moment, it suddenly occurred to me that it would be an excellent idea to take them along with us. We could have a look at them, then, before getting down to our tea. Besides, we've only taken the afternoon off because things are quiet at the Workshop. We're on Workshop time so we should still be doing *something* technical!"

A flash of interest momentarily replaced the hostility in Dick's expression.

"Well," he conceded, "I suppose you've got something there."

He lay down on his back. The lone butterfly, which had retreated at his noisy entrance, returned to the scene, hovered over him, then returned to its Heart's Ease.

"Well, I'm dashed," exclaimed Dick, turning over and resting his weight on one elbow as he gazed at the colourful creature, "that's a Swallow-tail!"

"A what?"

"A Swallow-tail," repeated Dick. "You don't see many of those around this part of the world."

The incident of the butterfly seemed to have broken the chain of discontent in Dick's mind, and he redirected his attention to the Serviceman.

"Let's get started," he suggested, "on those hints. You know I'm always interested in them."

"As you like," replied Smithy, obviously relieved at Dick's return to an amenable frame of mind. "Now, let's see what we've got here."

Smithy opened the flap of the portfolio and extracted a letter.

"Ah," he remarked, "now here's a good one to start off the proceedings. It's an idea for making a super-efficient soldering iron bit for work on small transistor layouts and things like that. What you do is get an ordinary copper bit and braze a small bit of silver on to it. The silver then forms the new working surface. The writer of the letter states that the idea works like a charm, especially with small work. I should imagine it would, too, as the silver would be far less liable to oxidise than does copper. The writer says he uses a bit modified in this manner for special jobs, and employs a normal copper bit for ordinary work. This is with a 25 watt iron, incidentally, which has interchangeable bits."

"That's a new one on me," confessed Dick, "but it's one I'd certainly like to try out."

"Apparently," replied Smithy, looking at the letter once more, "it's quite an oldie. Still, it's certainly new to me, and I think it's well worth passing on."

Smithy extracted another letter.

"Now this one," he remarked, "is quite a simple idea, but it's one of those which can save you a lot of time and trouble. It's particularly useful if you're stripping down surplus equipment and stuff like that. You very often have B9G, B7G or B8A valveholders in which the holes in the tags are rectangular in shape. If several wires have been passed through one of these holes they can often be very difficult to remove. (Fig. 1 (*a*).) This is particularly the case when one or more of the wires is twisted around the tag. So you commence by nipping off the top end of the tag (Fig. 1 (*b*)), after which slight pressure from the soldering iron towards the top causes all the wires to slide off quite easily. The result is that components connected to the valveholder are readily salvaged, no harm is done due to excessive heat, and a considerable amount of time is saved."

"What," asked Dick, "about the valveholder?"

"Well, that will be O.K. too," replied Smithy. "You can still use it again, if you want to, although its tags will be a wee bit shorter and jagged-looking, of course."

Smithy looked through the portfolio and extracted a third letter.

"Now here," he announced, settling himself more comfortably on the grass, "is quite a knobby scheme. The idea is for a simple home-made press-button switch which can be knocked up in a few minutes at negligible cost. Although it uses commonplace components the writer of the letter says that it's no worse, so far as reliability of contact is concerned, than such simple commercial switches as are found on a torch. The small size makes it particularly suitable for transistor circuits, and the writer has played about with the idea of adapting it for the keys of a toy electronic organ. The idea came into being when a small press-button switch was needed, as an afterthought, with a miniature circuit. An entire range of toggle, press and slide switches was checked but all were found to be too large. The writer solved the problem by using a small safety pin 1 inch long. The pointed end is bent to a hook with a pair of round-nosed pliers, and this hook and the centre loop are anchored to the insulated board on which the other components are fitted by means of 8BA nuts and bolts. There's a diagram in the letter illustrating all this."

Smithy leaned over and showed the diagram to Dick who, shading his eyes from the sun, examined it with interest. (Fig. 2.)

"The head of the pin," Smithy continued, "is bent over so that it protrudes through a hole in the front panel, and it is then covered with a blob of opaque coloured polystyrene cement. This disguises the origin of the switch and can even provide insulation if the front panel is made of metal. All that is needed to operate the switch is to press the head inwards, whereupon contact is made to a third bolt."

"The diagram in that letter," remarked Dick, "also showed the pin mounted to the front panel itself."

"That's right," agreed Smithy. "This is an alternative approach which allows the pin to be mounted direct to the back of an insulated front panel. In this case the head protrudes through a slot and you operate it by moving it sideways."

"That *is* neat, you know," said

Dick appreciatively. "The contact is quite good enough for most low-current low-voltage transistor circuits, and things like that. Also, there'll be a self-cleaning action because there's almost certain to be some rubbing between the surface of the pin and the bolt it makes contact to."

"Exactly," agreed Smithy. "And don't forget that a packet of small safety pins is a darned sight cheaper than the equivalent number of miniature switches!"

Smithy once more examined his stock of letters.

"I've got a letter here," he announced, "which has *two* hints in it. And the first of these has to do with iron dust cores jamming or breaking in threaded plastic coil formers."

"I still keep getting those," commented Dick frowning. "Murder, they are."

"They *can* be difficult," agreed Smithy, "but don't forget that iron dust cores get broken most often because people use incorrect trimming tools. Anyway, let's get down to the hint, which assumes that the core is already cracked or otherwise jammed, and that it's impossible to move it. The hint suggests that the first thing to do is to get the jammed core out by disintegrating it with a jeweller's screwdriver or similar instrument, and then shaking out the loose pieces. A process of this sort usually results in the thread of the former becoming burred, whereupon any attempt at screwing in a new core only results in that one jamming too, and you're back to Square One again. The solution is to clamp the new core in a pair of pliers or tweezers and to file off the thread until the core slides easily into the former. The modified core is then screwed into the former together with a thin piece of elastic. Sufficient grip is obtained to enable alignment to be carried out and the core is finally held in place with a suitable sealing compound."

Printed Circuit Board

Dick stretched himself luxuriantly in the heat of the sun.

"That's a good scheme," he remarked. "These jamming cores can be a dickens of a nuisance at times."

"They can, indeed," agreed Smithy. "But let's have a look at the second hint in this letter. This deals with clearing the solder out of the holes in a printed circuit board after a component has been removed. What you do is to heat the solder around the hole then force a *wooden* cocktail stick into the hole while the solder is still hot. This method requires the minimum application of heat and there is, in consequence, little risk of the conductor lifting from the board."

"Cocktail sticks," chuckled Dick. "It's surprising how many out-of-the-way gubbinses find uses in radio and TV servicing."

"I've got another one here," replied Smithy, "and the out-of-the-way gubbins that's used is a wooden lollipop stick!"

"A lollipop stick?"

"A lollipop stick," confirmed Smithy. "And a jolly good idea it is, too. You cut the end of the stick to the appropriate shape and dimensions (Fig. 3), after which it becomes just the job for adjusting iron dust cores with screwdriver slots. So from now on, Dick, you're going to have to increase your intake of lollipops, so that I can get a decent supply of trimming tools available in the Workshop!"

"Lollipops," repeated Dick thoughtfully. "That reminds me, Smithy, how about us having a start on this scoff you've brought along?"

He rolled over on the grass, turning towards the Serviceman.

"I must confess," he continued, "that I do appreciate your organising a break from the Workshop. And especially during the firm's time. It's a pity, though, that it had to include," his brow darkened at the thought, "what you so lightly referred to as a two-minute walk through the woods."

"Well," said Smithy defensively, "it's a long time since I last came here, and I may have made a slight mistake about the distance."

He leaned over and pulled the second suitcase towards him.

"Anyway," he continued brightly, as he opened the case, "let's get weaving on the most important thing. Tea!"

Smithy let the lid of the case fall back on to the grass and reverently placed its contents in a neat line on the grass. An expression of incredulity gradually spread over Dick's face.

"What on earth," he stuttered disbelievingly, "are all those things for?"

"These," said Smithy proudly, "are the makings. This, for instance, is the primus stove. It was made in Sweden, my boy, where all the best primus stoves come from."

"All the primus stoves I've ever seen," interrupted Dick, "are made of brass."

"So is this one," replied Smithy. "It may be a wee bit black in places, but that's only because it's given a lifetime of meritorious service."

"And what's that tin?"

"That's the tin I keep the pricker in," explained Smithy. "For pricking the jet when it gets bunged up."

"And that?"

"A bottle of paraffin, my lad," said Smithy, "for running the primus stove."

"And the other bottle?"

"That's petrol, my boy," answered Smithy, "for priming it up with."

"Ye gods," commented Dick, aghast. "All I can say is that it's a jolly good thing the law didn't catch me just now when I was carrying this little lot. I'd have been run in as an agent of the I.R.A. quicker than that. In any case, it's a miracle I didn't *explode* going through the darned wood with all that stuff!"

Smithy turned to the second suitcase and removed two further objects.

"Don't tell me," said Dick indignantly, "that I lugged *those* hulking great things through the wood as well!"

"These," said Smithy with dignity, as he placed the objects carefully on the grass, "are Winchester quart bottles. They were used in the Workshop before you were even born!"

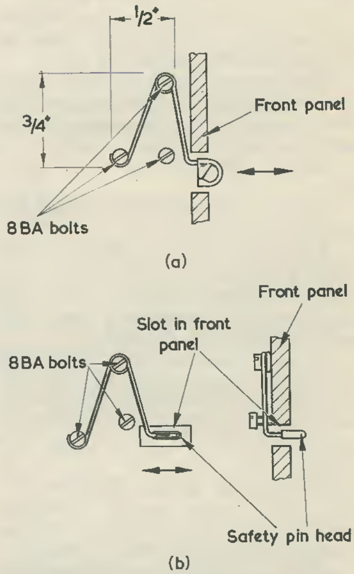


Fig. 2 (a). A simple switch made up from a 1in safety pin. The 8BA bolts are mounted on an insulated panel which is at right angles to the front panel
(b). An alternative version, in which the switch is mounted directly on to the back of the front panel

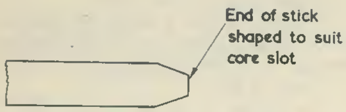


Fig. 3. A familiar object in an unusual application. With its end suitably shaped, a flat wooden lollipop stick makes an excellent trimming tool for iron dust cores!

"Blimey," said Dick, a note of reluctant respect creeping into his voice at the antiquity of the bottles, "and what were they used for?"

"For holding sulphuric acid," replied Smithy. "That was in the days when people used to bring their 2-volt accumulators round to have them charged."

"What's in them now?"

"Water," said Smithy. "Water for the tea."

"Well," snorted Dick, as the memory of his struggle through the woods arose once more. "You certainly made sure you weren't going to go short of it."

"It is," mildly remarked Smithy in reply, "rather a hot day, you know. And I *do* like a cup of tea."

"That," said Dick, looking bitterly at the heavy glass bottles, "must be the understatement of the year."

But Smithy was already busy coaxing the primus stove into action. Very soon, it commenced to hiss away merrily.

Smithy opened the other suitcase.

"Oh no," moaned Dick. "Not the Workshop kettle!"

But Smithy was not done yet, and Dick's groans were repeated as an all-too-familiar cracked china cup and battered enamel mug took their place alongside the kettle.

"I can't," wailed Dick, "take you *anywhere*. Last August you showed me up on the beach with all the Workshop crocks, and blow me if you don't go and do it again this year!"

"Nonsense," replied Smithy briskly. "All these utensils represent capital expenditure. They must be exploited to the full."

Dick gave up the unequal struggle, and watched helplessly as Smithy loosened the glass stopper on one of the Winchester quart bottles, filled the kettle and placed it on the primus stove.

"Shall we," said Smithy brightly, "have a go at some more of these readers' hints whilst we're waiting for the water to boil?"

"We might as well," grunted Dick ungraciously. "I *did* think we were going out into the country today, but the way things are going we might as well have brought a strip of turf into the Workshop and sat down on that instead!"

"The next hint," said Smithy breezily, ignoring his assistant's complaints, "concerns a method of checking stabilised h.t. power packs, or any other sort of h.t. power pack come to think of it, without using high wattage resistors."

"Oh yes," said Dick, his interest rising, "how do you do that, then?"

"By using," replied Smithy, "a high power valve instead. The writer of the letter had completed a stabilised h.t. power pack, but had no high voltage resistors available to check it with. So he used a high power valve instead, the actual type employed being an 807. Since the power supply gave a -100 volt output which could be used for bias, it was possible to rig up the valve very quickly in quite a simple circuit."

Smithy showed Dick the circuit diagram which accompanied the letter (Fig. 4).

"I can see what's been done," commented Dick. "The 807 heater is run from the power supply heater output, and the grid is hitched to a pot which enables its voltage to be controlled."

"That's right," confirmed Smithy. "The pot and the fixed resistor allow any bias voltage from about -50 to zero to be obtained, and the circuit forms a very convenient method of providing a variable load. Also included is a low value resistor in series with the screen-grid. The main point to look out for when using the circuit is to ensure that the maximum anode dissipation figure for the valve is not exceeded. The valve is not, in this case, handling a signal, and so anode dissipation is equal to anode voltage times anode current. Both of these are monitored by the two meters in the circuit."

"The screen-grid current," objected Dick, "passes through the same meter as does the anode current."

"True enough," agreed Smithy. "But in a simple application of this nature it would be best to work to anode dissipation on its own."

"What's the maximum anode dissipation for the 807?"

"No less," replied Smithy, "than 25 watts. So, using an 807 or any similar valve in a circuit of this type enables you to get quite a high level of dissipation which can be very easily controlled."

Smithy scratched absently at his leg, and selected yet another letter.

"This is another simple device," he remarked, "but I'm sure that quite a few people will find it useful. It consists of an armchair remote control for the radio or the telly."

Smithy examined the letter more closely.

"What you have," he said, "are a 250Ω pot and an on-off switch mounted in a small insulated box. This forms the remote point and is positioned at the armchair. It is coupled to the receiver by way of a 4-core flexible cable terminated in a 4-way plug. In the writer's set-up the 4-way plug consists, actually, of two 2-pin 2-amp flat flex connectors strappped together. The two plugs fit into appropriate sockets on the back of the receiver, whereupon the switch in the box is in series with the mains input circuit of the receiver and the pot is in series with the loudspeaker transformer secondary circuit. It's all shown here in a circuit diagram."

Smithy once more leaned over towards his assistant. Carefully, Dick examined the circuit (Fig. 5 (*a*)).

"Well," said Dick, "that all seems easy enough. The pot controls

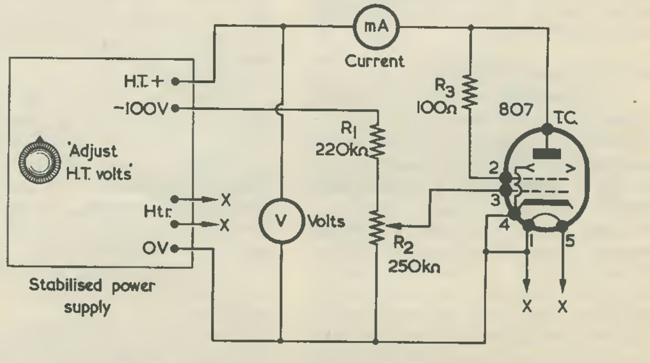


Fig. 4. Using an 807 as a variable load for testing an h.t. power supply unit

the volume from the speaker and the switch turns the set on and off."

He paused for a moment.

"What happens," he continued, "when you pull out the plugs going to the armchair control unit? Won't you then break the mains circuit and the loudspeaker circuit in the receiver?"

"Not a bit of it," replied Smithy. "The sockets used are special shorting types which short-circuit their contacts when the plugs are removed. Those used by the writer were 'Walsall' 2-amp 2-pin sockets and you should be able to obtain these through most electrical retailers. If not, all you need are a spare pair of plugs with their pins shorted over internally. When you remove the armchair control plugs you then insert the spare ones, and the receiver continues to function normally."

"Isn't it," asked Dick as another thought struck him, "rather naughty to insert resistance between the output transformer secondary and the speaker? Because of matching and all that?"

"It is a bit, perhaps," admitted Smithy. "It would probably be best to set the volume on the receiver just at the maximum point you're liable to want, whereupon it won't be necessary to insert too much resistance at the armchair control position for normal listening. It won't matter a great deal if you insert a *lot* of resistance, with a bit of consequent distortion, if you want the set turned down for conversation or when the commercials come on."

"I don't know about that," said Dick. "The commercials are the only things I look at these days!"

"Another point," continued Smithy, absently scratching his leg once more, "is that there are liable to be some pretty hefty a.f. voltages across the speaker transformer primary when the remote potentiometer inserts maximum resistance into circuit, because the secondary will then be very lightly loaded indeed. So I, myself, would add a fixed resistor permanently across the speaker transformer secondary. (Fig. 5 (*b*)). For a 3Ω speaker, this additional resistor could be of the order of 10Ω at 1 watt. It won't make much difference to normal receiver operation, but it *will* help to prevent excessively high audio voltages appearing across the primary. And, finally, don't forget that the circuits the armchair control plugs into can have some dangerously high potentials above earth on them. So all your wiring, plugs, sockets and insulation must be fully adequate for such potentials."

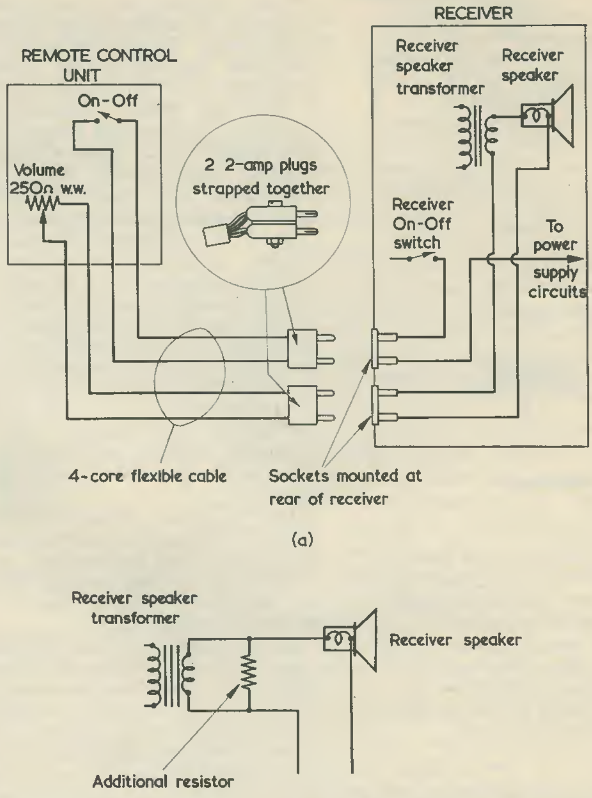


Fig. 5 (a). An armchair remote control unit for a television or radio receiver (b). To ensure adequate loading of the speaker transformer in the receiver at low volume levels, it would be preferable to connect an additional fixed resistor of appropriate value across the secondary

Tea Up

At that instant a low whistle broke the peaceful quiet of the glade. It soon intensified to a piercing shriek, and a cloud of steam appeared above the primus stove.

"Blimey," commented Dick, "just like home!"

Under Smithy's instructions, Dick quickly prepared the tea and it was not long before the Serviceman was quaffing great draughts of the life-saving fluid. The butterfly had disappeared when the kettle gave voice but it now returned. It seemed to be fascinated by the strange pair who had violated its sanctuary and who were engaged on such mysterious affairs.

"That Swallow-tail," commented Dick, " is back with us again."

"You seem," remarked Smithy, as he drank deeply from the battered enamel mug in his hand, "to be rather clued-up on insects."

"I have," said Dick modestly, "picked up one or two facts about them."

"I wish you knew something about wood-lice."

"Wood-lice?"

"That's right," confirmed Smithy. "Wood-lice. There appears to have been a veritable plague of them over the last few years. So far as I can see, they've just about taken over my garage!"

"There do," admitted Dick, "seem to be rather a lot of them around these days."

"They're darned cheeky, too," continued Smithy, indignantly. "They march into my garage as though they own the darned place. They don't know their way around, either, and they go crashing into things and bumping into each other. A proper pest, they are!"

A malevolent expression came

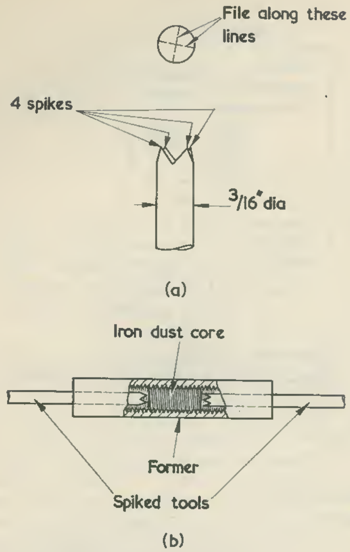


Fig. 6 (a). Filing across the end of a mild steel rod along the dashed lines indicated causes four spikes to be formed
(b). Two tools, prepared as in (a), may be used to gain a purchase on a jammed iron dust core and enable it to be screwed out of the former

over his face.

"Still," he said vindictively, "I've got an answer to them now."

"What's that?"

"I Hoover them!"

"You *what*?"

"I Hoover them," repeated Smithy, the fire of satisfied vengeance glowing in his eye. "I run a mains lead out from the house and I go around the garage with the vacuum cleaner. You ought to hear them clattering against the inside of the pipe as they go up it!"

"You revolting old devil," gasped the appalled Dick. "What on earth have the poor little wood-lice done to you?"

"They have intruded," replied Smithy, "on my property. Which means war to the death; and in such a war I intend to take full advantage of every weapon that modern science has made available to me!"

Dick shuddered.

"Charming," he commented. "I should by now be thinking about something to eat, but what you've just said has put me right off."

Yet again, Smithy abstractedly scratched himself.

"You'll soon feel hungry again when you see what I've brought," he remarked confidently. "It's all in a paper bag in that suitcase."

Dick reached into the suitcase indicated by Smithy and removed a large paper bag. He opened it out and looked at its contents doubtfully.

"It's all there," said Smithy proudly. "If you look through that lot, you'll find four chocolate eclairs, four cream puffs, two meringues, six cream doughnuts and six slices of chocolate log!"

It is a convention to use the written term "ugh" in dialogue to indicate aversion, even though the uttered sound is usually very different. In this case, however, Dick produced a sound which exactly matched its written counterpart.

"Ugh," said Dick, "ugh!"

"What's up?"

"What's up?" queried Dick indignantly. "Have you seen them? They're all squashed up and melted together."

Smithy leaned forward and examined the multi-coloured concoction which Dick indicated.

"There's nothing wrong there," he snorted. "They're just a bit mixed up, that's all."

He extended his hand, extracted some 80% of a cream puff, together with 15% chocolate log and 5% meringue, and carefully transferred this amalgam to his mouth. After some moments of what was obviously completely enjoyable mastication, he swallowed, and then proceeded to meticulously lick his fingers. He finished by picking up his mug and draining it with one gulp.

"Ah," he remarked. "Now that was *really* nice."

"Can we," asked Dick in a tone of utter revulsion, "proceed with another reader's hint?"

"By all means," replied Smithy cheerfully, picking up his portfolio once more. "I'll see what's next in the list."

Gate-Crashers

Subconsciously, Dick had been aware that Smithy had been scratching his leg quite industriously from time to time, and the matter rose to the surface of his attention when he saw the Serviceman repeat the action once more. Perhaps it was the fact that, this time, Smithy wriggled uncomfortably as well that had caught Dick's conscious eye. He decided, however, to dismiss the phenomenon as one which had no immediate interest, and concentrated instead on the next letter which Smithy had produced.

"This one," said Smithy, "brings us back to the old iron dust cores again. Although, in this instance, it's an idea for removing broken or jammed cores by unscrewing them. What you do is make up two similar tools from $\frac{3}{16}$in mild steel rod. You file two grooves at right angles at one end of each rod, giving you four equally-spaced spikes. (Fig. 6 (*a*)). You then insert one tool into each end of the former so that the spikes are applied to the core (Fig. 6 (*b*)), press inwards and turn. This should enable you to unscrew all but the most solidly jammed cores you're ever liable to encounter."

"Well, that *is* a good idea," remarked Dick appreciatively. "I can see myself knocking up a couple of those little tools myself when I get back to the Workshop."

"Yes," agreed Smithy, "they should be very helpful, too. Hullo, what's happening to those cakes of mine?"

Dick looked at the contents of Smithy's paper bag. Already, several dozen wasps were crawling avidly over this unexpected rich booty, and reinforcements were arriving at every second. Some of the wasps, detecting traces of sugar on Smithy's fingers, flew over to investigate. Smithy waved them away nervously.

"This," chuckled Dick, "must be the Revenge of the Wood-lice. The insect world has declared war on you!"

"I wish," snapped Smithy, "you'd stop trying to be funny and do something to keep these wasps away from me. Yerruff!"

With which singular utterance, Smithy suddenly sprang to his feet and proceeded to slap wildly at his nether regions. Dick watched the Serviceman with great interest, and suddenly remembered his previous unaccountable actions. Giving the wasps a wide berth he got up and examined the ground on which Smithy had been sitting.

"Well," he laughed, "if you *will* choose to sit on an ant-hill, you can hardly be surprised if its inhabitants come out to investigate!"

Going Home

Delicacy forces us to draw a veil over the scenes which followed, these including such dramatic episodes as the Retreat from the Wasps and the even more spectacular De-Anting of Smithy and his Appurtenances. However, it would be a pity to record a dismal ending to a day which, at the start, was so full of promise. Indeed, there is no need to do so, and the dusk found the pair motoring happily homewards in Smithy's car complete with a boot-load of two suitcases, sundry culinary effects and two empty Winchester quart bottles.

"Well," said Dick ruminatively, as Smithy changed up into top and attacked an invitingly empty stretch of straight road. "It was a bit tough at first today but after that everything went fine. I don't think I've laughed so much for ages!"

"It was," chuckled Smithy, in spite of himself, "a bit of a gag, I must admit. Anyway, I'm quite certain that we won't go back to *that* particular place if we have a quiet afternoon next August."

"Won't we? Then where will we go?"

"We'll stay," replied Smithy firmly, "in the safest place I know—the Workshop!"

Editor's Note

The hints described in this episode of "In Your Workshop" were submitted, in the order in which they appear, by G. M. Watson, W. Smith, T. E. Millsom, M. E. Miller, G. Maynard, J. R. Ault, J. Pickering and J. M. Colles. Further hints for this feature are welcomed and payment is made for all that are published.

"You Can't Win 'Em All"

By "W.S."

Just to show that things don't always go right in the realm of radio and television, we publish the following cautionary tale. The story is completely true in all details, but for obvious reasons we are keeping our contributor's name a very close secret!

A LATE LAMENTED RELATIVE OF MINE HAD A MOST endearing feature—he never bought anything but the best. When television came to my area, around 1952, he forthwith bought a magnificent TV set costing 130 guineas, and I must confess it was worth it, for it gave no trouble whatever until the I.T.A. opened up. The converter which was attached to the back of the set just didn't have enough gain to deal with the fringe signal available and so—about 1958, I think—one of the more modern sets became a necessity. The £1 allowance for the old set really surprised me. Ignoring the twenty odd valves, the 10in loudspeaker, etc., I reckoned there was enough walnut in the cabinet (with doors) to meet my fuel requirements for a considerable time and in any case, my house was better located for TV signals than his. So (to cut a long story short) I acquired the set. (Free of charge, actually—I'm from north of the border.) I should add that with minor adjustments and replacements the set still continues to function extremely satisfactorily.

I live (alone!) in a semi-detached house and as my neighbour, at the time I acquired the aforesaid set, already had a television aerial fixed to a long pole in his back garden, I decided to do likewise and rigged up B.B.C. and I.T.A. aerials on a steel pole about thirty feet long. To do this singlehanded for the first time, at least, was not very easy, but anyway I succeeded and was rewarded with excellent B.B.C. reception. But there was little joy with the I.T.A. After much deliberation I decided that the aerial was somehow at fault and on going out to work the morning after, I noticed that every I.T.A. aerial in the district had an upward tilt of about 15 degrees or so, and came to the conclusion that the slight downward tilt of mine was probably the cause of the poor reception.

By the time I got back from work it was dark, but I had evolved a simple plan. I would attach a heavy weight to a piece of garden twine and throw it over the reflector end of the aerial, then holding both ends of the twine, give a good hard tug. Nothing could be simpler. With torch in left hand focused thirty feet up, I took careful aim and let fly.

Surprise, surprise. The lead weight didn't come down at all, and further investigation revealed that it had missed its target by a considerable margin and had gone over the two telephone wires to my neighbour's house. It had also bound the twine round and round the wires about a dozen times, and no amount of tugging was of the least avail. Distant tinklings and the sound of raised voices were faintly audible in the darkness, and one thing was certain—something had to be done quickly.

With confidence born of despair, I lashed together a fifteen foot spar of wood I happened to have for repairing the garage, a rake, a push-hoe and a ten foot telescopic dinghy mast. With some ingenuity I attached a razor blade to the latter, and, torch in mouth, I attempted to wield this unwieldy implement over the rather large hedge separating the two gardens. The voices and the tinklings still continued from the darkness and I could now make out the occasional rude word. By now, too, although the night was cold, sweat was trickling from my chin.

It didn't take me long to realise that the razor blade idea was about as useful as a sporran full of haggis, but as has happened before, my innate genius came to the rescue. Replacing the razor blade by a large duster, which I had dipped in petrol, I thoroughly soaked the offending binding, then lit them both. The conflagration floodlit the entire neighbourhood.

Success was instantaneous but short-lived. Both telephone wires melted.

I leave to your imagination my reply the next morning to my neighbour's opening greeting: "The strangest thing happened to my 'phone last night . . ."

(Postscript: A Band III pre-amplifier was needed to solve the problem of the poor I.T.A. reception.)

Cover Feature

Phototransistor Sports Timer

By JOHN G. DEW, B.Sc.

Light-beam controlled timer for Car Rallies and other events.

THE AUTHOR WAS RECENTLY REQUESTED BY members of a car club to build an electronic timer for timing rally and sprint events. Since the cost of commercially available timers was in the neighbourhood of £100 it was thought that perhaps the author might be able to save the club some money!

The requirements were:
(*a*) starting and stopping the timing process by the passage of a car through a beam of light, the same beam being used for start and finish,
(*b*) indication of the time interval to 1/10th of a second, accurate to $\pm\frac{1}{2}$ second over periods up to 5 minutes,
(*c*) operation from a 12 volt car battery.

The last requirement ruled out the use of counting tubes like the "Dekatron" or "Numicator" for the display, as a a.c. d.c. converter for the high tension supply would then be necessary. This led to the choice of transistorised circuitry and an electro-mechanical counter. A block circuit diagram of the final design is shown in Fig. 1, and the theoretical circuit in Figs. 2 and 3. The circuit will be discussed stage by stage.

Phototransistor

There are many methods of detecting the presence of light: photo-voltaic, photo-resistive and photo-emissive devices can all be used. The most useful in the present situation, however, is the phototransistor, which operates on the first principle. Normally transistors are painted black, or have a metal case, which prevents the entry of light; a phototransistor is left unpainted, and furthermore the silica gel inside the glass is made as transparent as possible. The result is that light can fall on the base layer of the transistor assembly, where free holes and electrons are liberated. These diffuse through the base, producing in effect a base-emitter current, and so, when a collector voltage is applied, an amplified collector-emitter current can flow.

An output signal may be obtained by placing

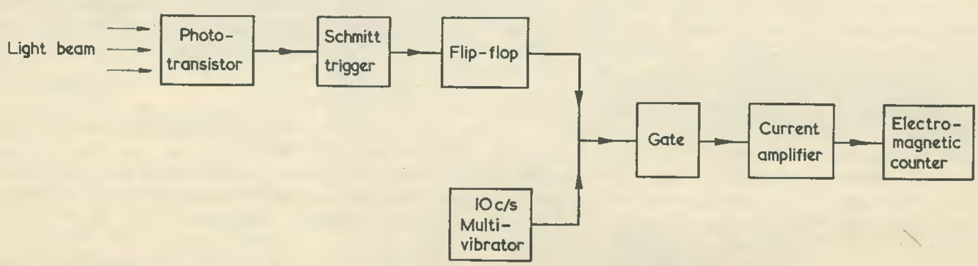


Fig. 1. Block diagram of the event timer

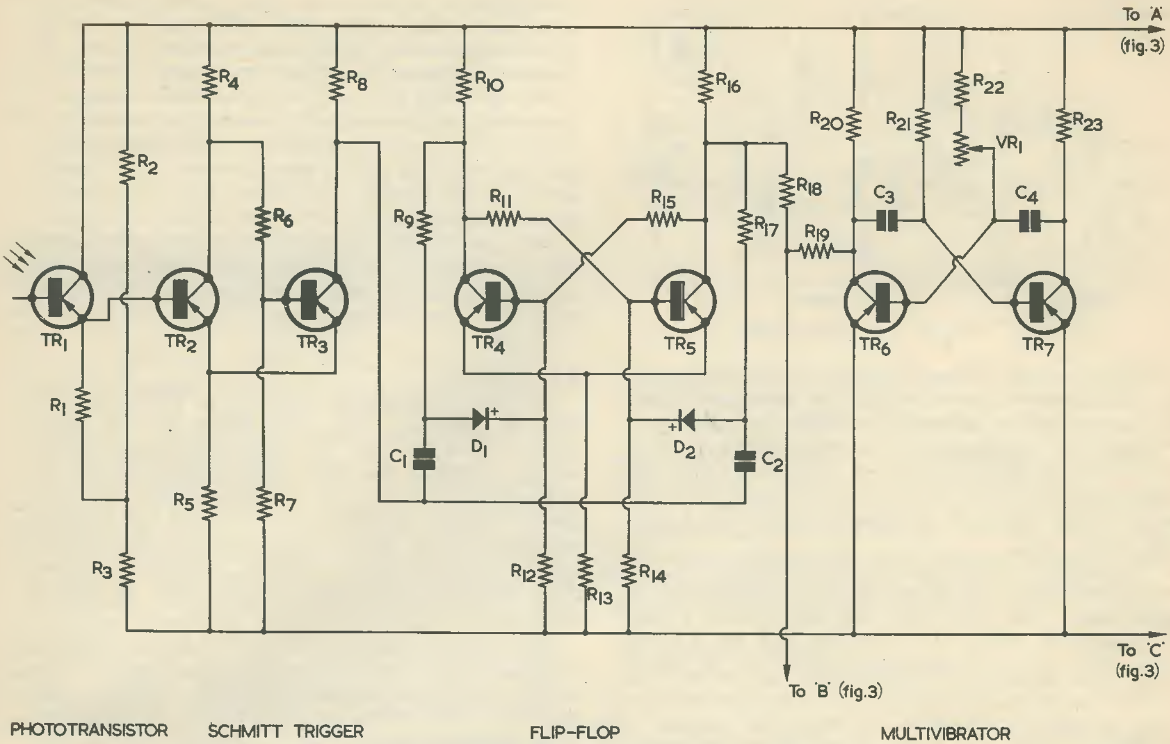


Fig. 2. The input circuits and 10 c/s oscillator

Components List

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

R_1	10kΩ			
R_2	4.7kΩ			
R_3	470Ω			
R_4	2.7kΩ			
R_5	1kΩ	R_{19}	10kΩ	
R_6	10kΩ	R_{20}	4.7kΩ	
R_7	10kΩ	R_{21}	82k	High Stability
R_8	2.7kΩ	R_{22}	82k	(see text)
R_9	33kΩ	R_{23}	4.7kΩ	
R_{10}	1kΩ	R_{24}	47Ω $\frac{1}{2}$ watt	
R_{11}	2.7kΩ	R_{25}	120Ω	
R_{12}	10kΩ	R_{26}	47Ω	
R_{13}	470Ω	R_{27}	3.3kΩ	
R_{14}	10kΩ	VR_1	10kΩ carbon, linear	
R_{15}	2.7kΩ	VR_2	500Ω preset	
R_{16}	1kΩ			
R_{17}	33kΩ			
R_{18}	10kΩ			

Capacitors
- C_1 0.05μF paper, 150V wkg.
- C_2 0.05μF paper, 150V wkg.
- C_3 1μF, 150V wkg. (see text)
- C_4 1μF, 150V wkg. (see text)

Semiconductors
- TR_1 OCP71 (see text)
- TR_2, TR_3, TR_4 OC70, OC71, MAT120, "red spot" or almost any low power transistor with a reasonable current gain
- TR_6, TR_7 OC200, OC201, 2S302 (silicon)
- TR_8 OC139, OC140, XA701 (n-p-n)
- TR_9 OC72, OC81
- TR_{10} XC141, OC35, GET573 (power)
- TR_{11} Any general purpose type
- D_1, D_2, D_3 OA70, OA81
- Z_1 VR9-B, or any 9V zener diode capable of 1 watt dissipation

Battery
- B_1 12V car battery

Switches
- S_1, S_2 On-off toggle

Counter
Type 100D, with 4.1Ω coil (Available from Service Trading Co., 47–49 High Street, Kingston, Surrey)

Meter
- M_1 0–10mA f.s.d.

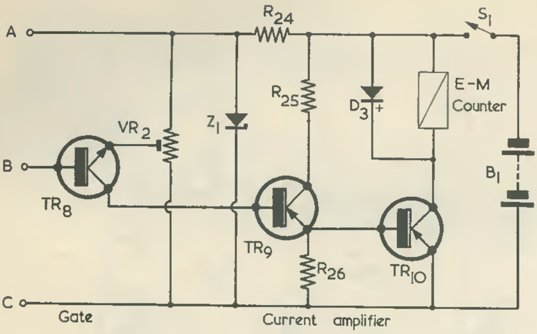


Fig. 3. The gate and counter stages

a resistance in the collector circuit or, more unusually, in the emitter circuit. Since the equivalent base current generator has infinite impedance the input "signal" is unaffected by emitter feedback, and so no loss of gain occurs. In the present case the signal is taken from the emitter, as a positive-going signal was required on cutting the light beam. See Fig. 2.

It should be noted that the recommended OCP71 phototransistor is simply an OC71 with an unpainted glass case. However, only the early OC71's had a translucent filling; later models had an opaque blue gel, and later still they were put in metal cans.

Schmitt Trigger

It was felt that "squaring up" of the phototransistor output was required as, otherwise, slowly moving cars might fail to operate the timer. A Schmitt trigger was therefore employed, consisting of transistors TR_2 and TR_3 of Fig. 2. Normally, the phototransistor is is illuminated, emitter current flows and the base of TR_2 is held negative. Hence TR_2 conducts heavily and, by virtue of the cross-coupling resistor R_6, TR_3 is held non-conducting. However, if the illumination is cut off, TR_1 ceases to conduct, the current in TR_2 falls and TR_3 can conduct. As there is emitter coupling (R_5) in addition to cross-coupling, the circuit becomes

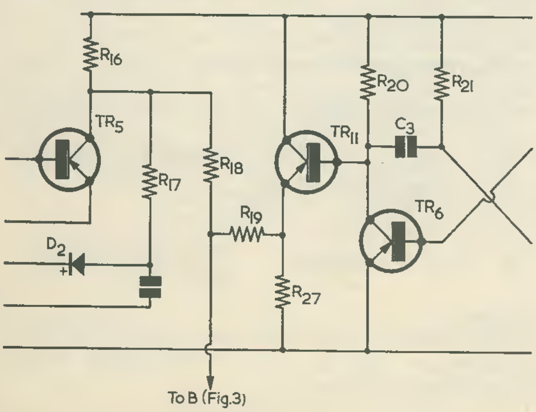


Fig. 4. Adding a buffer stage between TR_6 and the gate circuit

unstable and takes up its other stable state; TR_2 cut off and TR_3 conducting. If TR_1 is illuminated again the reverse procedure occurs. Thus the Schmitt trigger acts as an electronic switch, switching "off" when the base of TR_2 is less than about 2.4 volts negative, and "on" when it is more than about 3.3 volts negative. The difference between the two values is due to the "hysteresis" or "back-lash" of the circuit, but is not important in the present application.

The output signal, taken from the collector of TR_3, consists of a positive-going step when the illumination of TR_1 is cut off, and a negative-going step when it is re-illuminated.

The Flip-Flop

To the quick-minded reader a difficulty may now be obvious. The light beam will be interrupted once to start the timer, and interrupted again to stop it, but this will produce two similar outputs from TR_3, one of which must start the timer and one of which must stop it. A "divide by two" circuit is thus necessary, the mechanical analogy of which is a switch which is pressed once to switch on, and pressed again to switch off.

The circuit used to perform this function is the "flip-flop", or bistable, circuit. A glance at the circuit, which comprises TR_4, TR_5 and the associated components, is sufficient to indicate that it is entirely symmetrical in appearance, and will have two stable states; either TR_4 conducting and TR_5 cut off, or vice versa. (This circuit is used a great deal in computers, where the two stable states can represent the two binary numbers 0 and 1.) Since the circuit is symmetrical an input pulse would have the same effect on each "half", causing no change at all, were it not for the presence of the diodes D_1 and D_2.

It will be noticed that the diodes are connected to the bases of each transistor, and are biased by connection via fairly high value resistors (R_9 and R_{17}) to the appropriate collectors. When one transistor conducts heavily most of the supply voltage is dropped across the collector load, with the result that the collector voltage is small. Only a small voltage then appears between collector and base, so the diode remains unbiased and can conduct in the forward direction.

On the other hand, for the transistor which is not conducting, the collector-to-base voltage is quite large, and this reverse-biases the diode. Hence if a positive-going signal is applied to both diodes, one diode passes the pulse to its associated transistor (tending to switch it off), while the other diode blocks the pulse to its transistor.

By this "pulse steering" technique regenerative switching is initiated, and the circuit switches rapidly to its opposite state each time an input pulse is applied. As negative-going pulses have no effect, the circuit provides an alternate polarity output each time the illumination of TR_1 is cut off.

The Multivibrator

The "clock" circuit, comprising TR_6 and TR_7 is a simple free-running multivibrator operating at 10 cycles per second. Thus the final digit of the counter indicates 1/10ths of a second, the next digit indicates seconds, the next tens of seconds, and the final digit hundreds of seconds. This enables a total time of over fifteen minutes to be registered.

There are a few points worth noting in the design of the multivibrator, the first being the fact that silicon transistors are used. The frequency of a multivibrator is determined by the time constants of the coupling capacitors and base resistors, but the latter are shunted by the base reverse leakage of the transistors. With germanium transistors the reverse leakage varies markedly with temperature, but with silicon types there is no leakage worth mentioning. Hence temperature has little effect upon the repetition frequency.

Another point to note is the large values of the cross-coupling capacitors, C_3 and C_4. To ensure saturation of each transistor when it is "on", the base resistances should be less than α' times the value of the collector load, where α' is the current gain of the transistor. Now the α' value of silicon transistors tends to be low (typically 20, unless expensive types are used) and so the value of the base resistors is low ($4.7k\Omega \times 20 = 94k\Omega$). To obtain the low frequency of 10 c/s large coupling capacitors are therefore required.

Furthermore, because the capacitance of an electrolytic varies greatly with temperature, the coupling capacitors must be paper types. The author used two $0.5\mu F$ units in parallel to obtain $1\mu F$, but this was simply because they were handy.*

If very accurate timing is to be undertaken, it is as well to include a buffer stage (see Fig. 4) to reduce the loading on the oscillator stage.

The other item of interest is the variable resistor VR_1, which gives a small degree of control over the frequency of the multivibrator to compensate for variations in battery voltage, temperature, etc. The values of the base resistors R_{21} and R_{22} found in the Components List are intended only as a guide, and should be adjusted to give the correct calibration with VR_1 in mid-position.

Gate Circuit

The function of this circuit is to allow the transfer of 10 c/s pulses when the flip-flop is in one state, and to block the pulses when it is in the other.

In effect, a diode gate is used, the base-emitter junction of the n-p-n transistor TR_8 forming the diode. A negative bias potential is applied to the emitter by the potentiometer VR_2, and adjusted so that, when the collector of TR_5 in Fig. 2 is also negative, the gate is closed and, when it is near zero potential, the gate is open. (There is a difficulty of phraseology in connection with gates; one tends to confuse them with switches. However, when a switch is "open", a gate is "closed".)

* To ensure accuracy of timing despite changes of temperature it would be preferable to use capacitors having low temperature coefficients in the C_3 and C_4 positions. Suitable types would be T.C.C. Duomold or T.C.C. Polyester.—EDITOR.

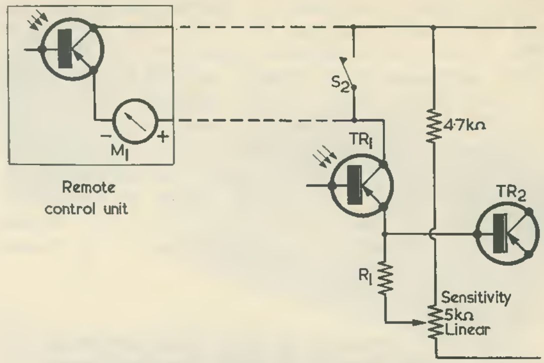


Fig. 5. Adding a second transistor. This diagram also shows how a sensitivity control may be introduced into the TR_1 circuit

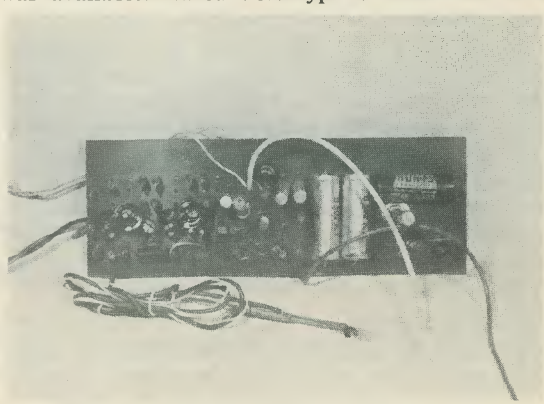
The main reason for using an n-p-n transistor is the simplification it produces in a d.c. amplifier. If an a.c. amplifier were used, the switching of the flip-flop would produce a change in d.c. level, causing unwanted counts to occur.

The Current Amplifier

The collector circuit of TR_8 connects directly to a super-alpha pair, TR_9 and TR_{10}, with no need for biasing whatsoever. (If thermal stability is considered a problem, a $4.7k\Omega$ may be connected between the base and emitter of TR_8.) The current demand of the counter is quite high—1 amp peak or 500mA average—hence the need for a two-stage amplifier. TR_{10} should be a power transistor for, although the heat dissipation is not great, it should run as coolly as possible since there is no thermal stabilisation except the resistor R_{26}. To this end TR_{10} should be mounted on an adequate heat sink—say 20 square inches of aluminium sheet.

The Counter

An electro-magnetic counter was chosen because, as mentioned earlier, a low voltage power supply was available. A suitable type of counter is the



The Paxolin chassis employed in the prototype

100D, which is capable of operation at 10 c/s, and has a coil resistance of 4.1Ω. The 100D is a four figure, non-resettable type, but it may be found desirable to be able to set the figures back to zero after each timing interval. However, although four figure resettable counters are readily available, they are rather expensive, and are normally fitted with high resistance coils intended for 48 volt operation. This would mean either a 48 volt supply or the rewinding of the coil. (Coils from the 100D are not interchangeable with those from resettable counters.)

Construction

A Paxolin board, 7 x 2½in, was prepared by drilling it with a grid of $\frac{1}{16}$in diameter holes, at ¼in spacing. Components were mounted on one side of the board, and their wires were used for interconnection on the other. This is a much cheaper alternative to the printed circuit, and is only slightly inferior.

The power transistor TR_{10}, the counter and the phototransistor TR_1 were all connected to the main circuit by flying leads, so that they could be mounted as convenient.

Setting Up

The phototransistor should be mounted at one end of a tube about 2in in diameter and a foot long, in order to exclude extraneous light. The type of light source used will depend on the separation of source and detector, and also upon the power source available. A car spot-light is normally used with the author's model but, with a sensitivity control (see Fig. 5) and a simple lens operation at distances up to 50 feet can be obtained with an ordinary torch.

If a milliammeter is available, this may be placed in the collector lead of TR_1, and the alignment of the light and phototransistor can be adjusted to give a maximum collector current. This should exceed 1mA.

Addition Of A Second Phototransistor

For timing over a straight course—as opposed to a circular one—two light beams are required, one at the start and one at the finish. In this case two phototransistors may be connected in series, as in Fig. 5.

Optical alignment of the first light and phototransistor can be accomplished with switch S_2 closed; operation can be checked by covering and uncovering TR_1. The alignment of the second optical system, which will presumably be remote from the main instrument, can then be carried out with the aid of meter M_1. The remote unit should be fitted either with a permanent meter, or with sockets for connecting a portable meter.

The Decibel

By

ARTHUR C. GEE

M.R.C.S., L.R.C.P., D.P.H.

In these days of high-revving petrol engines, pneumatic drills and screaming jet aircraft, we often read newspaper reports of noise measurements expressed in decibels without any mention being made of the standard reference level employed. This article, which is mainly concerned with decibels when used for measuring sound intensities, points out that the standard employed here is the Clinical Zero, and quotes numerical examples for many of the noise intensities with which we are familiar

One of the terms which the beginner will soon come across in electronics, whether in the field of radio or audio, is the "decibel", and it is probably true to say that it is the least well understood of any, to judge from the way many folk use the term.

The decibel, or "dB" as it is expressed, is a "unit of relative power". That is, it defines the ratio between two degrees of the same power source, frequently electrical. In practice, the decibel is also very often used in relation to such sources of power as noise.

Loudness

"Loudness" is, of course, judged by the ear, but here we run into difficulties. The ear cannot judge *absolute* loudness. It can only judge *differences* in loudness. Thus we see why the decibel, which defines a *ratio* is such a useful unit with which to measure loudness level. The ear can only estimate power ratios in relation to the sound it hears; and the decibel is a power-ratio unit.

For those with a mathematical turn of mind, we can define a decibel in the following manner. If we have two powers, P_1 and P_2, then the number of decibels representing the ratio P_2:P_1 is ten times its common logarithm. Expressed as an equation this gives us:

$$dB = 10 \log_{10}\frac{P_2}{P_1}$$

From the practical point of view, it so happens that a change in loudness, just detectable by ear, is equal to 1dB.

One great advantage in using the decibel scale where sound is concerned is that the range of loudness of sound, when expressed as a simple ratio, is so great that the figures necessary to indicate the extremes become inconveniently large. Thus the difference in power of the sound of a jet aircraft from the slightest noise which is only just audible to the average human ear is 1,000,000,000,000 to 1! On the decibel scale this represents a figure of 120 only.

On the decibel scale a ratio of:

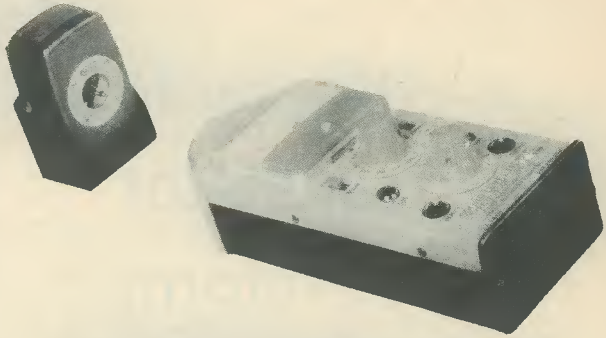
1:1 =zero dB
1:10 =10dB
1:100 =20dB
1:1000=30dB and so on.

Clinical Zero

Even though the decibel is a measure of relative power or relative noise, it is necessary to define what one might call "a unit decibel", particularly when the power ratio being measured is that relating to sound. A unit decibel, for use in this particular field, has consequently been defined as "the quietest sound that can be heard." This obviously depends on the hearing acuteness of the individual, so a further attempt to obtain a more accurate unit was made by averaging statistically the quietest sound heard by a large group of young adults. The result thus obtained is sometimes called the "Clinical Zero" in sound measurement, and is referred to as zero on the dB sound scale.

Using such a zero, it is interesting to note the dB measurement of some common sounds. Taking the threshold of hearing as zero, the "noise" in a quiet church or soundproof room averages out at about 10dB. A whisper or the background noise in a public library is around 20dB. Normal conversation is around 50dB; a radio set full on, or the noise in a car, 70dB; busy street noise or that in an Underground train, 90dB; pneumatic drills, 100dB and jet aircraft up to 120dB. But remember, these figures do not represent so many units, like pounds of potatoes; they represent the relative power of each sound, compared with the minimal.

With regard to the measurement of sound intensities if, in the equation given above, P_2 represents the sound intensity we wish to measure and P_1 the intensity of a known sound reference source expressed in decibels, then we can calculate the intensity of our test sound in actual decibels also. We could take the reference source as being the "quietest sound we can hear", but a more practical proposition is to employ a Standard Source of Sound which, used under specified conditions, gives a sound intensity of a known number of decibels. Such instruments are available for use in audio laboratories and one type takes the form of a small case, containing thousands of very small steel balls. On flipping the case over, the balls run down like sand in an hour-glass on to a small diaphragm, which emits the noise of the falling balls. The balls take a few minutes or so to run through, during which time their noise can be used as a reference sound source. The instrument is then flipped over again, whereupon the process can be repeated. Used under standard conditions as to distance from the microphone, background noise, etc., the instrument can provide a very accurate and sound intensity reference source.



The Dawe Instruments Falling Ball Acoustic Calibrator Type 1417 and Sound Level Meter Type 1400F. The calibration of the meter, including the microphone, may be checked with the calibrator. (Courtesy Dawe Instruments Ltd.)

Editor's Note

The internationally agreed reference level for sound pressure in noise measurement is 0.0002 dyne/cm^2, which is in the region of the threshold of audibility for a 1,000 c/s pure tone. Loudness measurements with sound level meters are taken against this pressure and at this frequency, but the frequency response of the measuring instrument is weighted to exhibit certain characteristics (which are described in British Standard 3489:1962—"Specification For Sound Level Meters (Industrial Grade)"). The weighting results in loudness readings which correspond with subjective perception. A typical weighted response curve, as would be given by response A of the Dawe Instruments sound level meter shown in the illustration, is 0dB at 1,000 c/s, falling to —10dB at 200 c/s, —20dB at 90 c/s and —35dB at 40 c/s.

ECONOMIC SILICON RECTIFIER

A series of economic silicon rectifier assemblies in single-phase bridge connection is now being produced by Westinghouse Brake and Signal Co. Ltd. Two basic ranges can be supplied, rated at 30 and 20A; each range being available in a variety of peak transient voltage ratings from 100 to 1500.

The units comprise two 4 x 8in aluminium cooling fins, each fitted with a normal and reverse polarity diode of the SxFx5 or SxFx8 type, mounted on 10 U.N.F. insulated spindles which may be employed for mounting the unit. Typical applications are in battery chargers, electromagnet supplies, general d.c. power supplies, etc.

Versatile Transistor Waveform Generator

By J. P. CREAN

An interesting experimental circuit which, by using a floating system to add functions together, can produce a wide range of waveforms

IN THE COURSE OF EVERYDAY WORK ONE OFTEN comes across components, particularly transistors, which are not quite "up to scratch" and yet are still sufficiently good to make it seem a pity to throw them away. These usually find their way into a box somewhere in the workshop, and reside there collecting dust until they are eventually thrown away.

The circuit described here was constructed out of the contents of just such a box in order to forestall their imminent consignment to the dustbin. The circuit will operate on any power supply between 1.5 and 15 volts, the current drain being 600μA at 9 volts. It produces square and triangular waveforms and various other functions.

None of the component values are critical, and all the transistors are used as switches and thus have only two levels of output. Lack of an internal earth ensures that voltages between any two points in the circuit can be tapped off, simply by connecting earth to one and obtaining an output from the other.

Circuit Operation

In the circuit diagram of Fig. 1, TR_1 and TR_2 form a conventional multivibrator operating (in this instance) at about 1 kc/s. If variable frequency or mark-space ratio is desired, this can be arranged by using potentiometers and/or switched capacitors. Because of the presence of C_1 and C_2, the collector waveforms of TR_1 and TR_2 are rather rounded.

To provide a square wave output, the base of TR_1 is connected to that of TR_3, a simple switching transistor which has a very neat square wave at its collector. TR_3, in turn, switches TR_4 via R_6.

TR_5 has L_1 (the primary of an old 470 kc/s transistor i.f. transformer) connected to its base. TR_4 collector is coupled to L_1 via C_3. C_3 and L_1 form a short time-constant which cuts TR_5 off briefly each time TR_4 is switched from its low current to its high current state. Thus, negative pips of very short duration and the full value of the supply voltage in amplitude appear across R_9.

Construction and Use

This waveform generator was constructed on a 4 x 4in piece of Veroboard, and there was still plenty of room left over. Various points in the circuit (shown by letters in Fig. 1) were connected to pins on a 26-way Electro-Methods MRE socket.

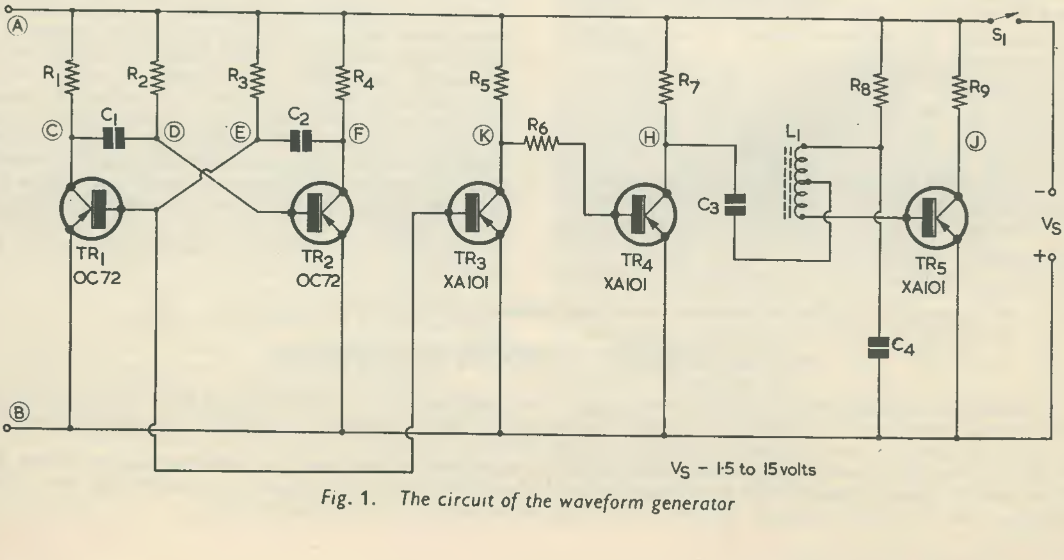


Fig. 1. The circuit of the waveform generator

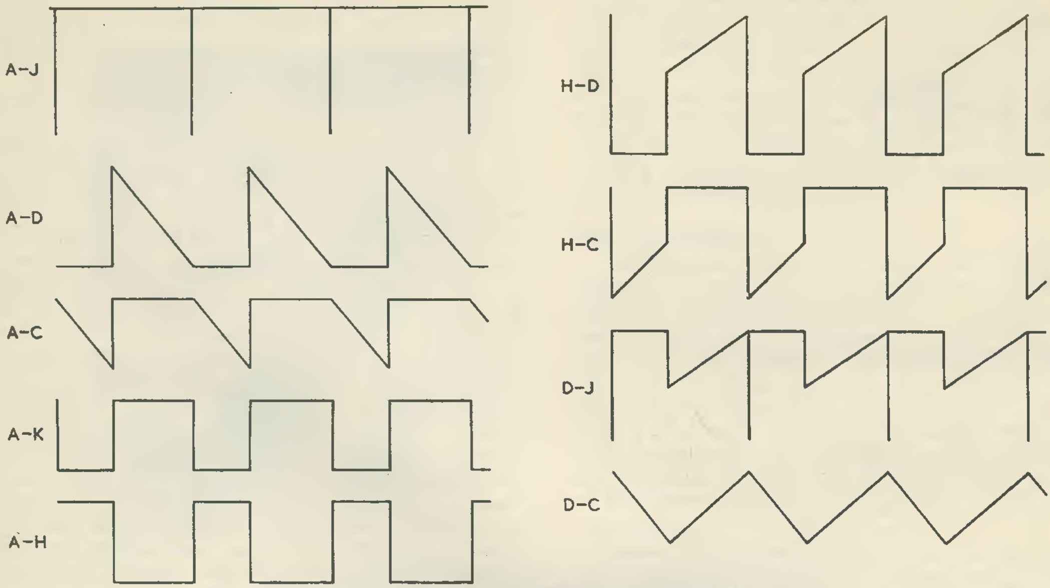


Fig. 2. Some of the waveforms obtained from the generator. These are given at the lettered points indicated in Fig. 1. There may be some rounding (not shown in detail here) on the waveforms associated with TR_1 and TR_2

Components List

Resistors
(All resistors ¼ watt 20%)
- R_1 22kΩ
- R_2 82kΩ
- R_3 56kΩ
- R_4 18kΩ
- R_5 56kΩ
- R_6 220kΩ
- R_7 82kΩ
- R_8 220kΩ
- R_9 10kΩ

Capacitors
- C_1 0.05μF paper
- C_2 0.001μF paper
- C_3 100pF ceramic or silver-mica
- C_4 5,000pF ceramic

Inductor
- L_1 Primary of i.f. transformer (see text)

Transistors
- $TR_{1,2}$ OC72
- $TR_{3,4,5}$ XA101

Sockets
- 9 output sockets or terminals (see text)

Switch
- S_1 s.p.s.t. on-off switch

Supply
- 1.5 to 15 volts (see text)

Using two MRE plug pins as jack plugs, the socket can be employed as a patchboard, various waveforms being taken from the appropriate points. Any waveform can be inverted by reversing the two connections to the socket.

Any other socket, or assembly of sockets, can be employed, of course, instead of that used by the writer.

MARCONI MARINE RADAR

Marconi Marine's most sophisticated radar, the stabilised-screen "Argus 16", has now been fitted on the world's largest passenger liners, the Cunarders *Queen Elizabeth* and *Queen Mary*.

With the stabilised-screen facility, plus true motion, the navigator is able to switch to bows-up or north-up as he wishes to obtain the type of presentation he needs for swift and accurate appreciation of any situation. The "Argus 16", with its 16in screen, gives ranges of ¾, 1½, 3, 6, 12, 18, 24 and 48 miles.

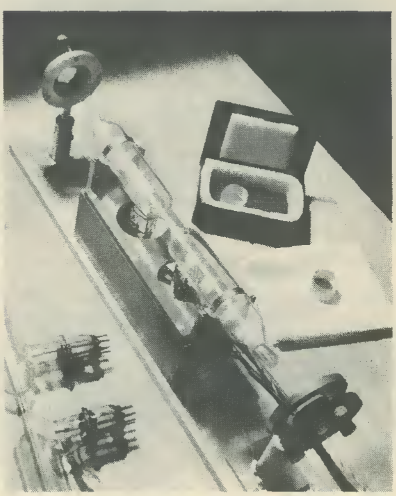
The two "Queens" have also been supplied with Marconi Marine's transistorised "Raymarc" radar as secondary installations.

LASERS

Part 3

Applications of Lasers

By J. B. Dance, M.Sc.



In this concluding article in our three-part series on lasers, our contributor describes the most important applications for these new devices in the commercial, medical and communications fields. Particular attention is paid to the possible use of the laser by the amateur. It is pointed out, finally, that great care must be observed when working with these devices as, apart from the risk of electrical shock, irreparable damage can occur to the eye and other parts of the body due to the concentrated power in a laser beam

Almost every week a new application is found for Lasers. It is obviously not possible to cover all of these applications, but the following discussion describes those which the writer feels are the most important at the present time.

1—Communications

Throughout the history of radio communication continual attempts have been made to increase the maximum frequency of the electromagnetic waves which can be used to carry information efficiently. The reason for this is well known; the greater the frequency of the carrier wave, the easier it is to obtain the necessary bandwidth to carry a large amount of information in a short time.

If one wishes to convey information by means of an electromagnetic wave, an adequate bandwidth must be employed or part of the information will be lost. Speech is relatively easy to transport on an electromagnetic wave, since it requires a bandwidth of only about 3 kc/s for intelligibility or 10 kc/s for good fidelity. However, television pictures (405 lines) require a bandwidth of about 3 Mc/s, since there is more information in one picture (which is transmitted in 1/25 second) than there is in 1/25 second of an audio signal. Obviously one cannot transmit a picture requiring a 3 Mc/s bandwidth on medium waves, since the modulating frequency alone would require more than the whole of the medium waveband (which is little more than 1 Mc/s from end to end). Television is not normally transmitted at frequencies below 40 Mc/s.

The medium and short wavebands are now so crowded that it is almost impossible to receive a first class signal at some distance from the transmitter at night on medium waves or at any time on short waves. (A first class signal is one received under true high fidelity conditions.) Television and other transmissions have gradually filled up the high frequency and v.h.f. channels and the latest B.B.C. television programmes have had to be transmitted in the u.h.f. region of the radio spectrum. Higher and higher frequencies are being used in the search for more space in the frequency spectrum. Microwave frequencies are now used for many purposes, for example the relaying of television picture signals or a large number of audio signals on one channel. Much more information can be put into a microwave carrier than into a longer radio wave, and an aerial of fairly convenient dimensions can be constructed to transmit the information in a narrow beam in the required direction.

As stated previously, it has not been possible in the past to modulate a light wave with a large amount of information, since ordinary light is not coherent. If only spark transmitters had been available, modern radio with its precision tuning would not have been possible, since incoherent waves from a spark transmitter require a very large bandwidth yet can convey little information.

The invention of the laser has immediately opened up a very wide field for investigation. The frequency band of the visible region alone occupies some hundreds of millions of megacycles and lasers can also be used in the infra-red; although it must be mentioned that at the present time the range of laser materials available will not allow all of these frequencies to be used. Prior to the invention of the laser, the total frequency bandwidth available was about 200,000 Mc/s.

It is expected that it will be possible to convey much more information per unit time by means of a laser beam than by any other communication link. In addition it is at least theoretically possible to divide the visible part of the electromagnetic spectrum into about 100 million television channels or about 100,000 million telephone channels. Laser transmitters have the advantage that the beam of radiation is emitted in a closely defined direction, the divergence being even smaller than that of a microwave beam. Thus the laser power can be concentrated where it is required, there is a very low transmission loss and it is not easy for unauthorised people to receive the information.

If a communications network is to be useful, it must have a very high degree of reliability. Radio waves can travel through fog, rain and clouds, but light waves cannot. Neither can light travel between two points which are not in a direct line of sight. Thus there is no question of the light waves from lasers eventually being used to completely replace conventional radio transmitters.

Light Pipes

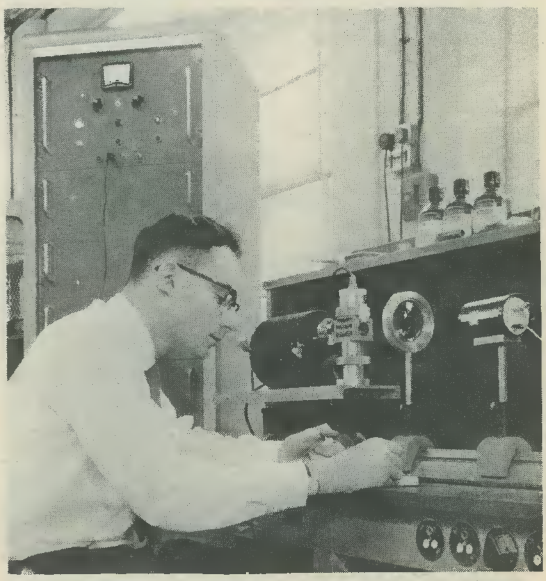
In order to avoid interference by atmospheric disturbances, it seems likely that laser communication will be carried out by means of tubes or light pipes which may possibly be evacuated. It has been suggested[12] that these pipes may take one of two forms. The first of these consists of a 1in diameter pipe with a reflecting inner surface and no very sudden bends. The transmission loss is expected to be about 2dB per mile. The second type employs long focal length lenses with no reflecting surface on the interior of the pipe. No bends would be permissible unless a mirror were placed at the bend. A servo mechanism would probably be required in this second type of pipe to keep the lenses exactly in the optimum position. The loss would also be about 2dB per mile. In this system the pipe merely prevents the beam from being attenuated or interrupted. Although the cost of the light pipe is not negligible, it may nevertheless be less than that of waveguides.

It appears that transmissions by light waves will be most useful when a signal containing a great deal of information is to be carried from one point to another point rather than broadcast to a large number of receiving points. Thus it seems likely that lasers will be used to provide light which will carry numerous telephone conversations or television pictures between two countries. It has been calculated[16] that a 4 Mc/s communications channel could be designed using laser light over a distance of 3,500 miles with a signal to noise ratio of 40dB and no amplification *en route*. For communications work between artificial satellites in orbit, a laser system would appear to be very suitable, since no atmosphere is present to disturb the propagation of the light.

The Transmitter

The semiconductor laser might, at first thought, appear to be ideal for communications work, since it is so easily modulated. Unfortunately the output from the currently available semiconductor lasers does not have a very stable frequency. This is largely due to the oscillator system jumping from one mode of oscillation to another. This also results in the output being quite noisy. Other disadvantages of the semiconductor laser are the necessity for cooling if high efficiencies are to be obtained and the comparatively large angular divergence of the output beam.

Experimental demonstrations have been given in which a gallium arsenide laser has been modulated with a television signal. Semiconductor lasers are usually fairly satisfactory when only one channel is to be transmitted, but for serious multi-channel communication work it seems that the gas laser will be much more suitable. Gas lasers have a very narrow bandwidth, but unfortunately it is difficult to modulate them at frequencies above about 1 Mc/s. It is obviously essential to use bandwidths greater than this if high efficiency is to be obtained. External modulators are therefore being developed which modulate the light after it has been emitted from the laser.



The Bradley Type 350 ruby laser. The laser itself is contained in the black elliptical box to the right of the operator's head. (G. and E. Bradley Ltd.)

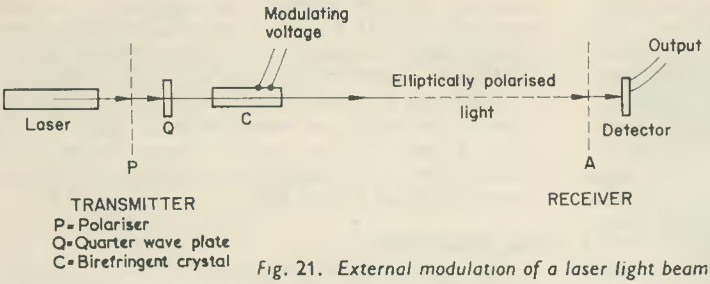
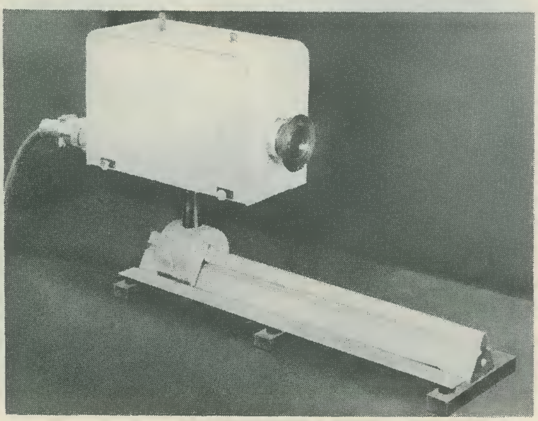


Fig. 21. External modulation of a laser light beam

A typical external modulator may be represented as shown in Fig. 21.[12] Light from the laser passes through the polarising crystal P and the quarter wave plate Q, which convert it into circularly polarised light. The crystal C consists of a material (such as ammonium dihydrogen orthophosphate) which becomes birefringent under the influence of an electric field. That is, when an electric field is applied across the crystal, the velocity of light polarised in one plane as it passes through the crystal is different from that of light polarised in a perpendicular plane. The greater the electric field, the greater the amount of birefringence. The circularly polarised light incident upon the crystal is, to a greater or lesser extent, converted into elliptically polarised light. The greater the applied modulating voltage, the greater the ratio between the major and minor axes of the ellipse.

The Bell Telephone Laboratories of the U.S.A. have found that a reverse biased gallium phosphide diode shows birefringence in the junction region. The amount of birefringence depends on the potential difference across the diode. Such diodes have been used to modulate the light of a helium-neon gas laser. Light from the laser can be coupled to the p:n junction of the gallium phosphide diode; this junction is only about 0.001cm. in thickness. The length of the light path through the diode is usually less than a millimetre. Light from the green region of the spectrum to the near infra-red can be modulated by means of these diodes.



The M.E.L. Equipment L650 doped crystal laser (M.E.L. Equipment Ltd)

At the receiver the elliptically polarised wave may be passed through an analyser crystal and the resulting amplitude modulated wave passed to a photosensitive detector. Unfortunately the analyser crystal allows only half of the power to pass through it, but other systems are being investigated which do not have this disadvantage.[17]

Such external modulation systems can operate at modulation frequencies up to about 10,000 Mc/s, but require a certain amount of modulating power which usually exceeds 1 watt.[12] A photo-multiplier tube may be employed as the detector provided that the maximum frequency of modulation does not exceed a few hundred megacycles per second. However, new forms of photosensitive device are being developed which will handle much greater modulation frequencies. These devices include a combined photosensitive diode and parametric amplifier and a photosensitive travelling wave tube.

The photoparametric diode, which is being developed at the Sperry Rand Research Centre, Massachusetts, U.S.A., is of particular interest, since it can demodulate light signals with modulation frequencies of up to 25,000 Mc/s even if the input level is as low as one thousand millionth of a watt. It has been predicted that diodes will be produced in the future which will be able to demodulate signals of an intensity as low as one million million millionth of a watt. The diodes are only about one eighth of an inch in diameter, but can produce parametric gains of at least 25dB. They have already been used as heterodyne detectors of gas laser signals.

Receiver Details

It is interesting to speculate on the probable form which a receiver of modulated lasers waves will take. A superhet type of receiver seems to be indicated at all very high frequencies. A local oscillator is therefore required and this must operate at a frequency which is not very different from that of the carrier wave being received. Thus the only possible form the local oscillator can take is that of a laser, since its output must be reasonably coherent.

As frequencies rise—even in the v.h.f. and u.h.f. regions of the radio spectrum—the frequency stability of the receiver becomes of the utmost importance. We have already seen that the slightest movement of a laser mirror will produce a very large change in the operating frequency. Such small movements will occur during changes of temperature or as a result of earth movements or local traffic. A laser receiver which drifted from 400 million megacycles to 401 million megacycles would not seem to be very useful, since the drift would be a million megacycles! It therefore appears that some highly efficient form of automatic frequency control is required. Substantial progress has already been made in this field.

One of the possible forms of laser receiver is shown in the block diagram of Fig. 22. The incoming light beam is mixed with the beam from the local laser oscillator at the partially silvered mirror and both beams are fed to the photosensitive detector. The intermediate frequency produced is, of course, equal to the difference in frequency between the incoming light wave and the light from the local laser oscillator. The intermediate frequency is amplified and detected in the usual way. If the intermediate frequency changes slightly, this change is detected by the error detector which feeds a voltage pulse to a piezo-electric element. The latter moves one of the mirrors in the laser local oscillator by a very small amount and so corrects the drift of the intermediate frequency.

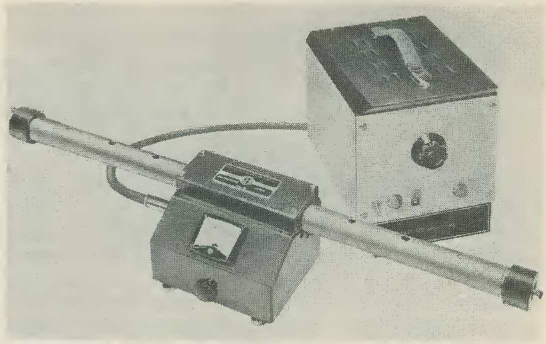
This type of system corrects for drift of either the transmitter laser frequency or the local laser oscillator frequency. Experimentally it has been found that the tracking error of two lasers can be kept at less than 3 kc/s (about 1 part in 100,000 million), but even better frequency stability is expected in the future.

Rather different types of receiver for use with gallium arsenide lasers have been designed by the IBM Company[18].

The laser is a device which was invented by physicists quite recently, and its applications in the field of fundamental physics have probably been more thoroughly investigated than its practical applications in the communication field. Nevertheless, now that lasers have reached many electronic engineers, a considerable amount of work is being carried out on their possible applications for communications. The G.P.O. have a research group working on this problem. The use of lasers in the communication field will only be a success if it is possible to achieve good results economically, since there is strong competition from other communication systems.

2—Welding, Hole Punching, etc.

A powerful ruby laser can provide over 1,000 joules of light in one millisecond, which represents a power level of one million watts. A suitable lens system can be employed to focus this light on to an area of about 0.01 cm. square (that is, 0.0001 sq. cm.). Over this small area the power dissipated is 10^{10} watts/sq. cm. Enormous light intensities of over ten times this value have already been obtained and will raise the temperature of a small area of a metal surface to over 5,000°C. A minute hole can be punched through a steel plate which is perhaps ¼in in thickness. It is amusing to note that the output of some of the early lasers was measured in "Gillettes"; a laser had an output of two Gillettes if it would just punch a hole through two razor blades stacked on top of one another!



The Bradley gas laser Type 601. The power supply is shown at the rear and the gas tube, with its associated equipment, in the foreground. (G. and E. Bradley Ltd.)

It is possible to employ the energy of a laser to make small spot welds, although it will probably be a few years before lasers are used on a large scale for this purpose. It is unlikely that they will ever be used for general cutting and welding of metal unless lasers of much greater power are developed. They are, however, very useful for operations on the micro-scale. If too much power is employed, part of the metal beneath the surface will be vapourised and the resulting shock wave will damage the surrounding material. There is not enough time during a pulse for an appreciable part of the heat developed to be conducted away.

The optimum conditions for welding aluminium sheet 0.025in thick have been given as 140 kilowatts per sq. cm. for 10 milliseconds and the total energy as 4.5 joules. For the same thickness of steel the optimum conditions are 60 kilowatts per sq. cm. for 90 milliseconds and a total energy of 17 joules[19]. It is interesting to note that one method employed for measuring the temperature of a metal surface during welding by a laser consists of the measurement of the number of electrons emitted by the surface, this acting as the cathode of a diode valve.

Another use which has been suggested for lasers is the production of the plates used in printing[20]. The system could be computer controlled.

Even transparent materials (which do not, of course, absorb much of the light incident upon

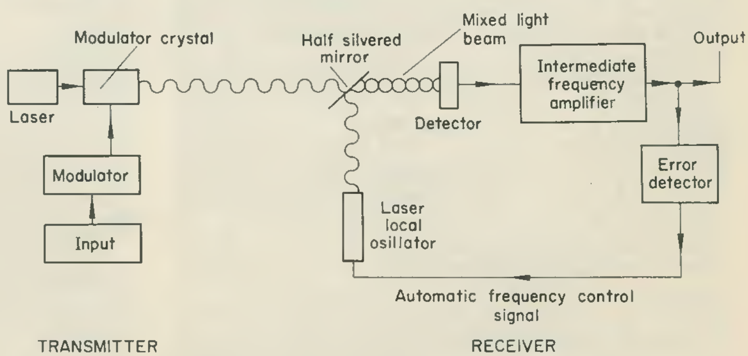


Fig. 22. The probable basic design of a laser communications system

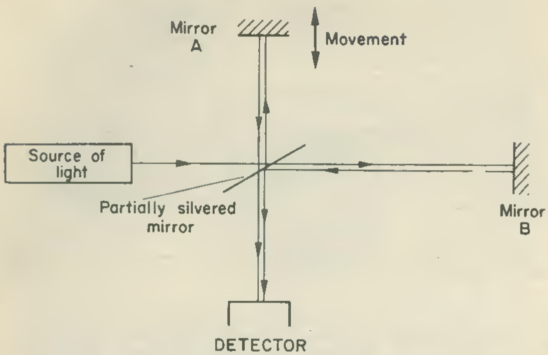


Fig. 23. An interferometer. (The rays are slightly displaced for clarity)

them) are affected by a high energy laser beam which has been focused to a small spot on the surface of the material. It has been shown that harmonics of the laser beam are generated when it strikes a transparent material, since the dielectric constant of the material depends on the frequency of the light and the electric field strength caused by it. If a very powerful laser beam is focused on to a small spot in a gas, the electric field strength becomes great enough to cause a spark. This sparking results in the scattering of the laser light.

3—Medical Uses

Lasers are creating considerable interest in the fields of medicine[21] and biology. The output radiation from a laser can be sharply focused on to any tissue which must be destroyed or cut out. Coloured parts can be selectively destroyed without harming adjacent tissue, since the coloured pigment absorbs light energy.

During the past few years detached retinas have been "spot welded" back into place in an immobilised eye by the light beam from a powerful xenon flash tube. Lasers can supply the energy required in about a millisecond and the eye need not therefore be immobilised. Small hand lasers which fit into an ophthalmoscope handle can be used for this purpose. Only a fraction of a joule is needed, since the dark coloured retina absorbs light readily. It is essential to use the correct amount of energy, which varies according to the colour of the eye.

Human tumours (i.e. cancers) which have been implanted in hamsters have disappeared after irradiation with laser light, whilst the adjoining tissue appeared unharmed. The laser is especially effective against coloured tumour cells (such as skin cancer melanoma), but thyroid carcinomas also appeared to be destroyed. Laser treatment of cancer has the advantage that the light can be focused very accurately and that it seems to be more selective against tumour cells than is X-ray or gamma ray treatment. Skin growths, moles and blemishes can be cauterised by laser light.

A laser beam can be used as a minute precision scalpel to cut tissues. Under the microscope the cut tissue looks as though it had been cut by a very sharp instrument. A part of a growing cell can be cut out in this way. If a chosen part of the cell is stained with a dye, it will absorb the laser light and will be selectively destroyed; the behaviour of the cell without the chosen part can then be investigated. When the action of laser light on a single cell is being investigated, a microscope is used—possibly with closed circuit television to protect the operator's eyes.

Apart from the possible use of a laser for drilling minute holes in bone, it has been suggested that lasers might replace dentists' drills[22]. A high intensity pulse can be directed at a sharply defined area, the light being selectively absorbed by the dark carious regions of the tooth. The temperature of the tooth as a whole is not raised appreciably.

4—The Measurement of Distances

The coherent light emitted by a laser is very useful for the accurate measurement of distances ranging from minute fractions of an inch to the distance between two artificial satellites in orbit[23 24].

A special type of miniature gas laser has been developed by the Bell Telephone Laboratories for the measurement of distances of less than one millionth of an inch. The short length of the gas tube (about two inches) reduces the number of possible modes of oscillation and results in greater frequency stability. A movement of 12 millionths of an inch of one of the laser mirrors produces a frequency change of the laser light of about 1,500 Mc/s.

An interferometer using an ordinary source of light can be used to measure changes in a distance very accurately. In the interferometer of Fig. 23 the light beam from the source is divided into two parts by the partially silvered mirror. One part passes to mirror A and is then reflected back through the partially silvered mirror to the detector, whilst the other part is returned by mirror B to the partially silvered mirror where it is then reflected to the detector. If the path lengths of the two parts of the beam differ by a whole number of wavelengths of the light used, the two beams will reinforce each other at the detector. Any movement of either of the mirrors A or B will alter the point on the detector surface at which the waves reinforce; that is, a movement of a mirror will change the position of the interference pattern. If one of the mirrors is replaced by the surface of a piece of metal being worked, the interference pattern will change as the metal is cut away from the surface. Each interference fringe may be counted as it passes the detector and the machining can be automatically stopped after a certain thickness of metal has been removed from the surface.

One of the main limitations of an interferometer is that no interference pattern will be obtainable if the path difference between the two beams exceeds a certain limit when the light is not coherent. This limitation is removed if the source of light is replaced by a gas laser. Lasers may therefore find an application in machine tool control. They are also expected to be used to survey missile launching sites, etc., to a much greater accuracy than is possible with current methods.

Larger distances can be measured by the "radar" technique, in which the time taken for a pulse of light to travel to an object and back again is measured. This technique has already been used to measure the height of dust and other clouds in the atmosphere and is likely to be used by map-makers for distance measurement. Lasers may also have a military use for optical radar, since they can provide an angular bearing on an object much more accurately than conventional radar[25]. They can be used in daylight for this purpose, the daylight merely contributing a little noise. At night time they may also illuminate the target for high speed photography.

An area of about 40 square miles of the surface of the moon was illuminated by light from a ruby laser in 1962[26]. The output of about 50 joules was focused on to a spot on the shadow side of the moon with a 12in telescope. The light reflected from the moon was focused by a 48in telescope on to a photo-multiplier tube. The reflection was received 2.6 seconds after the ruby was pulsed. The light from the laser at the surface of the moon was about as bright as a small flashlamp at the moon's surface. This radar technique may provide the most accurate method of measuring distances in the solar system, since light can be concentrated on to a smaller spot than a radio wave. The measurement of all astronomical distances are based on measurements within the solar system, so the laser may, indirectly, enable the distances of very distant objects to be measured more accurately.

5—Velocity Measurements by Doppler Shift

Lasers can be used to measure fluid velocities as low as 10 inches per hour by Doppler shift. It is even hoped to measure continental drifts of the order of one inch per year by Doppler shift when the stability of gas lasers has been further improved! The laser beam would have to be reflected some hundreds of times between two neighbouring continents. Fairly large velocities can, of course, be measured much more easily.

6—Physics Research

Lasers are now widely used by research physicists for many purposes, both fundamental[27] and applied. A few of their uses in applied physics have already been mentioned. There are many others; for example, a powerful ruby laser has been used to generate the highest ultrasonic frequency yet attained (60,000 Mc/s) in a sapphire crystal by electrostriction. (Electrostriction occurs when a material changes its length in an electric field.)

In fundamental research it is intended to investigate the interaction of beams of energetic electrons with laser beams and to try to obtain a polarised beam of electrons with aligned spins. It is also hoped to use a high energy laser to ascertain how a photon of light interacts with a high energy gamma photon.

The production of harmonics of laser light, which has already been mentioned, if of great interest to physicists. In this phenomenon two photons of light give up their energy to an atom which then emits all of this additional energy as a single photon of twice the frequency of the incident light.

Gas lasers have been used for checking the famous Michelson-Morley experiment of 1881 with a new degree of accuracy[10]. It was this experiment which showed that the velocity of light is unaffected by the motion of the earth through space and which laid the foundation for Einstein's special theory of relativity (and, incidentally, it was Einstein who first suggested that stimulated emission could take place!)

7—The Laser in Teaching

The narrow beam of coherent light provided by a gas laser is extremely useful in optics teaching. A lecturer can use the light from a laser to demonstrate many basic principles which have previously been visible only under a microscope. Practical details of such laser experiments on interference and diffraction, lens abberations and the Abbe theory of the microscope have been published together with demonstrations of the Doppler shift with light[28].

8—The Amateur and the Laser

If an amateur becomes interested in the possibility of carrying out some experimental work with lasers, he must first decide whether he wishes to construct (or partly construct) a laser himself or whether he wishes to experiment with a commercially produced laser. The cost of a commercially made laser is greater than that which most amateurs would wish to pay, but the cost will still be appreciable if an amateur constructs his own laser.

Liquid and ring lasers are essentially research instruments at the present time and will not therefore be considered further. Semiconductor lasers could not be constructed by the amateur and do not seem to be readily available in this country at the time of writing. The ease with which their output can be modulated makes them appear, at first sight, to be suitable for amateur work. Unfortunately they must be operated at low temperatures if either a high efficiency or continuous operation is required. Whilst liquid nitrogen is quite cheap (about 1s. 6d. per pint), the necessary arrangements for storing it are not normally available at the home of the average amateur. It might be possible for amateurs to operate a semiconductor laser under pulsed conditions at normal temperatures, but it must be remembered that the output is relatively low. One can only hope that future developments in the field will result in the production of a semiconductor laser which is suitable for continuous operation by amateur users at room temperature.

The components of a doped crystal laser comprise (1) the doped crystal with its reflecting ends, (2) the flash tube, (3) an elliptical or other reflector system, (4) the power supply, and (5) an optical bench (which is not essential). It is not possible for an amateur to construct either of the first two items and it is not at all easy to construct a first-class elliptical mirror. The cost of a low power ruby or neodymium doped glass laser purchased complete is about £600, whilst that of a very high power ruby laser approaches £10,000.

If, however, one considers the parts of a low power laser (with an output power of a few joules) individually, one finds that a doped crystal tested for its laser action costs about £100, the flash tube about £20, an elliptical mirror about £50 and the power supply for the flash tube about £400. Therefore an amateur might be able to substantially reduce the cost of a doped crystal laser by making the power supply himself, but nevertheless the total cost will still be too high for the average experimenter to seriously contemplate unless he is absolutely certain that the laser will perform a very useful function.

A doped crystal laser is not, in any case, suitable for efficient communication (which is presumably the application of greatest interest to the amateur radio enthusiast) since the output is not constant during the output pulse.

We are therefore left with the gas laser which has the advantages of continuous operation and narrow spectral line width. In addition it is easy to modulate the gas laser at frequencies up to about 1 Mc/s —which is more than an amateur would need for speech, since he is not likely to be interested in multi-channel communication. However, the modulation of a laser with a television signal of high definition would appear to necessitate the use of an external optical modulation system such as that described earlier.

The price of a complete helium-neon gas laser, about £350 or more, would seem prohibitive to most amateurs. The equipment consists of four major parts: (1) the gas tube, including the Brewster angle windows, (2) the dielectric mirrors, (3) the mirror and tube mounting system (which must be very rigid) and (4) the power supply for the gas discharge.

A gas tube, filled and laser tested, can be obtained for about £50. The dielectric mirrors are about £25 to £50 per pair for operation at any one of the wavelengths 6,328Å, 11,538Å and 33,900Å. An additional set of mirrors will be required if operation at more than one wavelength is desired. It should be possible for a good practical man to construct his own mounting system, although this is by no means easy.

The power supply used in most commercial gas lasers is usually priced at somewhat over £300 and supplies about one hundred watts of r.f. at about 30 Mc/s. Whilst some amateurs may think that the construction of such equipment would be "right up their street", it must be remembered that the amount of external radiation from the power supply must be kept down to a level which satisfies G.P.O. regulations. One does not wish to transmit at 474,000,000 Mc/s and 30 Mc/s simultaneously! Much careful screening is therefore required. It is possible to use a direct current to provide the pumping energy, but in this case heated electrodes may be needed in the gas tube. A 50 c/s supply of about 6,000 volts r.m.s. at about 20mA could be used to pump the gas tube, but the output would then be modulated at 50 c/s.

It was stated on page 7 of the October 1964 issue of the American radio amateur journal "CQ" that an article will be published in that journal giving details of the construction of a gas laser. Another article which has already appeared on this subject[29] gives practical details of the construction of a gas tube for a laser. However, the construction of this tube involves glass blowing (which is not difficult), the cutting of the ends of the tube very accurately at the Brewster angle and the fitting of the Brewster angle silica end windows. Much expensive high vacuum equipment and a helium-neon gas container are required for filling the tube. In addition it is essential that the last traces of unwanted gases are removed and the use of getters (as in a radio valve) is recommended for this purpose.

It is felt that the average amateur experimenter should be advised to purchase a commercially manufactured and tested tube, since this can be obtained more cheaply than the high vacuum equipment needed for the filling of the tube. If, however, the constructor has access to high vacuum equipment at his place of work or elsewhere, he may feel inclined to attempt to make a laser gas tube. The dielectric mirrors must, in any case, be purchased, since it is not possible for the amateur to deposit the exact thicknesses of the required coatings on a base material.

Amateurs will not normally find it convenient to transmit to one another through light pipes. It seems likely that they will use gas lasers to transmit to one another between two relatively elevated points between which there is a direct line of sight, for example between two hills. From the amateur point of view the use of lasers for communication would appear to have relatively limited practical possibilities, but nevertheless amateurs will still learn a great deal from their experiments with lasers. (It is probably hardly necessary to mention that the laser offers the one form of efficient communication by means of an electromagnetic wave for which no licence is required.)

Safety

The light output from a gas laser is great enough to cause very severe damage to a person's eye if it happens to come in the beam. A ruby laser can provide enough output to completely destroy the retina of an eye in less than a millisecond. When using a laser care must be taken not only to avoid placing one's eye in the output beam, but also to ensure that no material can reflect a large portion of the output light into an eye. Ruby lasers can also destroy skin.

In addition it must be remembered that the power supply to a gas or to a doped crystal laser is at a relatively high voltage and is likely to be lethal if a contact is made between it and any part of the body.

The Future

The laser field is still in an early state of development and is changing very rapidly indeed. So far as the future is concerned, new types of laser will almost certainly appear and the performance of existing types will be very much improved. New laser materials will be found which will provide new wavelengths. Possibly the most notable developments, however, will be in the applications of lasers in still wider fields. Could it ever be that large hotels will use a laser to "boil" eggs in a millisecond instead of the normal three minutes?

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G. & E. Bradley Ltd., Neasden Lane, London, N.W.10.
Elliott Electronic Tubes Ltd., Elstree Way, Boreham Wood, Herts.
Ferranti Ltd., Kings Cross Road, Dundee.
International Research & Development Co. Ltd., P.O. Box 6, Wallsend, Northumberland.
Maser Optics Inc., 89 Brighton Av., Boston 34, Massachusetts, U.S.A.
M.E.L. Equipment Ltd., Manor Royal, Crawley, Sussex.
Perkin-Elmer Ltd., Beaconsfield, Bucks.
H. Prescott, Main Street, Northfield, Massachusetts, U.S.A.
Raytheon Co. (of U.S.A.); represented in England by Messrs. Walmore Electronics Ltd., of 11–15 Betterton St., Drury Lane, London, W.C.2.

RADIO TOPICS . . .

by Recorder

In these days of synchronous satellites perched some 22,000 miles above the surface of the earth (and wasn't it a pity that one of the first multimillion-viewer telecasts which the technical brilliance of Early Bird made possible was the Clay-Liston business?) it comes as rather a shock to realise that the world's first traffic-carrying submerged cable repeater was put into service only nineteen years ago. This historic repeater was inserted, in June 1946, in the cable link which had been installed between Lowestoft and Borkum, in Germany, during the previous year. Laid by the British Post Office, it gave trouble-free service from its station under the sea right up to 20th February of last year, after which it developed a fault that brought its working life to an end. I am, incidentally, indebted to *The Post Office Electrical Engineers' Journal* for the account of this particular repeater and its eventual demise.*

Noise Faults

Initially, the Lowestoft–Borkum cable, a polythene type, provided two telephone circuits to the British forces in Germany, but the insertion of the repeater raised this to five telephone circuits. Multi-channel voice-frequency telegraph circuits are at present routed over the cable, the five telephone circuits providing a capacity of 120 telegraph circuits.

The repeater amplified in the 24 to 44 kc/s band, offering a gain of 73dB at 44 kc/s. The heaters of its two valves were in series with the line itself, and about 250 volts h.t. negative was taken from the cable at the repeater, the positive h.t. potential being provided by a sea earth. The power supply, installed at the Lowestoft end, fed 630mA through the cable to provide heater and h.t. current, the power supply circuit being terminated at Borkum by components across which a final 69 volts appeared. The power supply return, from Borkum to Lowestoft, was via earth.

It was in July 1963 that the first sign of trouble appeared, this taking the form of intermittent crackling. It was very probable, however, that the crackling was due to a cable fault and it wasn't until a second noise fault occurred on 20th February, 1964 that the repeater became involved. It is not an easy job to pin-point the location of a submerged cable fault and when, as occurred in this case, the fault was of a mild nature (but still sufficiently severe to interfere with service) and intermittent as well, the difficulties became immense. At any event the first fault was located, after some fascinating electronic detective work, at an original 1945 splice made at the time of cable laying, and was due to a crack in the polythene covering. The second fault was then traced to the repeater itself,

* G. A. Axe and E. C. Vogel, "Replacement of the World's First Traffic-Carrying Submerged Repeater", *The Post Office Electrical Engineers' Journal*, April 1965.

this being brought aboard the cable ship H.M.T.S. *Iris* on 16th April, 1964 and replaced by another of similar type. With the insertion of the new repeater, the second fault cleared completely.

When the repeater was finally examined it was found that the cause of the fault was the first-stage valve in the amplifier unit. There could, however, have been a *third* fault, due to what *might* have been a dry soldered joint between one of the cable glands and the internal apparatus unit. Unfortunately, this joint had to be parted to permit further investigation, and it will never be known whether it contributed to the faults which appeared on the cable after July 1963.

Nevertheless, this historic underwater cable repeater gave a completely satisfactory working life of 17¾ years and it may well be that this was terminated by a valve fault only. It is considered that no submerged repeater now in use can beat such a record until March 1968, when repeaters in the Key West–Havana cable may reach the same age.

Marconi Export Breakthrough

The Marconi Company has always been well to the fore in the export of electronic equipment, and has now effected a further breakthrough into the American market with the first British television transmitters to be sold in the U.S.A.

Marconi television cameras and transmitters will be exported to America in early September for a new u.h.f. television station to be built by Television Chicago, a joint venture controlled by Field Communications Corporation. Field Communications Corporation is a wholly owned subsidiary of Field Enterprises, Inc., whose Newspaper Division publishes the *Chicago Sun-Times* and the *Chicago Daily News*.

This is the first time that British television transmitters have ever been sold in the United States, and the contract also includes the first export sale of the new Marconi Mark V camera.

Television Chicago chose Marconi equipment after an intensive appraisal of the equipment available on the market; and the export order was won in competition with all the principal television manufacturers in the United States.

The purchase includes six Marconi Mark V cameras, which were introduced in the U.S.A. at the National Association of Broadcasters Convention as recently as March of this year. These fully transistorised cameras are the smallest and lightest 4½in image orthicon cameras in production in the world. They incorporate an integrated zoom lens which removes previous restrictions on focal length of shots and allows each shot to be individually framed at the producer's direction. All electronic controls have been relegated to the equipment racks, leaving the cameraman free to control the position and field of view of the camera.

Television Chicago has also ordered two 25kW u.h.f. transmitters and associated drive units, similar to the transmitters which have been ordered by the B.B.C. for their second channel. These transmitters incorporate a unique system of diode modulation which ensures maximum linearity for possible future use with colour transmissions.

Mains Operated Transistor Receivers

What is almost certain to make a considerable alteration to the domestic broadcast radio market in America in the very near future is the introduction, by Radio Corporation of America, of a package-deal "kit" of four transistors and one (or two) silicon rectifiers. These allow the mass-production of a broadcast-band a.m. receiver which can be powered directly by the mains supply and which does not require bulky heat-producing dropper resistors or step-down transformers. The design of these receivers is relatively simple because the American broadcast band consists of medium waves only, and because the American mains voltage has the low figure of 117.

The "kit" comprises a type 40261 p.n.p. mixer-oscillator, a type 40262 p.n.p. i.f. amplifier, a type 40263 p.n.p. a.f. driver and a type 40264 n.p.n. output transistor. The latter has a maximum collector-base voltage of 300 and can give 1 watt output at less than 10% distortion when run in Class A.

A receiver circuit recommended by R.C.A. appears in the June issue of our American contemporary *Radio-Electronics* and employs the 40261 and 40262 transistors in a conventional mixer-oscillator and i.f. amplifier circuit. The second i.f. transformer feeds a 1N295 diode detector, with an a.g.c. loop coupling back to the 40262 base. After these stages appear the volume control, the 40263 driver and the 40264 output transistor. The latter runs at some 100 to 130 volts collector-emitter voltage, a special circuit arrangement ensuring that excessive collector voltage does not appear in the event of a sudden transient such as would be given by a flash of lightning. The collector is connected to one end of the speaker transformer primary winding, the h.t. positive supply connection (the 40264 is n.p.n. and requires a positive collector supply) being made to a centre tap in this winding. The other end of the primary is coupled back to the emitter via one of the silicon diodes in the "kit". Under normal conditions the primary of the speaker transformer is positive of the emitter and the diode is so connected that it does not then conduct. A heavy transient may cause the output transistor to momentarily pass a very high collector current, after which the transformer can offer the usual inductive "kick" and swing the collector heavily positive. This causes the other end of the transformer primary to swing negative by a similar amount until it reaches the same potential as the emitter. The silicon diode then conducts, damps the transformer winding (by way of the emitter bypass capacitor) and prevents the formation of any further voltage. The circuit then settles down to normal operation.

A silicon rectifier, of the same type as that just referred to, functions in a half-wave rectifier circuit running, via a 250Ω limiter resistor (which also gives a slight drop in rectified voltage) direct from 117 volt a.c./d.c. mains.

It is anticipated that the 4-transistor superhet made possible by the "kit" will be mass-produced in the form of exceptionally cheap mains-operated medium wave receivers having small size and the advantage of instant operation immediately after switching on. One manufacturer hopes to sell his version at around six dollars (about two guineas) only. The sets are not intended to be serviced—it would be cheaper to buy a new one!

The *Radio-Electronics* account is taken from R.C.A. Application Note 1CE-313, 9-64, revision 1, available from R.C.A. Electronic Components and Devices, Harrison, New Jersey.

New Oscilloscope

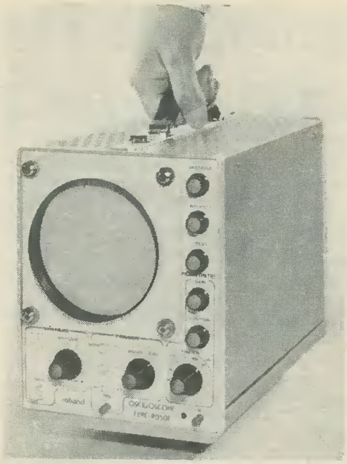
A new oscilloscope, the type RO501, is announced by Roband Electronics Ltd., Charlwood Works, Lowfield Heath Road, Horley, Surrey, and is shown in the accompanying illustration. The latter also gives a good idea of the small overall size of the instrument.

The RO501 oscilloscope has a 5in c.r.t. operating at 3.3kV stabilised to ensure high brightness displays at any sweep speeds, and uses a single printed circuit board with all main components coded.

Bandwidth is from d.c. to 6 Mc/s, with a risetime of 55nS. Sensitivity is 50mV/cm to 20V/cm covered in nine calibrated ranges and with a measuring accuracy of ±5%. The sweep range is from 1μS/cm to 100mS/cm in six calibrated steps, a 10:1 continuously variable control extending the range to 1S/cm. At the same time, a X5 variable magnifier offers a maximum sweep speed of 200nS/cm.

It is possible to select the trigger point for sync, and an interesting feature is that a built-in TV field integrator allows the timebase to be triggered from television field pulses.

An internal calibrator is fitted, the two-colour graticule is edge lit, and the oscilloscope accepts standard cameras on 5in centres. The overall size of the R0501 is only 9⅞in high, 14¾in deep and 7½in wide. Weight is 17½lb.



The new Roband RO501 oscilloscope. This has a comprehensive specification together with low weight and small dimensions

Joining Copper Wire

It isn't always an easy job connecting together two lengths of enamelled copper wire, this being especially true with the thinner gauges, but a reader, Mr. Colin Hart of Streatham, London, has developed a very simple method for carrying out this task. I quote from his letter.

"Whilst winding the 'output' winding of the transformer for the '2mA Indicating Lamp For Transistor Radios' by R. M. Marston in the March 1964 issue of *The Radio Constructor*, I evolved a method for joining ends of thin enamelled wire (42 s.w.g. in this case).

"This consisted of twisting the two ends together for about an inch. A lighted match was then held under the end of the twist. This burnt off the enamel and melted the copper together, fusing it into a ball of metal. The joint is quite strong, being virtually welded. No flux was necessary.

"By using a gas fire lighter, much larger gauges of wire can be jointed with ease, and the range of the match when used as a source of heat appears to be from about 40 s.w.g. upwards. It is interesting to note that the melting point of copper is 1,083°C."

Mr. Hart has sent us a number of sample joints with wires ranging from 42 s.w.g. to 20 s.w.g. and, in all of these, the joint was electrically sound. The wires forming the joint were tightly twisted, ending in a fairly large blob of copper where the two had fused together. I had expected to find that the insulation was of the self-soldering variety but this was not so. Checks showed that some samples had oil-based enamel whilst the others had the tougher "synthetic" enamel.

The idea certainly works and it provides a rather novel answer to one of the annoying little constructional problems which beset us from time to time.

NEW INEXPENSIVE WIDE RANGE R.F. SIGNAL GENERATOR

The G.30 is a very convenient and inexpensive Signal Generator covering the frequencies from 120 kc/s to 240 Mc/s in seven switched bands. This wide coverage makes it extremely useful for most experimental and alignment work. The r.f. output which is in excess of 100m/V can be internally or externally modulated, the internal modulation being supplied at 400 c/s. The depth of modulation is adjustable from 0–50% by a knob control. The 400 c/s modulating frequency is also available at two sockets on the front panel. The G.30 Signal Generator is priced at £24.15.0.

Supplied by K.L.B. Electric Ltd. of Croydon, Surrey.

Radio for the Sea Traveller

With reference to the item published on page 852 of our July 1965 issue, it has been brought to our attention by Eddystone Radio Ltd. (formerly Stratton & Co. Ltd.) that they have for many years marketed receivers specifically designed for seafaring folk.

Converting Output Transformers for Transistor Use

By Arthur Brett

How to adapt those discarded valve transformers for use in transistor circuits

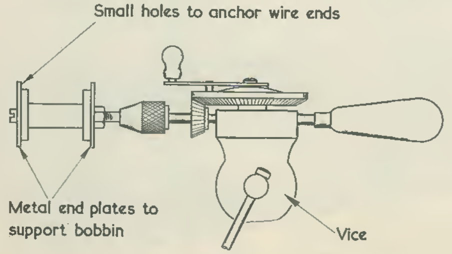
WITH THE POPULARITY OF TRANSISTORS IN SMALL amplifiers and receivers, many constructors find that they have a large number of valve components left over from earlier days. The purpose here is to describe an easy method of converting valve output transformers for use in transistor circuits without the need for going into transformer design.

Basic Facts

A few basic facts regarding output transformers should, however, be considered.

1. The power rating of a transformer is fixed by its core size.
2. The voltage developed across the secondary is equal to $\dfrac{\text{secondary turns} \times \text{primary voltage}}{\text{primary turns}}$
3. The current in the secondary is equal to $\dfrac{\text{primary turns} \times \text{primary current}}{\text{secondary turns}}$
4. The inductance of the primary is proportional to the number of primary turns squared.
5. The impedance reflected between primary and secondary is proportional to the turns ratio squared.

Before an output transformer may be modified two facts must be ascertained, firstly the impedance of speaker it is intended for, and secondly that the power rating will be sufficient. As an approximate guide to transformer ratings, those used in a battery valve portable using the DL96 range of valves would be 250mW, and the ones in small domestic mains valve receivers 1 to 3W. Higher power transformers are usually marked or are from equipment whose power is known.



A simple method of winding bobbins using a hand drill

After a suitable transformer has been selected, the first step in carrying out the modification is to unsolder the tagstrip, if fitted, and remove the laminations. Care should be taken not to damage the lamination insulation, which may be paint or very thin paper attached to one side of the laminations. Next unwind the primary paying no attention to the number of turns and then unwind the secondary, this time counting the number of turns. The secondary is usually the inner winding but this should be checked before the outer winding is removed.

At this stage we will have established the number of turns, which we will call N, for a particular known loudspeaker impedance.

Rewinding the Secondary

If the transformer is required to match to the same impedance speaker as before rewind the secondary with the same number of turns. If a different impedance is required the number of secondary turns needed is given by

$$N\sqrt{\frac{\text{Required impedance}}{\text{Original impedance}}}$$

The current flowing is inversely proportioned to the number of turns and hence the new wire cross-sectional area will be given by

$$\frac{\text{Old cross sectional area} \times N}{\text{Turns required}}$$

The appropriate wire gauge may then be found from wire tables. The ratio of the transformer should now be decided on and the primary turns will be given by number of secondary turns x ratio. The wire gauge is found by using the same formula as for the secondary.

As a large safety margin is usually used in designing these transformers the wire gauge does not have to be exact and several gauges either way will be suitable. If no micrometer or wire tables are available an acceptable result may be obtained using 22 to 26 s.w.g. for the secondary and 28 to 36 s.w.g. for the primary. Since the voltages used in transistors are relatively low very little insulation is needed, one layer of thin paper being sufficient between primary and secondary. A layer of any adhesive tape is sufficient for the outside but a layer of paper should be placed over the winding first, as certain adhesives have harmful effects on enamel insulations.

All that remains is to re-insert the laminations in the same manner as occurred in the original transformer and reconnect the tagstrip.

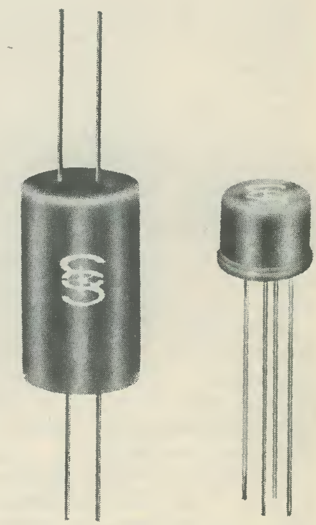
Interstage Transformers

The above procedure could also be used for converting small transformers for interstage use provided the primary or secondary impedance being matched is known. However, it is not recommended, as the number of turns required are very high and the wire of a fine gauge.

The rewinding of a transformer bobbin may be made easier by fitting to a simple mandrel using a wheel brace held in a vice as shown in the diagram. The gear ratio between the hand wheel and chuck may be established by counting the teeth on each. When winding, it is then only necessary to count the revolutions of the hand wheel.

The RAYLAY

Two models are available at the moment. The model 651 employs a small tungsten filament incandescent source of light, whilst the model 661 employs a gas discharge tube as the light source. The model 651 has the lower "on" resistance and can be actuated by lower voltages, but the model 661 has the higher speed of operation.



The Raylay shown on the left is model 661 which employs a neon light source and that on the right is model 651 with a tungsten filament light source

ORDINARY RELAYS ARE LARGE DEVICES WHICH do not fit at all easily into modern miniature semiconductor equipment and, like most devices employing moving parts, have a reliability which is considerably lower than modern semiconductor devices. The "Raylay" is a modern miniature device which can replace the relay in many circuits and has a number of special advantages.

The control signal is fed to the two input terminals of the "Raylay" and is used to generate light inside an opaque box. The output terminals of the device are connected to a photoconductive cell which is also placed within the box. When a signal is applied to the input, the light falling on the photocell causes the resistance of the latter to fall by a factor of up to one million and a current can pass between the output terminals.

It should be emphasised that the output of the "Raylay" is completely separated from the input (as in the ordinary relay). When compared with the relay, the "Raylay" has the advantages that it is silent in operation, has a life of the order of 100,000 hours or more, has a much higher resistance to shock and vibration, has an increased speed of operation, and requires a smaller amount of operating power. In addition contact bounce, contact pitting and radio frequency noise are eliminated. The "Raylay" is recommended for missile and similar applications.

The "Raylay" is manufactured by Messrs. Solid State Electronics Corporation, of 15321 Rayen Street, Sepulveda, California and can be obtained in England from Messrs. Associated Instrument Marketing Ltd., of 22 Charing Cross Road, London, W.C.2.

Nominal Characteristics

	Model 651	*Model 661*	
Control Voltage	2	135	volts
Control Current	24	2	m A
"ON" Resistance	700	1500	Ohms
"OFF" Resistance	500	500	Megohms
Max. Dissipation (Derate 3 mw/°C)	250	250	Milliwatts
"Switch-on" Time	20	1	Millisec.
"Switch-off" Time	30	7	Millisec.
Temperature Range	−55 +70	−55 +70	°C

A.C. Voltage Measurement with a D.C. Voltmeter

By L. BAILEY

Although, in radio and TV work, d.c. voltages are measured much more often than a.c., a reliable a.c. voltmeter is still very useful. By using a silicon h.t. rectifier connected in series with it, any moving-coil voltmeter can be used to measure a.c. voltages.

The d.c. ranges of a multirange meter usually retain their accuracy for a longer period than the a.c. ranges. The calibration depends mainly on the movement and the series resistor and, if treated with care, these should be stable over many years. When, as in multirange meters, a rectifier is added for the a.c. ranges, this introduces another possible source of calibration error.

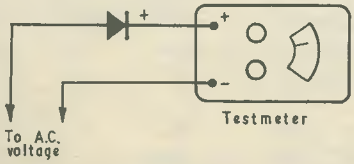
Instrument rectifiers usually give good results, but sooner or later their internal resistance starts to increase. Often, the drift in calibration is very gradual, and it may not be noticed until a considerable amount of time has been wasted looking for some non-existent fault.

Currently available silicon h.t. rectifiers can be used to check the calibration of an a.c. meter, to take a.c. voltage measurements when the a.c. ranges of a meter are known to be faulty, and to enable any moving-coil voltmeter to give a.c. voltage readings of sufficient accuracy for most work.

Connecting the Rectifier

The silicon rectifier is connected in series with the d.c. voltmeter, with the cathode to the positive terminal of the meter. It could, indeed, be made up into a probe.

The rectifier should have an adequate peak inverse voltage rating, in this instance greater than 1.414 times the r.m.s. value of the a.c. voltage to be measured. Some rectifiers have a p.i.v. of 800, and these would be suitable for use up to 566 volts r.m.s.



Inserting a silicon h.t. diode in series with the positive test lead of a d.c. testmeter

An h.t. rectifier intended for use on 250V a.c. mains will have a p.i.v. rating of at least 250 x 1.414 x 2=700V (approx).

A moving-coil meter used with a rectifier reads the average value of the current. With full-wave rectification, the average voltage multiplied by 1.11 is equal to the r.m.s. voltage, and as r.m.s. is most commonly used in a.c. measurements, most a.c. meters are calibrated to indicate r.m.s. voltages.

Due to the half-wave current supplied to the meter when using a half-wave rectifier, the d.c. reading is half of the full-wave average voltage.

TABLE

Readings Obtained with a Half-Wave Rectifier

A.C. Volts (r.m.s.)	D.C. Meter Reading	x 2.22	x 2.3	x 2.4
2.5	1.0	—	—	2.4
5	2.1	—	—	5.04
7.5	3.2	—	—	7.68
10	4.3	—	9.68	10.3
15	6.3	—	14.5	15.1
20	8.9	19.8	20.4	
25	11.2	24.8		
30	13.5	30		
50	22.5	49.9		
75	34	75.4		
100	45	100		
150	68	151		
200	90	200		
225	101	225		
230	105	233		
235	107	235		
250	111.2	250		
360	162	360		

To obtain the r.m.s. value from the d.c. reading, we must therefore multiply this by 2.22. For d.c. readings of 10 volts or more this will give an accurate indication of the a.c. voltage to within 2 or 3%, depending on the accuracy of the d.c. meter used. When lower voltages are measured, the forward resistance of the rectifier has some effect on the reading, and the d.c. reading must be multiplied by a different figure. For d.c. readings between 5 and 10 volts, 2.3 is suggested, and 2.4 or 2.5 for voltages lower than 5 volts.

Experimental Readings

The Table gives details of experimental readings taken by the author. These were obtained using meters having an accuracy better than 2% of f.s.d. and, as may be seen, quite reliable a.c. readings can be obtained.

Various types of moving-coil voltmeters having sensitivities from 50μA to 6mA for full-scale deflection have been used in experiments in this method of a.c. measurement.

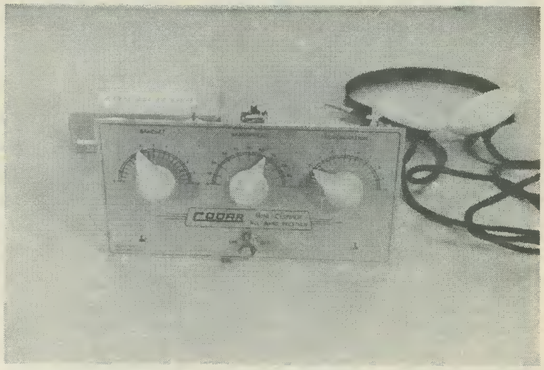
Different silicon rectifiers with suitable ratings were tried, and consistent results obtained.

When using this method of a.c. measurement, the same care in selecting a suitable range for the d.c. meter should be used as with any other measurement of voltage. The silicon rectifier has a low forward resistance and could pass sufficient current to damage the meter if the latter was switched to an incorrect range.

TRADE REVIEW . . .

The Codar "Mini-Clipper" All-Band Receiver

(10-2,000 metres)



THE BEGINNER WISHING TO MAKE HIS DEBUT INTO the fascinating realm of short wave listening cannot do better than select one of the kits available from various suppliers when planning to build his first s.w. receiver. A kit of parts supplied specifically for this purpose has much to recommend it, containing as it does, selected components and an attractive panel, complete with a chassis to make the receiver look something of which to be proud. It is often difficult for the beginner to know just what components to purchase, the rating of resistors and types of capacitors often presenting a stumbling block in this respect. At a later stage in the hobby, when more experience has been acquired, such problems will not arise. Until that stage has been reached, the intending constructor is advised to profit from the experience of others in this field.

Of the kits available, that supplied by the Codar Radio Company of Southwick, Sussex, the Mini-Clipper All-Band Receiver, is illustrated here. This uses a valve in the basic circuit and has provision for adding a two transistor amplifier as an optional extra unit. The beginner can thus firstly experiment with his completed one valve s.w. receiver and then follow this by secondly obtaining better results and experience of building transistorised equipment without having to scrap his original work.

The basic kit contains all the parts required for building the one valve set. It includes an IT4 valve, chassis, front panel, one coil, all necessary components, wire, solder, etc., and detailed instructions for building the receiver. Four further coils can be purchased as required, headphones, battery pack, etc., can also be obtained as extras.

The instructions for assembly are clear and are given step-by-step. A point-to-point wiring diagram is provided in addition to the circuit diagram. We would advise beginners to purchase the additional parts for the two transistor stages at the same time as the basic kit, this additional stage improving the overall perofrmance of the receiver.

If the instructions are carefully followed, no difficulty should be experienced when constructing this receiver. The chassis is supplied pre-punched and with all holes drilled. With the aid of the point-to-point diagrams, no difficulty occurs with respect to component positioning. Provided a good soldered joint is made, the beginner may construct a successful s.w. receiver from this kit in one evening.

The receiver uses 1.5V filament supply and 69V h.t. potential, the latter being a modest voltage which cannot harm the inexperienced. These voltages are provided from a battery pack via a miniature 4-pin plug.

Codar kits are available from the manufacturer —Codar Radio Company, Bank House, Southwick Square, Southwick, Sussex.

Queries. We regret that we are unable to answer queries other than those arising from articles appearing in this magazine nor can we advise on modifications to equipment described. Queries should be submitted in writing.

Correspondence should be addressed to the Editor, Advertising Manager, Subscription Manager or the Publishers as appropriate.

Opinions expressed by contributors are not necessarily those of the Editor or proprietors.

Contributions on constructional matters are invited, especially when they describe the building of particular items of equipment. Articles should be written on one side of the sheet only and should preferably be typewritten, diagrams being on separate sheets. Typewritten articles should have maximum spacing between lines. In handwritten articles, lines should be double-spaced. Diagrams need not be large or perfectly drawn, as our draughtsmen will re-draw in most cases, but all relevant information should be included. Sharp and clear photographs are helpful, where applicable. If negatives are sent, we usually work from these rather than from prints. Colour transparencies normally reproduce badly—black and white photographs are very much better. Details of topical ideas and techniques are also welcomed and, if the contributor so wishes, will be re-written by our staff into article form. All contributions must be accompanied by a stamped addressed envelope for return, if necessary, and should bear the sender's name and address. Payment is made for all material published.

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FOR SALE. Small domestic broadcast receiver, K.B. Minuet, red plastic case, cream dial. £5 plus postage. —Box No. F242.

FOR SALE. Creeds teleprinter No. 3 with matching Westinghouse power rectifiers. Both items £5. Carriage paid. Brown Bouverie voltage regulator. Brand New. Cost £300. Any offer considered.—Box No. F243.

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continued on page 71

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continued from page 69

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