THE Radio Constructor

RADIO
TELEVISION
AUDIO
ELECTRONICS

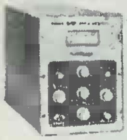
VOLUME 16 NUMBER 2
A DATA PUBLICATION
PRICE TWO SHILLINGS

September 1962

"Clymax" 6-Transistor Printed Circuit Pocket Superhet

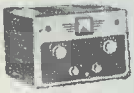
Heathkit

DAYSTROM



SB-10U

SINGLE SIDEBAND ADAPTOR. Model SB-10U. May be used with most A.M. transmitters. Less than 3w R.F. input power required for 10w output. Operation on 80, 40, 20. 15 and 10m bands on U.S.B., L.S.B. or D.S.B. **£39.5.0**



DX-40U

AMATEUR TRANSMITTER, Model DX-40U. Covers all amateur bands from 80 to 10 metres; crystal controlled. Power input 75W C.W., 60W peak controlled carrier phone. Output 40W to aerial. Provision for V.F.O. Filters minimise TV interference. **£33.19.0**

GD-1U

GRID-DIP METER. Model GD-1U. Functions as oscillator or absorption wave meter. With plug-in coils for continuous frequency coverage from 1.8 Mc/s to 250 Mc/s. **£10.19.6**

Three Additional Plug-in Coils Model 34-1U extend coverage down to 350 kc/s. With dial correlation curves. **17/6**

TRANSISTORISED VERSION. Model XGD-1. Similar to GD-1U. Fully transistorised with a frequency range of 1.8 to 45 Mc/s. **£10.18.6**

O-12U

5" OSCILLOSCOPE. Model O-12U. Has wide-band amplifiers, essential for TV servicing, FM alignment, etc. Vertical frequency response 3 c/s to over 5 Mc/s. without extra switching T/B covers 10 c/s to 500 kc/s in 5 ranges. **£38.10.0**

2½in. SERVICE 'SCOPE. Model OS-1. Light, compact portable for service engineers. Dim. 5" x 8" x 14½" long. Wt. 10½lb. **£19.19.0**

S-3U

ELECTRONIC SWITCH. Model S-3U (Oscilloscope Trace Doubler.) Enables a single beam oscilloscope to give simultaneous traces of two separate and independent signals. Switching rates approx. 150, 500, 1,500, 5,000 and 15,000 c/s. Sig. freq. response 0–100 kc/s. +1dB. Separate gain controls and sync. output. Sig. input range 0.1–1.8V r.m.s. **£11.15.6**

C-3U

RESISTANCE CAPACITANCE BRIDGE Model C-3U. Measures capacity 10pF to 1,000μF, resistance 100Ω to 5MΩ and power factor. 5–450V test voltages. With safety switch. **£9.5.0**

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. **£21.9.6**

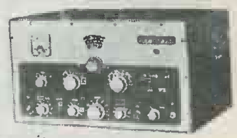
AG-9U

TRANSISTOR INTERCOM. Models XI-1U & XIR-1U. The master unit uses a 4-transistor amplifier, constructed on a printed circuit board, and an internal 9V battery. Remote stations use a similar battery for call only. Up to five remote units can be ordered for each master.

XIR-1U (remote) **£4.7.6**

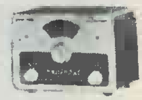
XI-1U (master) **£10.19.6**

SUGDEN MOTOR UNIT "CONNOISSEUR CRAFTSMAN." Heavy duty motor operating at 33⅓ and 45 r.p.m. Very heavy 12" turntable. Virtually no rumble. **£18.3.6**



DX-100U

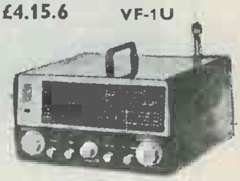
AMATEUR TRANSMITTER, Model DX-100U. The world's most popular, compact and completely self-contained Amateur Transmitter. Covers all amateur bands: 160–10 m. 150W d.c. input. Careful design has achieved the stability and high performance for which the DX-100U is noted and no less than 35 disc ceramic capacitors reduce TVI to a minimum. **£74.19.0**



VF-1U

VARIABLE FREQUENCY OSCILLATOR. Model VF-1U. Calibrated 160–10 m. Fundamentals on 160 and 40 m. Ideal for our DX-40U and similar transmitters. **£11.17.6**

BALUN COIL UNIT. Model B-1U. Will match unbalanced co-axial lines to balanced lines of either 75 or 300Ω impedance. **£4.15.6**



GC-1U

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 circuit boards, telescopic whip antenna, tuning meter and large slide-rule dial, 10 transistors. **£39.17.6**

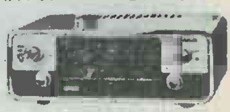
THE BEST QUALITY

RSW-1

4-WAVEBAND TRANSISTORISED PORTABLE RECEIVER, Model RSW-1. This model possesses Medium, Trawler and two Short-wave bands and is midway between the domestic broadcasting and professional general communications receiver. Ideal and inexpensive for those who wish to listen to world broadcasts, shipping and aviation communications. It is not the set to buy if you wish only to enjoy domestic broadcasting. In a handsome leather case, it has retractable whip aerial and socket for car radio use. **£22.8.0**

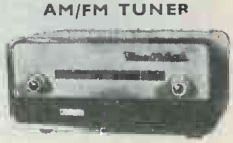
UXR-1

TRANSISTOR PORTABLE RADIO. Model UXR-1. Pre-aligned I.F. transformers, printed circuit and a 7" x 4" high-flux speaker. Real hide case. **£14.3.0**



AM/FM TUNER

HI-FI AM/FM TUNER, Model AFM-1. Available in two units which, for your convenience, are sold separately: Tuning heart (AFM-T1—£5.5.6 incl. P.T.) and I.F. amplifier (AFM-A1—£20.13.0). Printed circuit board, 8 valves. Built-in power supply. Total **£25.18.6**



FM TUNER

HI-FI FM TUNER, Model FM-4U. Also available in two units as above: R.F. tuning unit (£3.2.0 incl. P.T.) with I.F. output of 10.7 Mc/s, and amplifier unit, with power supply and valves (£12.6.0). Total **£15.8.0**

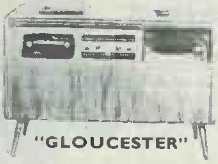
POWER SUPPLY UNIT. Model MGP-1. Input 100/120V 200/250V, 40–60 c/s. Output 6.3V, 2.5A A.C.: 200, 250, 270V, 120mA max. D.C. **£5.2.6**

MONEY-SAVING "PACKAGED DEALS"

For the benefit of customers wishing to purchase several units of their Hi-Fi equipment at the same time, useful price reductions are offered. Such "Packaged Deals" may include RECORD PLAYERS and TAPE DECKS of your preference, not necessarily featured in our catalogue. Two money-saving examples are given here and quotations for your own special requirements will gladly be sent on request.

GL-58 Transcription Unit	£19.12.6	TA-1M	£19. 2.6
S-33 Stereo Amp.	£13. 7.6	Collaro "STUDIO"	£17.10.0
Twin SSU-1 Speakers		USC-1	£19.10.0
(Bookcase Type)	£22.10.0	MA-12	£11. 9.6
	£55.10.0		£67.12.0
	Packaged £53.4.0		**Packaged £63.15.0**

All models directly available from the makers: **DAYSTROM Ltd** GLOUCESTER



"GLOUCESTER"

HI-FI EQUIPMENT CABINETS. Our four equipment cabinets meet a wide variety of tastes and requirements: the "CHEPSTOW" was designed for those who have little floor space, the contemporary "MALVERN" for the Tape and Gram. enthusiast, and the "GLOUCESTER" Mk. I and II for those with traditional tastes. All parts are pre-cut and drilled for easy assembly, and left "in the white".
Prices from **£11.12.6** to **£18.10.0**

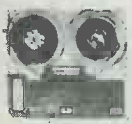
GL-58

TRANSCRIPTION RECORD PLAYER (STEREO). Manufactured by Goldring-Lenco. This 4-speed unit is fitted with a G60 pick-up arm. Infinitely variable speed adjustment from 33⅓ to 80 r.p.m. Fixed speed of 16 r.p.m. Its balanced turntable (3¾ lb) reduces rumble, wow and flutter to very low level. The unique lowering device fitted provides absolutely safe means of placing pick-up on record **£19.12.6**

S-33

6W STEREO AMPLIFIER, Model S-33. 3 watts per channel, 0.3% distortion at 2.5 w/chnl., 20dB N.F.B. Inputs for Radio (or Tape) and Gram., Stereo or Monaural, ganged controls. Sensitivity 100mV. **£13.7.6**

AT LOWEST PRICES



Truvox D83

TRUVOX D83 & D84 TAPE DECKS. High quality mono/stereo tape decks.
D83, 2 track, for highest fidelity. **£31.10.0**
D84 (identical presentation), 4-track, for most economical use of tape. **£29.8.0**

COLLARO "STUDIO" TAPE DECK. The finest buy in its price range. Operating speeds: 1⅞, 3¾ and 7½ i.p.s. Two tracks. "Wow" and "flutter" not greater than 0.15% at 7½ i.p.s. Long Term Speed Stability better than 0.5%. **£17.10.0**

"STUDIO"

HI-FI STEREO/MONO PRE-AMPLIFIER. Model USP-1. Extremely versatile unit. Gain may be preset over a wide range. Input 2mV-20mV. Output 20mV-2V **£7.7.6**

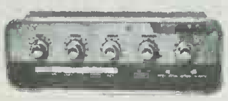
HI-FI SINGLE CHANNEL AMPLIFIER Model MA-12. 12W output, wide freq. range, low distortion. **£11.19.6**

TAPE RECORDING AND REPLAY HI-FI AMPLIFIER

Mono model TA-1M, Stereo model TA-1S. For use with most tape decks. Thermometer type recording indicators, press-button speed compensation and input selection, 3-position bias level and printed circuit construction.

TA-1S

TA-1M	£19. 2.6
TA-1M & Collaro STUDIO	£30.10.0
TA-1M & TRUVOX D83 ...	£47. 2.6
TA-1M & TRUVOX D84 ...	£45. 5.0
TA-1S	£24.10.0
TA-1S & STUDIO	£35.14.0
TA-1S & TRUVOX D83 ...	£52. 6.0
TA-1S & TRUVOX D84 ...	£50. 9.6

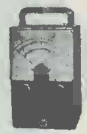


USC-1

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

FINEST ELECTRONIC KITS IN THE WORLD

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 impedance 11MΩ. dB measurement has centre-zero scale. Complete with test prods, lead and standardising battery. **£13.18.6**



V-7A

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. **£12.10.0**

MM-1U

R.F. SIGNAL GENERATOR. Model RF-1U. Up to 100 Mc/s fundamental and 200 Mc/s on harmonics and up to 100mV output on all bands. **£12.15.6**

AUDIO WATTMETER. Model AW-1U. Up to 25W continuous, 50W intermittent. **£15.15.6**

AUDIO VALVE MILLIVOLTMETER. Model AV-3U. 1mV-300v A.C. 10 c/s to 400 kc/s. **£14.17.6**

RF-1U

AUDIO SINE-SQUARE WAVE GENERATOR. Model AO-1U. Covers 20 c/s to 150 kc/s and square waves to 50 kc/s in four ranges. Maximum output 10V, distortion less than 1%. **£13.15.0**

CAPACITANCE METER. Model CM-1U. Direct-reading 4½" scale. Full-scale ranges 0–100μμF, 0–1,000μμF, 0–0.01μF and 0–0.1μF. **£15.15.0**

SSU-1

HI-FI SPEAKER SYSTEM. Model SSU-1. Ducted-port bass reflex cabinet "in the white". Twin speakers. With legs £11.19.6. **£11.5.0**

HEATHKIT ELECTRONIC WORKSHOP, Model EW-1. This educational kit will teach and amuse your children. It can make 21 exciting experiments including transistor radios, burglar alarm, radio or TV silencer, intercom., etc. **£7.18.0**

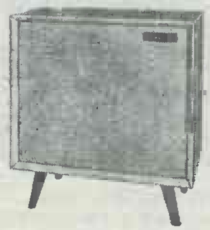
UJR-1

JUNIOR TRANSISTOR RADIO, Model UJR-1. Single transistor set. Excellent introduction to radio. An instructive present. **£2.13.6**

HI-FI STEREO AMPLIFIER, Model S-99. 18W output. Ganged controls. Stereo/mono gram., radio and tape recorder inputs. Push-button selection. Printed circuit construction **£27.19.6**

S-99

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 32–20,000 c/s. Capable of doing justice to the finest programme source, its polar distribution makes it ideal for really Hi-Fi Stereo. Delivered complete with speakers, cross-over unit, level control, Tygan grille cloth, etc. All parts pre-cut and drilled for ease of assembly and left "in the white" for finish to personal taste. **£23.4.0**



THE "COTSWOLD"

Prices include free delivery U.K. Deferred terms available over £10

★ **SEND THIS COUPON NOW FOR FURTHER INFORMATION**

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Without obligation please send me (Tick here)

BRITISH HEATHKIT CATALOGUE ....

FULL DETAILS OF MODEL(S) ....

DAYSTROM LTD DEPT RC9 GLOUCESTER . ENGLAND

A member of the Daystrom Group, manufacturers of the

WORLD'S LARGEST-SELLING ELECTRONIC KITS

STERN'S MULLARD DESIGNS

Designed by MULLARD—presented by STERN'S strictly to specification

MULLARD "5-10" MAIN AMPLIFIER

For use with the MULLARD 2-valve pre-amplifier with which undistorted power output of up to 10 watts is obtained. We supply **SPECIFIED COMPONENTS AND NEW MULLARD VALVES**, including **PARMEKO MAINS TRANSFORMER** and choice of the latest Ultra-Linear **PARMEKO** or the **PARTRIDGE** Output Transformer.

COMPLETE KIT OF PARTS (**PARMEKO** Output Trans) **£10.10.0**

Alternatively we supply ASSEMBLED and TESTED. **£11.10.0**

INCORPORATING PARTRIDGE OUTPUT TRANSFORMER, £1.6.0 EXTRA.

MULLARD'S PRE-AMPLIFIER TONE CONTROL UNIT

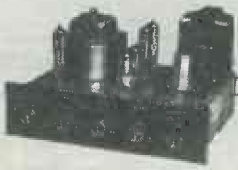
Employing two EF86 valves, and designed to operate with the MULLARD **MAIN AMPLIFIERS**, but also perfectly suitable for other makes.

PRICE COMPLETE KIT OF PARTS **£6.6.0** ASSEMBLED AND TESTED **£8.0.0**

Supplied strictly to **MULLARD'S SPECIFICATION** and incorporating:

- Equalisation for the latest R.I.A.A. characteristics.
- Input for Crystal Pick-ups, and variable reluctance magnetic types.
- Input (a) Direct from High Imp. Tape Head. (b) From a Tape Amplifier or Pre-Amplifier.
- Sensitive Microphone Channel. ● Wide range **BASS** and **TREBLE** Controls.

THE MULLARD "510/RC" AMPLIFIER



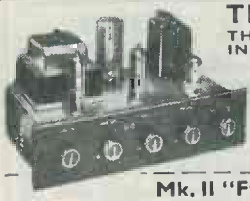
The popular and very successful complete "5-10" incorporating Control Unit providing up to 10 watts high quality reproduction. Only Specified Components and new **MULLARD VALVES** are supplied including **PARMEKO MAINS TRANSFORMERS** and choice of the latest **PARMEKO** or **PARTRIDGE ULTRA**-Linear Output Transformers.

KIT OF PARTS **£11.10.0** OR ASSEMBLED and TESTED **£13.10.0**

H.P. Dep. £2.6.0 12 months at 17/-. Dep. £2.14.0 12 months at 19/10

ABOVE incorporating PARTRIDGE OUTPUT TRANS. £1.6.0 extra

THE MULLARD "33/RC"



THE IDEAL AMPLIFIER FOR A SMALL HIGH QUALITY INSTALLATION PROVIDING EXCELLENT REPRODUCTION OF UP TO 3 WATTS OUTPUT

COMPLETE KIT OF PARTS **£7.10.0** OR ASSEMBLED and TESTED **£8.19.6**

(plus 6/6 carriage and insurance) H.P. Terms: Deposit £2.0.0 and 8 months at £1.0.0. Complete to MULLARD'S SPECIFICATION including Mullard valves and a **PARMEKO OUTPUT TRANSFORMER.**

Mk. II "Fidelity" FM TUNING UNIT

An attractively presented Unit incorporating MULLARD PERMEABILITY TUNING HEART and corresponding Mullard valve line-up. Very suitable to operate with our Mullard.

KIT OF PARTS **£10.0.0**

ASSEMBLED AND TESTED **£14.5.0**

Deposit £2.17.0. 12 months of £1.0.11.

A BULK PURCHASE ENABLES US TO OFFER

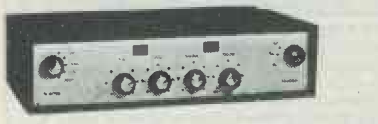
THE "TUDOR" AM/FM TUNING UNIT

A SELF POWERED HIGH FIDELITY TUNER OF OUTSTANDING DESIGN, PROVIDES FULL COVERAGE of the VHF/FM TRANSMISSIONS and also the LONG and MEDIUM WAVE BANDS.

PRICE ONLY **£19.19.0** Deposit £4.0.0 and 12 months £1.9.4

Provides full coverage of the VHF/FM band (87-108 Mc/s) and also the LONG and MEDIUM Wavebands. Incorporates Multiplex outlet socket for stereophonic purposes (when adopted) and separate controls for tuning FM and AM bands. Operates perfectly with the STERN-MULLARD AMPLIFIERS and contains matching FRONT PANEL in Black/Gold or White/Black. Also operates equally well with any Amplifier requiring input of 100 to 350 m/Volts.

THE "TUDOR" STEREO AMPLIFIER



For Only **£18.18.0**

Deposit £4.0.0

12 months £1.9.4

A self contained Amplifier designed to provide high quality stereophonic and monophonic reproduction. Each channel provides a rated output of 6 watts and for monophonic operation approx. 12 watts is produced. Separate BASS and TREBLE CONTROLS, DESCRIPTIVE LEAFLET IS AVAILABLE.

PRICE REDUCTIONS

(a) The KIT OF PARTS to build both the "5-10" Main Amplifier and the 2-valve PRE-AMP CONTROL UNIT H.P. Dep. £3.7.0 and 12 months at £1.2.9 .... **£15.15.0**

(b) The "5-10" and the 2-stage PRE AMP both ASSEMBLED and TESTED H.P. Dep. £3.16.0 and 12 months at £1.7.8.......... **£18.18.0**

With Partridge O/put Transformer £1.6.0 extra.

RECORD PLAYERS

The Standard **GARRARD "AUTO-SLIM"** 4-speed Autochanger with Crystal Pick-up...... **£8.10.0**

COLLARO "JUNIOR" 4-SPEED SINGLE RECORD PLAYER with separate Crystal Pick-up .... Carriage and Insurance 5/-. **£3.15.0** Above Pick-up separately for £1.6.6.

GARRARD "AUTOSLIM DE-LUXE" 4-speed Autochanger incorporates transcription Pick-up Arm.......... **£12.14.6**

The **NEW COLLARO C60** 4-speed Autochanger unit with Studio "O" Pick-up........ **£7.19.6**

B.S.R. MODEL UA14. A 4-speed mixer Autochanger with Crystal Pick-up **£7.19.6**

GARRARD MODEL TA/Mk.II 4-speed Player fitted high output Crystal Pick-up.......... **£8.10.0**

PHILIPS MODEL AG1016 A 4-speed Player which can be operated both manually and automatically. Suitable for Mono or Stereo operation **£13.13.0**

Carriage and Insurance on each above 5/- extra.

MULLARD FOUR CHANNEL MIXING UNIT

Self powered. Cathode follower output. Incorporates Two inputs for MICROPHONES, One input for CRYSTAL PICK-UP and a fourth for RADIO or TAPE

Complete Kit of Parts **£8.8.0** Assembled and Tested **£10.0.0**

TERMS: Deposit £2 and 12 months at 15/-.

Alternatively **MODEL I.L.** provides for one microphone Input matched for moving coil or Ribbon Mike. £1.17.0 extra.

SPECIAL CASH OFFER

This very attractive **PORTABLE AMPLIFIER CASE** together with a good quality **GRAM AMPLIFIER** and a matched **P.M. SPEAKER.**

ALL for ONLY **£8.7.6** (Plus 7/6 Carr. & Ins.)

A 2-stage Amplifier incorporating 3 B.V.A. valves. Separate BASS and TREBLE CONTROLS. The Case also accommodates almost any make of Autochanger. Attractively finished in Grey Rexine.

WE ALSO SUPPLY SEPARATELY—

(a) The **AMPLIFIER £4.2.6** (b) The **CASE £3.17.6**
(c) 6½in. **P.M. SPEAKER** 18/9. Carriage and Insurance 4/- extra.

THE "TRUVOX" TOUCH

With the New "SERIES 60" RECORDERS

TWO MODELS ARE AVAILABLE

R62. A Twin Track Recorder with speeds of 1⅞ and 3¾ i.p.s.

R64. A Four Track Recorder with speeds of 3¾ and 7½ i.p.s.

PRICE FOR EACH MODEL **£40.19.0**

Deposit £8.4.0., 12 months of £3.0.1.

They offer full MIXING, MONITORING and SUPERIMPOSING facilities. There is an AUTOMATIC STOP, a REV COUNTER and a storage compartment for 7 in. spools tape.

DESCRIPTIVE LEAFLETS READILY AVAILABLE

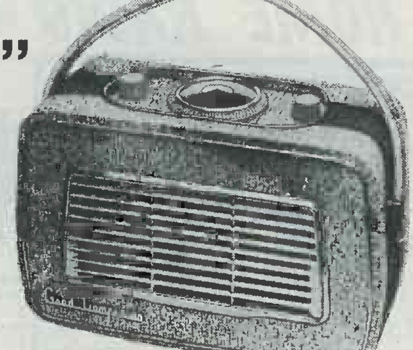
STERN RADIO
PREMIER RADIO
MAIL ORDERS and all POSTAL ENQUIRIES to

Britain's MOST Popular Portable

The "GOOD COMPANION Mk. 2"

CAR RADIO & PORTABLE

USING LATEST CERAMIC TRANSFILTERS



DE-LUXE CABINET 20/- extra

One of the finest of its kind available. The design is the combined efforts of our technicians and of those of several of the leading manufacturers in the country, and the resulting set has a performance as good as if not superior to those selling at £20 and more. *It has the eight transistor set performance.* Features include **American Philco R.F. transistors and Mullard A.F. transistors**—Q.P.P. output giving 750mW—full coverage on Medium and Long—very fine tuning arrangement—excellent reception of difficult stations like 208—variable feed-back control—full tonal qualities—really superior looking cabinet size 11" x 8" x 3" approximately—car aerial attachment—several months operation from battery costing only **3/6**.

Circuit employs six transistors and two diodes. It incorporates all latest refinements. The transfilters are set, so no I.F. alignment is necessary. Anyone who can solder competently can make this set. The instructions are fully comprehensive with plenty of illustrations. Service is available in the unlikely event of your getting into difficulties. All components fully guaranteed.

Price of all components for Mk. 2 circuit and Standard Cabinet **£9.19.6** **Post and Insurance 5/– Battery 3/6 extra**

The Good Companion is fully described in last issue, pages 54–59

AGENTS
wanted to build up our Companion Receivers. Send addressed envelope for full particulars to Eastbourne.

STANDARD CABINET

The "TREMENDO COMPANION"

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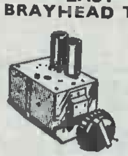

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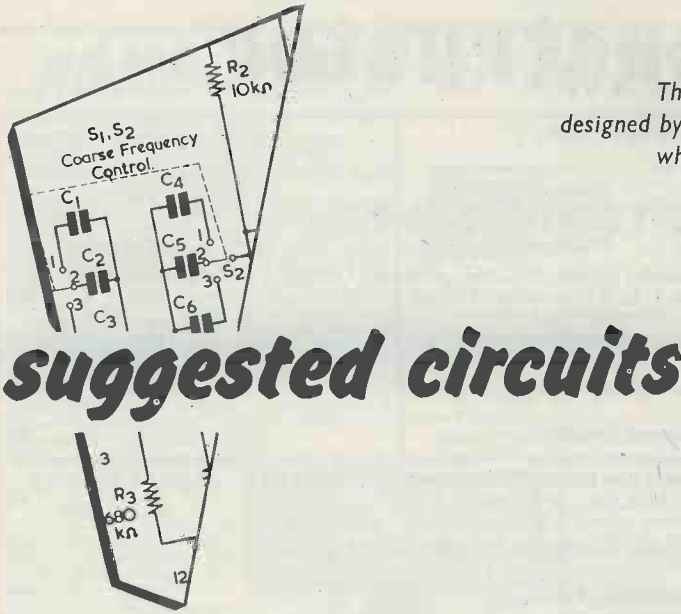

suggested circuits

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No. 142 Remote Volume Control Employing an L.D.R.

LIGHT DEPENDENT RESISTORS HAVE a number of interesting applications apart from their conventional usage in television automatic brightness or contrast control circuits. As an example, some L.D.R. light-operated relay circuits were described in "Suggested Circuits" No. 139[1], whilst the present article discusses the use of an L.D.R. in a remote volume control application.

Remote Volume Control

It is frequently desirable to control the gain of audio amplifying equipment from a remote point, typical examples being given in extension loudspeaker installations or with high fidelity equipments where the optimum listening position is some distance away from the pre-amplifier. However, it is very desirable to apply the volume control to an early voltage amplifying stage, and this results in the leads to the remote point having to carry a signal voltage which is both at low level and high impedance. A number of difficulties then arise, the most important of these being hum pick-up and the attenuation of the higher audio frequencies due to the self-capacitance of the screened wire which is required. In the device described here, remote volume control is achieved by varying the resistance of an L.D.R., and it has the advantage that the L.D.R. may be mounted in the amplifier chassis at the voltage amplifying stages into which it connects. No a.f. is, therefore, carried to the remote point and the risk of hum pick-up and loss of high frequencies is completely obviated.

A basic method of remotely controlling volume by means of L.D.R.'s is shown in Fig. 1. In this diagram two L.D.R.s form an effective potentiometer across which a.f. from a preceding voltage amplifier, or from the amplifier input terminals, is applied. Each L.D.R. is illuminated independently by a small lamp, the brightness of the lamps being controlled by a physical potentiometer sited at the remote point. When the slider of the remote potentiometer is at the top of its track, Lamp 2 is fully illuminated and Lamp 1 is extinguished. In consequence, L.D.R.1 has a high resistance, L.D.R.2 has a low resistance, and very little a.f. appears at their junction for application to the succeeding amplifier stages. When the slider of the remote potentiometer is at the bottom of its track, Lamp 1 is fully illuminated and Lamp 2 is extinguished. L.D.R.1 now has a low resistance, and L.D.R.2 has a high resistance, and almost all the applied a.f. is passed on to the following amplifier stages.

The arrangement of Fig. 1 provides remote volume control, mini-

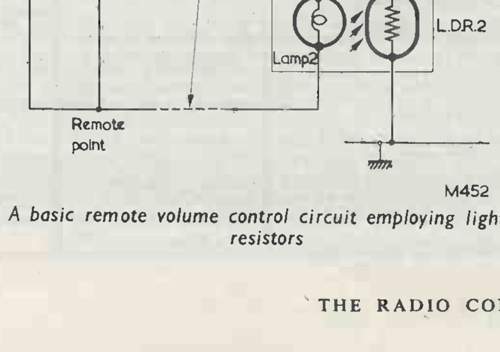


Fig. 1. A basic remote volume control circuit employing light dependent resistors

[1] "Light Dependent Resistor Control Circuits", June issue.

mum volume being given when the remote potentiometer slider is at the top of its track and maximum volume when it is at the bottom of its track. Obviously, intermediate volume levels will be given by intermediate settings of the remote potentiometer. The two L.D.R.'s may be mounted close to the a.f. stages into which they couple, and a.f. wiring may be short in consequence. The wiring to the remote point merely carries the d.c. supply for the lamps.

L.D.R. Performance

It was decided to employ a Mullard ORP12 for checking the circuit, since this type is a robust L.D.R. which has an adequate resistance range, and which is readily available to the home-constructor.[2]

Initially, an ORP12 was checked in an experimental rig to check resistance variation against illumination.

[2] The Mullard ORP12 may be obtained from Henry's Radio Ltd., 5 Harrow Road, London, W.2.

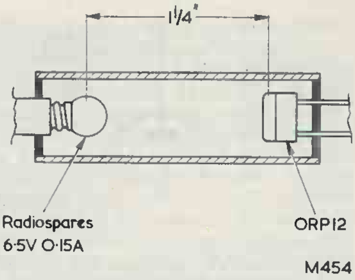


Fig. 3. A suitable lamp and L.D.R. assembly

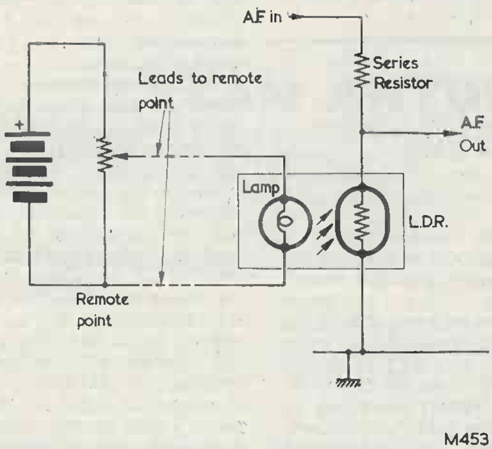


Fig. 2. An alternative to Fig. 1, which requires only one L.D.R.

tion. It was found that satisfactory results were given by the assembly shown in Fig. 3, wherein the light-sensitive area of the ORP12 is mounted 1¼in away from the filament of a RadioSpares 6.5 volt 0.15 amp dial lamp. These two components were mounted inside a cylinder having an internal diameter of ¾in, all external light being excluded.

Different voltages were then applied to the lamp, and the corresponding resistance of the L.D.R. was measured. The result is shown in the curve of Fig. 4. As will be noted, minimum L.D.R. resistance is 170Ω at 6.2 volt lamp potential, and rises to 1MΩ for 0.7 volt lamp potential. With resistance plotted on a log scale the curve is not excessively non-linear and indicates the feasibility of a useable remote volume control in a circuit such as that shown in Fig. 2, wherein the remote potentiometer would be a linear component.

The circuit of Fig. 1 offers a practicable means of remote volume control and should be capable of functioning adequately in practice. However, very nearly the same range of volume control can be achieved with a single L.D.R., together with a consequent reduction in costs and complexity. The basic single L.D.R. circuit is illustrated in Fig. 2 and, as may be seen, this consists quite simply of an L.D.R. in series with a fixed resistor. As the resistance of the L.D.R. varies, according to the setting of the remote potentiometer, so does the ratio between the applied a.f. and that appearing across the L.D.R. The arrangement of Fig. 2 has the disadvantage of giving an insertion loss of some 3.5 to 6dB according to circuit requirements, but this may normally be made good in most amplifier circuits. Fig. 2 has an additional advantage over that of Fig. 1 in that only two lamp circuit leads are needed for connection to the remote point instead of three. The circuit of Fig. 2 is that which has been investigated by the writer for this article.

Fig. 4. The curve for lamp voltage and L.D.R. resistance given with the assembly of Fig. 3

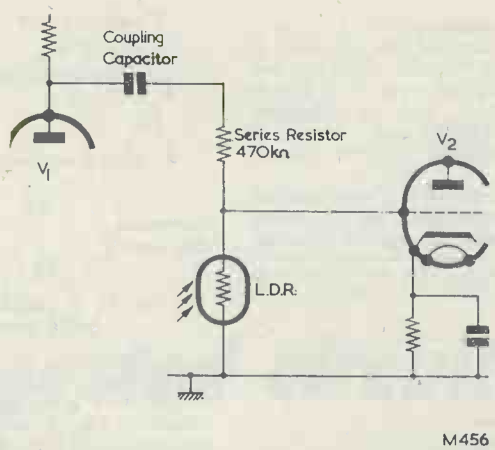


Fig. 5. The L.D.R. and series resistor of Fig. 2 connected into a practical a.f. amplifier circuit. V_1 and V_2 are voltage amplifiers

Attenuation in Practical Circuits

The L.D.R. checked by the writer offered a resistance range of 170Ω to 1MΩ. The manufacturer's data for the ORP12 indicates a minimum resistance of 75 to 300Ω and a maximum resistance (in total darkness) of 10MΩ or more. It would seem reasonably safe to assume that an ORP12 may, in practice, be considered capable of offering a useful range of 300Ω to 1MΩ in the present application.

Fig. 5 indicates the attenuator of Fig. 2 applied between two voltage amplifier stages. The ORP12 forms the grid leak of the second valve, V_2, and a 470kΩ series resistor precedes it. It is assumed that the a.f. voltage on the anode of V_1 remains constant, regardless of the resistance of the L.D.R. At maximum volume setting the L.D.R. has a resistance of 1MΩ. In consequence, approximately ⅔ of the available a.f. is applied to the grid of V_2, causing a loss of some 3.5dB. At minimum volume level the L.D.R. has a resistance of 300Ω. In this instance only 0.0006 of the applied a.f. is passed to the grid of the following valve and the loss is slightly greater than 64dB. Thus the circuit can offer a volume control range of at least 60dB.

It is worth noting that this volume range may be slightly expanded by increasing the value of the series resistor. If this were increased from 470kΩ to, say, 10MΩ, maximum volume level (L.D.R.=1MΩ) would result in a loss of 20dB, and minimum volume level (L.D.R.=300Ω) in a loss of 90dB, giving an overall range of 70dB.

Although we have assumed a maximum resistance of 1MΩ in the ORP12 this can in practice rise to 10MΩ or more. Such a resistance may be excessive for some amplifying valves. The limiting grid leak value for the ECC81 and ECC83 is, for instance, 1MΩ; whilst for the EF86 it is 3MΩ or 10MΩ according to anode dissipation and, for the new Brimar ECC807, is 2.2MΩ with cathode bias. To protect such valves a resistor should be connected across the L.D.R., its value being equal to the limiting grid leak figure for the valve. If a 1MΩ resistor were so connected the insertion loss of the volume control circuit, for 1MΩ L.D.R. resistance and a series resistor of 470kΩ, becomes 6dB. The overall volume control range then becomes 58dB.

In Fig. 5 the L.D.R. circuit follows the anode of a preceding voltage amplifier. It may, of course, similarly follow the input terminals of the amplifying equipment, provided that no matching problems are involved.

It is important to note that the a.f. applied to the ORP12 should not be such as to cause its maximum voltage or power dissipation ratings to be exceeded. The maximum voltage rating of the ORP12 is 110, and the maximum power dissipation is 200mW up to 40° C and 100mW at 50° C.

Power Supply

In Figs. 1 and 2 a battery power supply is illustrated for the lamps and the remote potentiometer. In practice, the use of a battery is undesirable, because it would be quickly exhausted.

A suggested mains unit circuit for powering the lamp and potentiometer is shown in Fig. 6. A bridge rectifier is employed and this may be any conventional low-voltage type. A smoothing circuit is necessary for the lamp as, otherwise, its filament will be modulated at the ripple frequency which will then be injected into the a.f. amplifier via the L.D.R. No values are shown for the smoothing components in Fig. 6 as these depend upon the characteristics of the rectifier and the degree of a.f. amplification following the L.D.R. A reasonable value for the potentiometer would be 40Ω whereupon the maximum current drawn from the supply would be of the order of 300mA (lamp plus potentiometer). Low working voltage electrolytic capacitors having values of 100μF or more are readily available, and these should provide sufficient smoothing for the present purpose. The secondary voltage of the mains transformer could possibly be the 6.3 volts offered by a standard heater transformer, although it may be necessary to use a higher voltage in order that the smoothing resistor can have an adequate value. These factors are experimental and are best

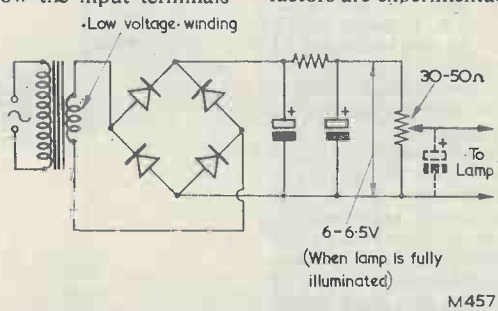


Fig. 6. A suggested power supply for the lamp and its potentiometer. This power supply would be sited at the remote point. No values are given for smoothing components and these are determined experimentally. The capacitor shown in dotted line may be needed if hum is difficult to clear

determined by the constructor to meet his particular needs.

It should be remembered that any ripple voltage impressed on the L.D.R. by the lamp *modulates* the a.f. applied to the circuit. In consequence, evaluation of hum level should be carried out in the presence of signal.

Practical Results

The writer checked the assembly of Fig. 3 at the input circuit of a practical a.f. amplifier following an f.m. tuner unit. The lamp circuit was powered initially by a battery. It was found that the circuit offered the expected range of control. There was a slight sluggishness of operation as a new volume setting was made, this being most noticeable at the maximum volume end of the range. Such sluggishness would be due to the time taken for the lamp filament to assume its new temperature and, possibly, for the ORP12 to respond to a reduced level of illumination.[3] In all cases, the delay was shorter than one second.

The battery was then replaced by a bridge rectifier as in Fig. 6, but without smoothing components. Sufficient voltage was available from a 6.3 volt heater winding. A slight hum was evident around quarter volume level and this was reduced to very low proportions by connecting a 100μF capacitor across the lamp. The amplifier checked did not have an extensive bass response, and more effective smoothing might be necessary with alternative audio equipment.

[3] There is some delay before the ORP12 achieves maximum resistance under conditions of total darkness.

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

R1475 Receiver.—A. Hitchcock, 38 West Road, Spondon, Derby, urgently requires the circuit of the power pack for this receiver.

* * *

RL85 VHF Receiver.—K. Laycock, 274 Leeds Road, Bradford 3, Yorks, requires information on this receiver.

* * *

No. 19 Set, Mk. III.—G. Rowley, 61 South End Villas, Crook, Co. Durham, would like to borrow or purchase the circuit diagram of this receiver and its control box.

* * *

Ex-Admiralty Tuner Amplifier B.21.—A. C. Lewis, Bradley Villa, 41 West Street, Ryde, I.O.W., would like to obtain the manual, circuit diagram or any information on this receiver. Official sources have been tried without success.

* * *

1392(D) Receiver.—J. H. Bray, 53 Gloucester Road, Trowbridge, Wilts, wishes to obtain the circuit diagram or would purchase manual.

* * *

Indicator Unit Type 248.—A. Gillanders, 17 Gibwood Road, Manchester 22, is interested in gaining information, circuit diagram, handbook, etc., of this unit (believed part of Monitor 56) and associated power supply.

* * *

Combination Tester, Espey Model, 104-TC, Type SC.—N. Bolland, 27 The Chase, Clapham Common, London, S.W.4, requires the manual or handbook of this unit (part of Test Set I-56-H) either on loan or purchase. Also required is some guidance on the setting of control "C" when testing valves with this instrument.

* * *

BC454B Receiver.—H. L. Briggs, 10 North Drive, Ormesby, Middlesbrough, wishes to obtain the circuit diagram of this receiver.

Class D Mk. II Wavemeter.—W. R. Longmire, Overlea, Stanah Road, Thornton Cleveleys, Lancs, would like to receive details of converting this unit from 6V d.c. to 6V a.c. operation.

* * *

R1392 VHF Receiver.—B. Hayes, G3JBU, 31 Beverley Crescent, The Headlands, Northampton, requires the manual of this ex-R.A.F. receiver and also any information on converting to a tunable unit.

* * *

Philips Receiver Type 289A.—E. Hart, 52 Glenthorne Avenue, Shirley, Croydon, Surrey, wishes to borrow or purchase the service sheet for this 9 valve receiver.

* * *

AR77 Receiver.—D. Bowers, 88 Grenfell Avenue, Saltash, Cornwall, requires the loan, or would purchase, handbook for this receiver. Also required are any details of modifications to the "front end" and a copy of *Radio Handbook* by Editors and Engineers, 1949 to 1956.

* * *

Hammarlund BC794.—T. J. Evans, G2DFX, The Pharmacy, Eynsham, Nr. Oxford, would like to borrow the circuit or manual for this receiver, or its companions BC779, BC1004, R129/U or SP200.

* * *

R1224A Receiver.—S. Duggan, 224 Upper Chorlton Road, Whalley Range, Manchester 16, wishes to purchase or borrow the service manual and any details of modifications to this receiver.

* * *

1392DReceiver.—F. V. Batt, 36 Phipps Bridge Road, London, S.W.19, requires the instruction manual for this receiver and any information on modifications, etc. Loan or purchase, all expenses defrayed.

STEREO PICK-UP ARM

By N. A. BARGERY

Advanced research work by Cosmocord, Decca and others has established that if the downward pressure of a pick-up stylus can be reduced to around 2 grams, and the tip mass of the stylus confined to not more than a milligram, then wear of disc and stylus is negligible and reproduction quality is improved, especially with stereophonic discs.

Unfortunately, pick-up arms capable of allowing cartridges to track at such low pressures are quite expensive, even though there are suitable cartridges available reasonably cheaply—for instance, the Decca "Deram" transcription crystal.

The writer has constructed many arms capable of allowing cartridges to track at low pressures and has recently completed one made with ¼in Perspex, a substance which is easily fashioned and pleasant to use. It is stressed that the model, as described, is not a "show-piece", but readers of *The Radio Constructor* will no doubt be quite capable of modifying or embellishing it to their own requirements of size or appearance.

When very low downward pressures are used, one must take into account the effect on the arm of the force generated by the rotating disc. This force moves the arm towards the centre of the disc and, consequently, can upset tracking and cause distortion which is detectable in high quality equipment. In the arm described here, a counter force is given by imparting a torque to the conductor leads where they leave the rear of the arm. This torque can be decided when a smooth disc is placed on the rotating turntable, the movement of the arm towards the centre being arrested by tensioning the outer lead with a twist or two. The tensioning is correct when the arm remains stationary on the disc wherever it is placed. A suitable smooth disc can be fashioned from hardboard, wax polished to a mirror finish. Ensure that it is dead flat by glasspapering with a large glasspaper block.

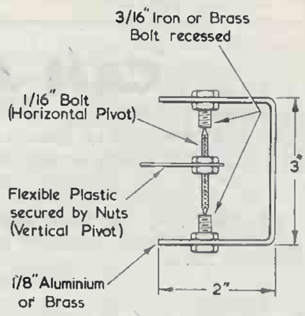


Fig. 2. Details of the horizontal pivot and frame

General Construction

The construction of the arm is illustrated in Figs. 1, 2, 3 and 4.

Extreme care is needed in setting up the pivots. (See Fig. 2.) An electric drill is very useful for fashioning the pivot points, and for drilling the sockets to take these. The performance of the arm depends on the accuracy with which the frame is bent, together with the positioning of the sockets. The arm can be tested for accuracy easily enough. When it has been constructed, and before the cartridge is fitted, balance it by temporary weights, and secure the frame to a dead level surface. The arm should then have no tendency to swing laterally until it is moved, and its arc of lateral movement

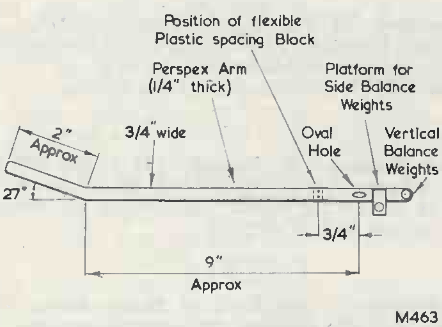


Fig. 1. The pick-up arm fitted with balance weights

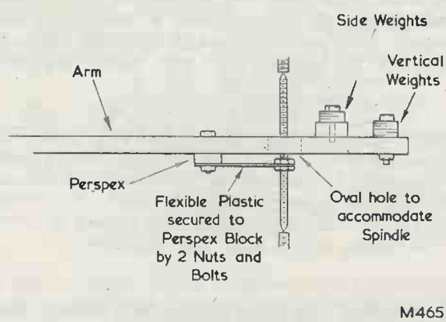


Fig. 3. The plastic vertical pivot

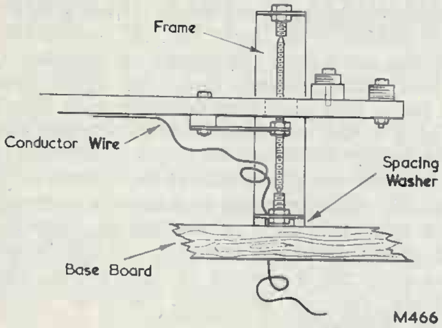


Fig. 4. Fitting the conductor wires

should be parallel to the level surface on which the arm is secured. Freedom of movement is correct when a strip of cartridge paper, 4in long and ½in wide has one end placed against the head, the other end being grasped by thumb and forefinger. The arm should be able to move when it is pushed by the hand, via the paper strip, without the strip bending more than a trifle.

The Pivots

The arm is made of ¼in thick Perspex, to the approximate dimensions of Fig. 1. The horizontal pivot (Fig. 2) is fashioned from a $\frac{1}{16}$in diameter brass or iron bolt, pointed at both ends by using an electric drill. The bolt is held in the chuck and the ends ground and polished to a point. The sockets are $\frac{1}{16}$in or ¼in brass bolts, recessed again by drilling with a $\frac{1}{16}$in drill.

The frame is ⅛in aluminium, brass or mild steel.

An interesting item is the vertical pivot, and this employs a strip of flexible plastic. (Fig. 3.) The strip is secured to the horizontal pivot by two nuts, one above and one below. $\frac{1}{16}$in thick acetate, celluloid, or p.v.c. is suitable, and the strip should be approximately 1in long and ½in wide. The strip is secured to the arm via a narrow bar of Perspex to hold it off the arm, and to prevent fouling as it flexes when the arm is raised or lowered.

Regarding balance weights, these are punched from lead sheet. The side balance weights are small and fixed to a small platform cemented to the arm near the rear. (Fig. 1.) Note the *oval* hole through which the horizontal pivot passes. The hole is oval to allow movement up and down of the arm without fouling the pivot.

Balancing is done with the cartridge *in situ*, and the conductor wires affixed. In the author's model these wires are thin flex covered with fine copper braid shielding and an outer plastic sheath, and is readily obtainable. The sheath is stripped off, as it restricts movement; although it can be retained, however, for protection at the point where the conductor wires enter the base of the frame. With some cartridges it is advisable to isolate the two shield braids from each other, and the outer plastic cover ensures this. The conductor wires are cemented to the underside of the arm, although Sellotape can be used instead, if desired. To achieve balancing both vertically and sideways, hammer a 2in nail into

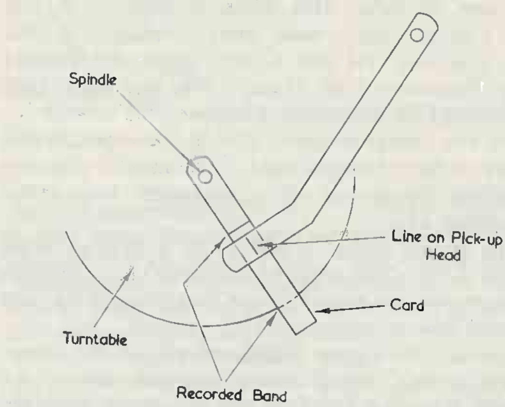


Fig. 5. A method of obtaining accurate tracking

a heavy block and, with the arm resting on the nail head centrally at the point where the plastic strip is to be fixed, mount the weights for both vertical and side balancing so that eventually a balanced arm is achieved that has no tendency to roll either way off the head of the nail. (Protect the stylus point during this operation with a strip of adhesive tape.) This balancing is done, of course, with the arm off its horizontal and vertical pivots. When reassembled on its pivots with the conductor wires passing correctly through the frame, one on either side of the nuts securing the bottom pivot socket, the operation of dynamic balance previously mentioned can be undertaken.

Setting Up

For setting up a "commercial" arm templates are provided. With this arm, whose dimensions may be varied by constructors, the following method will ensure optimum accuracy in tracking.

The stylus should in theory, follow a path which is the true diameter of the disc, and the driving element must be at right angles to this diameter. Now, obviously, this cannot be achieved over the whole of the disc from periphery to centre, but since the recorded material on the disc occupies a 3in wide band only, then tracking can be made *almost* exactly correct over this restricted band.

To find the position for the pivot frame, cut a 7in strip of stiff card, about 1in wide. Cut a hole in one end so that the card can fit over the turntable spindle. (See Fig. 5.) Draw a pencil line from this hole to the other end of the card. Mark on the card the width of recorded material on a normal 12in disc (about a 3in band, as has been stated), and slip the card over the turntable spindle. On the pick-up head, directly over the stylus point, mark a line. This line must coincide with the line on the card at the inner end of the recorded band, as shown in Fig. 5. When the required position has been found, screw down the pivot frame to the motor board. The tracking will then be correct at the most important part of the record, namely at the end of the recorded material. It will be only slightly out at the beginning of the record, where more error can be permitted without causing noticeable distortion.

The Tunnel Triode

THOSE READERS WHO WERE INTERESTED IN THE articles which have been published in this magazine on the tunnel diode (November 1960, December 1960, January 1961 and April 1962 issues) may be interested to know that a new device called the tunnel triode is now in the experimental stages. Like the tunnel diode, the tunnel triode also functions by means of a quantum mechanical tunnelling effect.

The tunnel triode is effectively a double based tunnel diode. The negative resistance characteristics between the two terminals can be affected by a base current flow through the third terminal.

One of the biggest disadvantages of the tunnel diode is that, being a two terminal device, the output from the circuit is not separated from the input. It is not therefore possible (with present circuitry) to have two or more tunnel diodes following one another in an amplifier operating at a single frequency (such as an i.f. amplifier). If this difficulty can be overcome by the introduction of a tunnel triode, it is possible that tunnelling devices may be much more widely used in simple circuits. At the moment they are mainly used as oscillators and in computers.

Four terminal tunnelling devices (which could presumably be called tunnel tetrodes) are also being investigated. More than one type of this device has been described.

It is much too early to say whether tunnel triodes and/or tunnel tetrodes will find a wide application in modern electronic circuits, but it is to be hoped that novel circuits will be developed for these potentially interesting devices.

Reference: *Theory and Experimental Characteristics of a Tunnel Triode*, by W. Fulop and S. Amer; *The Journal of the British Institution of Radio Engineers*, Volume 23, No. 2, February 1962.

International Radio Communications Exhibition

The Radio Society of Great Britain's Exhibition in future will be called International Radio Communications Exhibition and will be transferred to the Seymour Hall, Seymour Place, Marble Arch, London, W.1. It will be held earlier this year, and for a period of four days, from Wednesday 31st October to Saturday 3rd November.

Catering accommodation will be larger with increased seating and tables and improved luncheon and tea service. Bar services will be in a separate room and with more accommodation. A stage presentation, better hall lighting, exhibitors and press reception facilities will now be available.

As in other years a special display of home-built equipment will be shown. Silver plaques will be presented for the most outstanding home constructed radio equipment and for a manufacturer's outstanding equipment contribution to the radio world.

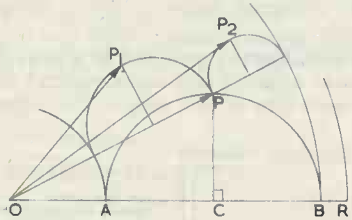
The Armed Services, and it is expected Government Services, will again show latest developments and offer educational and recruiting services to all visitors. Exhibitors will be requested to feature latest developments to members and the public in communications, components and latest low noise u.h.f. valves, transistors, aerials, hi-fi and television, also test gear.

SPOOLED TAPE MEASUREMENTS

By S. G. CASPERD, A.M.I.E.E., A.M.BRIT.I.RE.

On many occasions it is useful to know the halfway point on a reel of recording tape not marked off for this purpose. The accompanying diagram shows a simple means of calculating this halfway point.

Represent to scale the radius of the tape spool by OR and the part occupied by the tape by AB. Then bisect AB at right-angles and on the point of intersection at C draw a semicircle of radius CB. Where the bisector of AB cuts the semicircle at P the halfway point is given, the distance of the halfway point from the centre of the spool being clearly represented by OP. By repeating the process either



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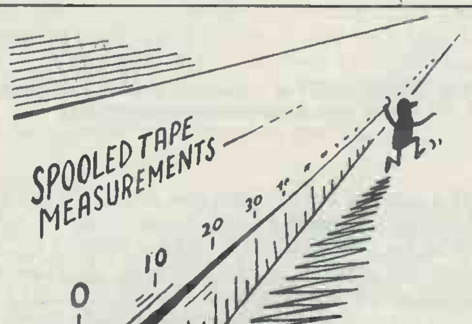
way from point P it is quite easy to obtain divisions P_1 and P_2 respectively, and so on for further divisions of the tape if required.

Each loaded spool of tape can thus be marked off quite accurately to show at a glance the length of tape used or unused as a fraction of the total



length. It avoids the laborious running through of a tape, which in some cases may not be possible in the time available, as would occur with borrowed tapes for recording or reproduction by dramatic societies, clubs, and the like.

The Silicon Controlled Rectifier

By M. J. DARBY

Transistors and semiconductor diodes can replace valves in almost all types of circuit but, until the invention of the silicon controlled rectifier, no really satisfactory simple semiconductor device has been found which will replace the thyratron.

A silicon controlled rectifier has the structure shown in Fig. 1, that is, it is a four layer n-p-n-p device. The main current flows through all the semiconductor sections, but the control or gating current is fed into one of the two central layers.

E227

Fig. 1. The structure of a silicon controlled rectifier

Basic Characteristics

The basic characteristics of a silicon controlled rectifier are shown in Fig. 2. The reverse characteristic, OA, is very similar to that of a normal silicon diode, but the device can exhibit two entirely different forward characteristics. When a small forward voltage is applied across the device, the forward characteristic exhibits the high impedance type of curve, OB, shown in Fig. 2. In fact this forward characteristic is practically a mirror image in the vertical axis of the reverse characteristic and consequently very little current flows.

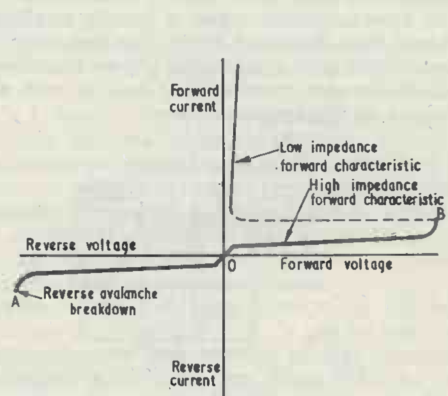


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Fig. 2. Basic characteristics

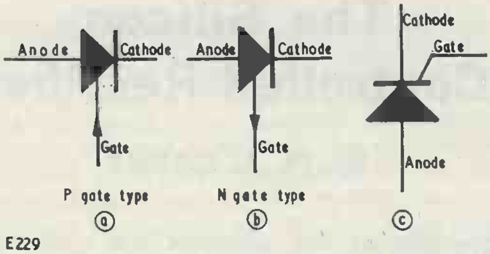


Fig. 3. Some circuit symbols used for silicon controlled rectifiers

"Breakover"

When a voltage greater than that shown by point B in Fig. 2 is applied to the device, there is a very sudden change in the forward characteristic and the impedance of the semiconductor drops to a point on the low impedance curve shown in the figure. This sudden switching action is known as "breakover" and the voltage and current at point B are known as the breakover (or threshold) voltage and current respectively.

The Gate

A third electrode known as the gate enables the breakover voltage to be varied from the point B on Fig. 2 down to a value of one or two volts. This is accomplished by the injection of a suitable triggering current.

Once breakover has occurred and the low resistance state has been established, the silicon controlled rectifier remains in the low impedance condition until the main current is reduced to nearly zero by the removal of either the supply voltage or open circuiting the load. No alteration of the gate current alone can restore the high impedance condition.

Types

There are two possible types of silicon controlled rectifier, the p gate type and the n gate type. Two of the most common types of circuit symbols are shown in Figs. 3 (*a*) and 3 (*b*). The direction of the arrow on the gate connection shows the direction in which the gate current must flow in each of the two types to initiate breakover.

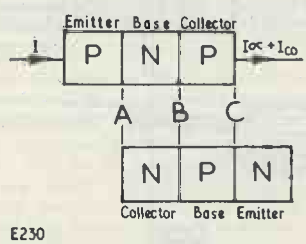


Fig. 4. The silicon controlled rectifier can be considered to be a combination of a pnp and an npn transistor

In the p gate type, the signal is applied between the gate and the cathode whilst for the n gate type it is applied between the anode and the gate. Another common circuit symbol for a silicon controlled rectifier is shown in Fig. 3 (*c*).

Trinistors

The silicon controlled rectifiers manufactured by the Westinghouse Brake and Signal Company Ltd. are also known as "Trinistors".

Theory of Operation

The silicon controlled rectifier may be considered to be two junction transistors combined together, one being a p-n-p type and the other an n-p-n type as shown in Fig. 4. The base of the p-n-p is the collector of the n-p-n and the collector of the p-n-p is the base of the n-p-n.

Let the current gain of the p-n-p transistor from emitter to collector be $\alpha_1 = \frac{\delta i_c}{\delta i_e}$. (This is the grounded base current gain and is always less than unity because some of the holes emitted remain in the base region and do not pass to the collector.)

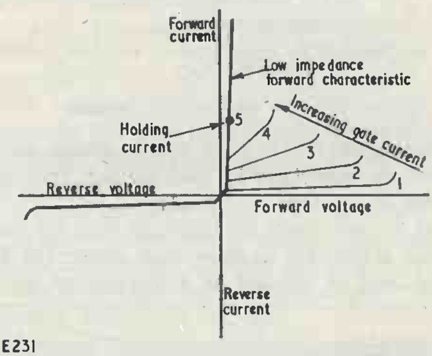


Fig. 5. The effect of increasing gate current on the high impedance forward characteristic

If a current I flows into the emitter in the p-n-p transistor as shown in Fig. 4, the collector current will be $I\alpha_1$. In addition a leakage current I_{co} flows across the reverse biased junction, B. The input current to the p-n-p transistor must be equal to the output current, as no connection is made to the base in the case being considered.

$$I = I\alpha + I_{co}$$

Avalanche Effect = Magnification Factor

This equation only applies when the voltage across the junction B is fairly small. When the voltage across this reversed bias junction increases, the current passing is increased due to the avalanche effect. Electrons and holes passing through the junction acquire enough energy to knock electrons from atoms of the semi-conductor material and these charged particles formed in turn are accelerated until they create still more charged particles by the same process. The additional charged particles enable a much greater current to pass. Thus for any applied voltage we can write:

$$I = IM_1\alpha_1 + I_{CO}$$

where M_1 is the magnification factor in the p-n-p transistor due to the avalanche effect. It is equal to the average number of charged particles formed for each particle initially entering the junction. When the applied voltage is small, $M_1 = 1$.

This multiplication effect is analogous to the gas multiplication in thyratrons where the electrons acquire enough energy to knock other electrons from the molecules of gas in the bulb.

Let the emitter to collector current gain of the n-p-n transistor equal α_2 and the magnification factor in this transistor equal M_2. The electrons injected from the emitter of the n-p-n transistor will increase the total current passing through the junction B by an amount $IM_2\alpha_2$.

Therefore the total current passing through the p-n-p-n device, I, is given by the equation:

$$I = IM_1\alpha_1 + IM_2\alpha_2 + I_{CO}$$

Transposing:

$$I = \frac{I_{CO}}{1-(M_1\alpha_1 + M_2\alpha_2)} \quad \ldots \text{ Equation 1.}$$

Effect of Magnification

The two centre layers of p and n material respectively are made much wider than the base layers of silicon junction transistors so that the junctions can withstand fairly high reverse voltages. α_1 and α_2 are therefore fairly small. Let us assume that $M_1 = M_2 = 1$ when the applied voltage is low and that $(\alpha_1 + \alpha_2) = 0.9$, then from equation 1, $I = 10\ I_{CO}$.

If, owing to an increase in the applied voltage, both M_1 and M_2 increase from 1 to only 1.111 and assuming $(\alpha_1 + \alpha_2)$ is still equal to 0.9, then $I = I_{CO}/0.0001$ . . . from equation 1. Therefore $I = 10{,}000\ I_{CO}$.

Thus a very small increase in the magnification factor due to the avalanche effect can result in a very large increase in the current passing.

Low Impedance

In actual practice M_1 and M_2 could increase to a figure much larger than 1.111 and many holes and electrons would be generated in the junction B. The latter then acts as a forward biased diode. Thus the silicon controlled rectifier becomes virtually three forward biased diodes in series and therefore has the same type of characteristic as a normal forward biased silicon diode. The current flowing is determined mainly by the external circuit resistance.

Holding Current

Once breakdown has occurred, the device remains in the low impedance state until $(M_1\alpha_1 + M_2\alpha_2)$ falls below unity. Generally the device can only be made to revert to its high impedance state by reducing the current to a value below which the above expression becomes less than unity. This value of current is known as the "holding current" and is usually symbolised by IH.

This behaviour may be compared to the operation of thyratrons where the anode voltage must be reduced below a certain value before conduction ceases. It should be remembered, however, that thyratrons are essentially voltage operated devices whereas silicon controlled rectifiers are essentially current operated (compare valves and transistors).

The holding current is usually very small. For example a holding current of 10mA may be adequate to keep a silicon controlled rectifier capable of controlling 15 amps in its low impedance state.

PNPN Diodes

Four layer two-terminal switching diodes (without any third electrode) are manufactured, but such devices can only switch to the low impedance state when a voltage greater than the specified breakover voltage is applied.

The junctions used in the devices may be all diffused or all alloyed or may be a combination of these types of junctions.

The series load must be of sufficiently high resistance to limit the current flowing through the device in its low impedance condition to a safe value. In order to ensure that the device will move to its conducting state at the breakover voltage, a capacitor should shunt the load. The value of this capacitor partly determines the switching time. The switching on time is usually between 10^{-8} and 10^{-5} second, but the recovery time to the high impedance condition is generally much longer.

If a voltage in excess of the breakover voltage is applied and if the load resistance is increased so much that the static current in the low impedance state would be less than the minimum sustaining value, the circuit will oscillate.

PNPN Triodes

As stated previously, an extra electrode known as the "gate" is normally used to control the point at which breakover occurs. If a gating current is injected into the inner p layer, a forward bias current is supplied to the n-p-n layers which act as a transistor. This current effectively increases α_2, but α_1 is only affected by the main forward current flowing through the device. Thus the denominator in equation 1, that is $1-(\alpha_1+\alpha_2)$, depends on both the gate current and the main current.

The breakover point is therefore controlled by both the main forward current (or voltage) and the gate current. Breakover can be initiated by a change of gate current at a constant main current. In fact this is the way in which most silicon controlled rectifiers are used in practical circuits.

A typical family of characteristics for different gate currents is shown in Fig. 5. It can be seen that if the gate current is large enough, no high resistance forward state occurs and the device behaves just like a conventional silicon p-n junction rectifier. In addition to lowering the breakover voltage, an increase of gate current also increases the holding current whilst decreasing the impedance when the silicon controlled rectifier is in its high impedance condition or "off" state.

Switching Speeds

If the breakover is effected by increasing the value of the main current above the holding current, the switching time is usually limited only by the external circuit.

If, however, the switching is effected by a gate current, the device takes a definite time to reach the fully conducting state. There is a certain delay time before anything occurs and after this has passed, the impedance of the device gradually decreases during the so-called rise time. The rise time is a function of the current eventually drawn; the larger this current, the larger the rise time. These times are taken up by the establishment of the necessary charge carrier-density gradients in the base regions. The total time (delay plus rise time) is often of the order of a few microseconds.

Stored Charge

When the device is in its low impedance state, the base regions carry a considerable stored charge. The removal of this charge is necessary before the device can revert to its high impedance state, but this takes a small time. Turn-off times are several times larger than turn-on times; they are the times required to block a reapplied forward voltage and are often about ten to twenty micro seconds in length.

If a reverse voltage is very suddenly applied to a conducting diode, a fairly large reverse current will flow until the charge carriers are removed. The time to block the reverse voltage is known as the reverse recovery time.

The maximum alternating frequency at which the silicon controlled rectifier can operate is largely determined by the turn-off time and by the power dissipated in the junction during the turn-on interval. They can be expected to work at least up to several kilocycles.

Comparison with Transistors

Silicon power transistors are often used for switching applications, but in many cases the use of silicon controlled rectifiers is preferable. The base layer of power transistors must be very narrow in order to achieve a high current gain, but the base width of the silicon controlled rectifier can be made much larger (as the current gain is relatively unimportant) and the breakdown voltages can therefore be much higher.

When a transistor is used, a comparatively large base current drive (of the order of half an amp) must be employed in order to obtain a collector current of, say, 5 amps. In the case of the silicon controlled rectifier, however, only a few milliamps of gate current are needed to cause breakover and thus to switch on currents of several amps. An additional advantage possessed by the silicon controlled rectifier is that after about a microsecond the gate current can decline to zero without the main current being affected in any way.

Temperature

It has already been shown that breakover can be induced by a change in voltage or current in the main circuit or by a change in the gate current. The temperature of the device also has a significant effect on the point at which breakover occurs, but this apparent disadvantage might possibly be put to good use by employing silicon controlled rectifiers to control thermostats, etc.

The manufacturing spreads must also be taken into consideration when circuits using silicon controlled rectifiers are being designed.

Ratings

There are quite a large number of ratings which are usually quoted by manufacturers for each type of silicon controlled rectifier. These include peak reverse voltage, peak gate voltages (forward and reverse), mean forward current, surge current, gate current and gate dissipation.

Maximum peak inverse and forward blocking voltages up to 400 volts are quite common.

Advantages

The silicon controlled rectifier can replace the thyratron in most applications with the advantages that it is much smaller for the same current handling capacity, it requires no heater supply and the voltage drop across it in the forward conducting state is normally much less than that across a thyratron, leading to increased efficiency and the possibility of its use at low supply voltages.

Thyratron cathodes are easily damaged by ion bombardment, especially if the anode voltage is applied before the cathode is fully warmed up. No such difficulties occur when the silicon controlled rectifier is used.

The silicon controlled rectifier is extremely fast in operation and the ease with which these devices can switch a kilowatt or more into a load within a fraction of a microsecond renders them very valuable tools for the circuit designer.

Applications

The silicon controlled rectifier can obviously be used as an extremely high speed relay provided some separate means of breaking the circuit is included. This principle can be extended to the operation of d.c. inverters which convert d.c. to a.c.; the breaking of the circuit is performed automatically by a voltage pulse induced in the transformer. The silicon controlled rectifier can also be used in d.c. to d.c. converters which convert a d.c. input voltage into another d.c. voltage which is required to supply other equipment. The thyratron or grid controlled mercury arc rectifier can also be used in this type of equipment. The efficiency of such inverters and converters employing silicon controlled rectifiers is usually about 60% to 80%.

A.C. Power Control

When silicon controlled rectifiers are used in a.c. circuits, much simpler circuitry is usually possible than when the input is a steady voltage, as the polarity of the supply changes twice per cycle and the switching off to the high impedance forward condition is automatic. The switching off circuit is thus eliminated. Nevertheless two silicon controlled rectifiers are normally required, one for each half cycle

If a suitable pulse is applied to the gate electrode near the beginning of each half cycle, the silicon controlled rectifier will conduct for the whole of the half cycle and maximum power will be delivered to the external load. If, however, the gate pulses are slightly retarded in time, the rectifiers will only conduct during a portion of each half cycle and the amount of power delivered to the load will decrease as the time by which the gate pulses are retarded increases. This is the principle by which the devices can be used in circuits to control a.c. power. Almost exactly the same principle has been used in circuits in which thyratrons have been employed to control a.c. power.

Silicon controlled rectifiers can also be used in very similar circuits which control power passing to a load and which rectify the power at the same time; push-pull or bridge circuits are used in this application.

One of the most popular applications of these devices is the control of the speed of a.c. or d.c. motors, for which purpose thyratrons or magnetic amplifiers have been used in the past.

Conclusion

The silicon controlled rectifier is a fairly new invention and time must pass before its importance can be accurately assessed. Nevertheless it appears that these devices will to some extent replace the magnetic amplifier and transductor for power control and they will certainly be much used in inverters and converters, for example in aircraft.

References

1. *The Silicon Controlled Rectifier* by J. A. F. Cornick and Z. A. A. Krajewski. *Power and Works Engineering*, May and July 1961.

2. Texas Instruments Ltd., *Application Notes for Silicon Controlled Rectifiers.*

3. Details of ratings, etc., may be found in *The Use of Semiconductor Devices* (2nd Edition) published by The Electronic Valve and Semiconductor Manufacturer's Association.

COURSES OF INSTRUCTION

EAST LONDON R.S.G.B. GROUP

The following classes organised by the East London R.S.G.B. Group, in conjunction with the Essex County Council, are available for all those interested in amateur radio irrespective of whether they are members of any society or of the general public:

1. **Radio Amateurs Examination Course**
   Wednesday 7.15 to 9.15 p.m. 8-month course for those intending to take the examination.
2. Thursday, 7.15 to 9.15 p.m. This course is for those who possess a basic knowledge of electricity and magnetism, a 2-year course.
3. **Morse and Codes of Practice**
   Monday, 7.30 to 9.30 p.m. 6-month course for those who wish to learn morse up to G.P.O. requirements for an amateur licence. Arrangements have been made with the G.P.O. for those who, in the opinion of the Masters have reached the required speed, to be tested at the College by a representative of the Post Office.

Venue for the above classes: The Ilford Literary Institute, High School for Girls, Cranbrook Road, Ilford. It is adjacent to Gants Hill Station on the Central London Line and buses pass the door.

Fees for those living in the Essex County Council area are: 30s. for the R.A.E. Course; 20s. for the Morse and Codes of Practice; 35s. for both Courses. Students from other parts of London will be admitted as out-county students provided the local authority is notified.

Enrolment nights—10th to 13th September, 1962, 7 to 8.30 p.m. Classes commence week beginning 24th September, 1962. These classes have been running for the past 12 years and over 240 students have passed the R.A.E. examination. Those interested in the first instance write to: Mr. C. H. L. Edwards, A.M.I.E.E., A.M.Brit.I.R.E., 28 Morgan Crescent, Theydon Bois, Epping, Essex, for the reservation of a place. A stamped addressed envelope should be enclosed for a reply.

BRADFORD TECHNICAL COLLEGE

A course of lectures in preparation for the City and Guilds of London Institute's Radio Amateurs' Examination will be held during the forthcoming session at Department of Engineering, Central Hall, Bradford 5, on Wednesday evenings from 7 to 9 p.m. Lecturer: D. M. Pratt, G3KEP. Further information and details of registration, etc., may be obtained from the General Office, *Telephone* 25763. Registration takes place at Carlton Grammar School on 10th, 11th and 12th September at 7 p.m.

NORTHWOOD EVENING INSTITUTE

Potter Street, Northwood, Hills, Middlesex. R.A.E. and Morse, commencing 24th September, enrolment 17 to 19th September.

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

part 13

understanding radio

By W. G. MORLEY

In last month's contribution to this series we introduced the subject of magnetism and carried on to inductance. In the present article we shall examine some practical points concerning inductors, after which we shall deal with inductor symbols, and series and parallel connection.

Practical Inductors

We cannot, at this stage, cover practical inductors in great detail because many of the design techniques employed are intended to meet circuit requirements which we have not yet encountered. However, we can still examine some of the basic aspects of practical inductors, and such an examination will provide a valuable background when we return to this subject at a later date.

Practical inductors consist almost always of components having wire wound into the form of a coil. As we have seen,[1] winding wire into a coil causes the resultant magnetic field to be considerably stronger than that which exists around a straight wire carrying the same current. Nevertheless, the fact that a straight wire possesses a magnetic field infers that it also has inductance, even if this inductance is very small when compared with that of a coil. In some radio and electronic circuits the very small inductances of straight wires can be put to advantage, and the wire may then be occasionally referred to as an "inductor". Conductors having shapes between the straight and coiled conditions, such as U-shapes, may also be occasionally referred to as "inductors" if they are used for this function.

The fact that a straight wire possesses inductance can sometimes be a nuisance, and when it connects two circuit points together it may then become necessary to reduce its inductance by keeping it as short as possible.[2]

Inductors which are true coils can be divided into two main categories. One of these categories consists of coils having cores of magnetic material and these are described generally as *iron-cored coils* (or *iron-cored inductors*). The other category consists of coils having no core and these are usually described, to distinguish them from iron-cored coils, as *air-cored coils* or *air-cored inductors*. Normally, the presence or otherwise of a core of magnetic material is obvious from a consideration of an inductor's function, and these two descriptions are usually only employed when it is desirable to differentiate between the two categories.

The shapes and magnetic qualities of the cores employed with iron-cored coils vary extensively, and depend upon the purpose to which the coil is to be put. For this reason we must deal with such cores at a later stage in these articles.

Winding Methods

Practical coils, whether iron-cored or air-cored, are almost always wound on a *former* (American terminology: *form*) made of insulating material. The former consists of a tube or cylinder having the cross-sectional shape required by the overall design of the inductor. It is easiest to wind coils on a former having a round cross-section (Fig. 67 (*a*)) and this shape is employed with nearly all air-cored inductors. The round shape is retained for some

[1] In last month's article.

[2] The inductance of a straight wire reduces also as its thickness increases. The effect is small, but it is often sufficient to make it worthwhile using relatively thick wire or conductors in instances where inductance must be kept as low as possible. We shall be able to explain this effect at a later stage in these articles. Provided that the outside dimensions of a *coil* are not affected, the thickness of wire used in winding it has no significant effect upon its inductance.

iron-cored inductors, but the core shape of the latter frequently demands a square or rectangular cross-section (Figs. 67 (*b*) and (*c*)). Formers having square and rectangular cross-sections may have their external corners rounded off to avoid applying undue strain to the wire wound on its immediate surface.

A *single-layer* coil is illustrated in Fig. 68 (*a*). With the single-layer coil each turn of wire may be wound so that it touches its neighbour, or the turns may be regularly spaced out. In the first instance each wire must, of course, be covered with some form of continuous insulation to prevent adjacent turns from short-circuiting. A *multi-layer* coil is shown in Fig. 68 (*b*). In this case, the layers of wire must be wound with adjacent turns touching each other (or very nearly touching each other) in

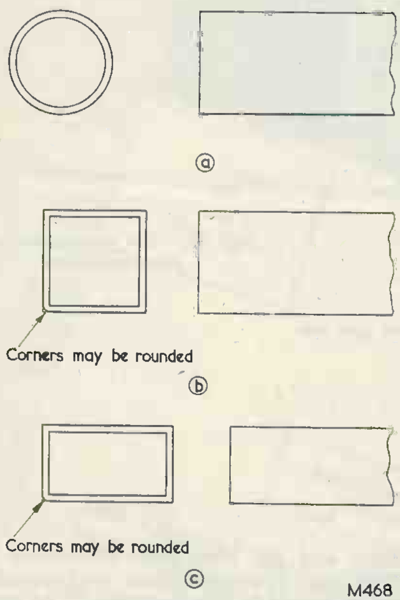


Fig. 67. *Coil formers used for practical inductors may have cross-sections which are (a) round, (b) square, or (c) rectangular*

order that succeeding layers may be supported. It is frequent practice to insert one or more thicknesses of *interleaving paper* between layers to provide mechanical strength and insulation. Interleaving paper has good electrical insulating properties, and is chemically inactive in order to ensure that no long-term deterioration of the winding wire takes place.

In the manufacture of a typical multi-layer coil of the type shown in Fig. 68 (*b*), the winding wire is fed via a pulley on to the former as the latter rotates. (Fig. 69.) The pulley moves laterally as winding proceeds, thereby laying the wire evenly on the former. At the end of a layer interleaving paper is introduced and winding continues with the pulley moving in the reverse direction. If wound in this

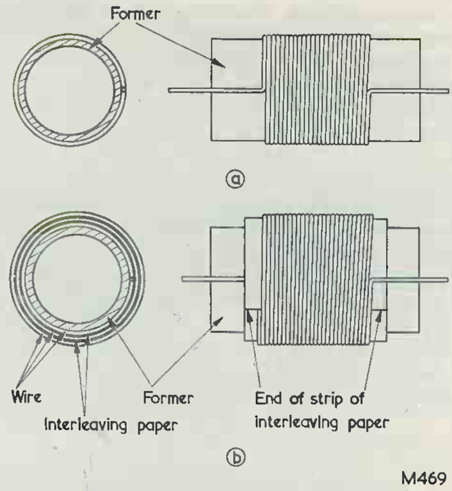


Fig. 68 (*a*). *A single-layer coil*
(*b*). *A multi-layer coil with interleaving paper between layers. Only three layers are shown here but, in practice, most coils of this type have many more layers*

fashion, the first layer of the multi-layer coil of Fig. 68 (*b*) would proceed from left to right, the second layer from right to left and the third layer from left to right again. The lateral movement of the pulley of Fig. 69 may be imparted by a worm drive coupled to the former by a train of gears, the latter being adjusted to ensure that pulley movement for each revolution of the former is equal to (or very slightly greater than) the diameter of the wire being wound on to the coil.

In practical production, six or more multi-layer coils of the type discussed here are wound in one operation on a single long common former. The coils are wound side by side, wire being fed to them

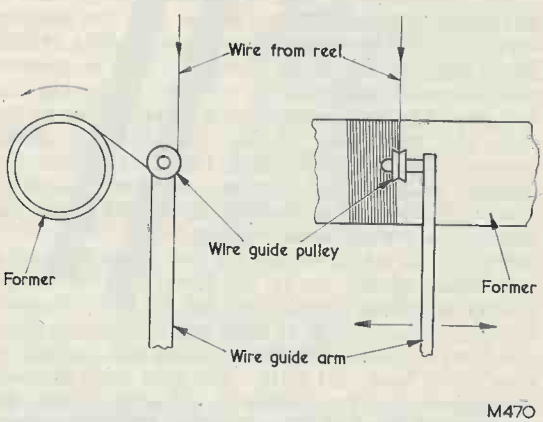


Fig. 69. *Winding a multi-layer coil. The wire guide arm travels laterally in one direction until the end of a layer, whereupon its direction reverses for the next layer*

by a corresponding number of wire guide pulleys moving laterally in unison. The former can consist of "presspaper" or "pressboard".[3] When wound, the multiple assembly is described as a "stick" of coils, and these are then cut into their individual sections by knives which pass through the inter-leaving paper (applied over the whole length of the stick) and the former.

Multi-layer coils may also be wound on Bakelite formers or on formers made of other plastics materials. It is still possible to wind such coils in sticks, but in this case the knives would be used to cut through the inverleaving paper only when parting the wound coils. Each coil would then be available on its own individual former, which would have been previously fitted on to the former-holding spindle.

distinctive "criss-cross" appearance illustrated by the coil in Fig. 70.

We know that a capacitance exists between two conductors, the value of the capacitance increasing as the conductors approach each other. Similarly, capacitance exists between the turns of a coil. It is possible to assume that all the individual capacitances appearing between all parts of the wire making up the coil form one single capacitance across its terminals, and this capacitance is known as the *self-capacitance* of the coil. Wave-wound coils have, in general, a much lower self-capacitance than layer-wound coils such as that shown in Fig. 68 (*b*), and this is an advantage in many radio applications. The self-capacitance of a wave-wound coil can be reduced by winding it in sections, or *pies*, as in Fig. 72. Each individual pie has its own self-

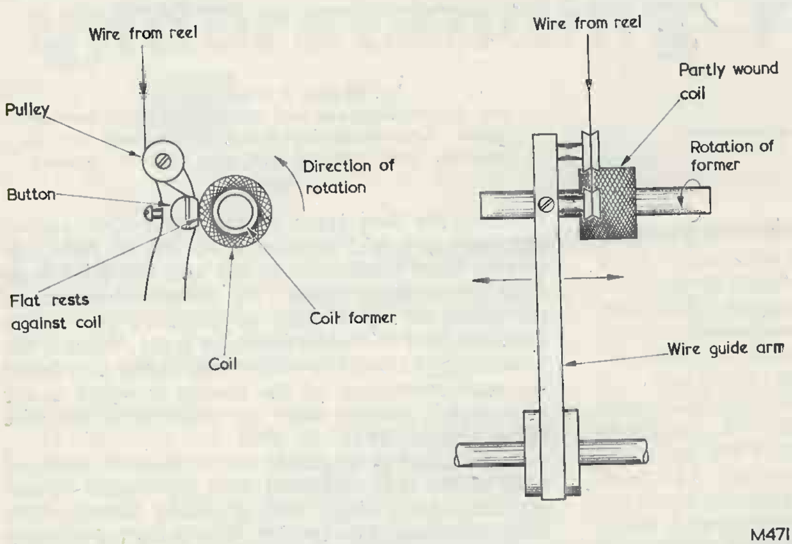


Fig. 70. The production of a wave-wound coil

An alternative method of manufacturing coils is by means of *wave-winding*. In this case the winding wire is not fed on to the former via a pulley spaced away from it, but by a "button" held in contact with the coil, whilst it is wound, by springs or weights. The button presents a smooth face to the coil, the remainder of its circumference being grooved like a pulley. (See Fig. 70.) When the former rotates, the button oscillates laterally, causing the wire to be continually moved across the former. A typical wave-winding build up is shown in Fig. 71, in which we see the first seven turns of a coil being wound on to the former. The former surface is shown opened out flat for one complete revolution, and it will be seen that succeeding turns of wire are positioned further along this surface as they travel back and forth. The gear train between the former and the button is adjusted to suit the diameter of the wire being wound. When complete, a wave-wound coil is self-supporting and has the

capacitance, and the total self-capacitance of the coil, given by the individual self-capacitances connected in series, is less than would be given by a single-pie coil wound for the same inductance with the same wire. However, more turns are needed for the same inductance when an inductor is divided into a number of pies, because turns are spaced further apart than in the single-pie coil.

Another winding technique employs a former, or *bobbin*, having *cheeks*, such as that shown in Fig. 73. Bobbins may be wound (in sticks if desired) by the method shown in Fig. 69. No interleaving paper is used and the wire forming the coil is bounded by the two end cheeks. If care is taken with pulley settings it is possible to wind fairly even layers of wire on the bobbin, but there may always be a tendency for end-turns to pull down or build up at the cheeks. Coils wound in this manner are usually described as "random-wound" or "scramble-wound" (although the latter more frequently infers a completely non-regulated application of the wire, as would be given if the bobbin were held in one hand and the wire wound on with the other).

[3] These are specially treated paper-like materials which have good insulating properties and are rather similar in appearance to tough cardboard. A familiar trade name is Prespahn.

Due to end-turn build up and pulling down, some turns which would be well-spaced in the layer-wound coil of Fig. 68 (*b*) may closely approach each other in a random-wound coil, and this can cause an increase in self-capacitance. However, the self-capacitance of a random-wound coil is in any case higher than that of an equivalent layer-wound coil because of the absence of interleaving paper. Random windings can be given a reduced self-capacitance by making the coil in sections, as in

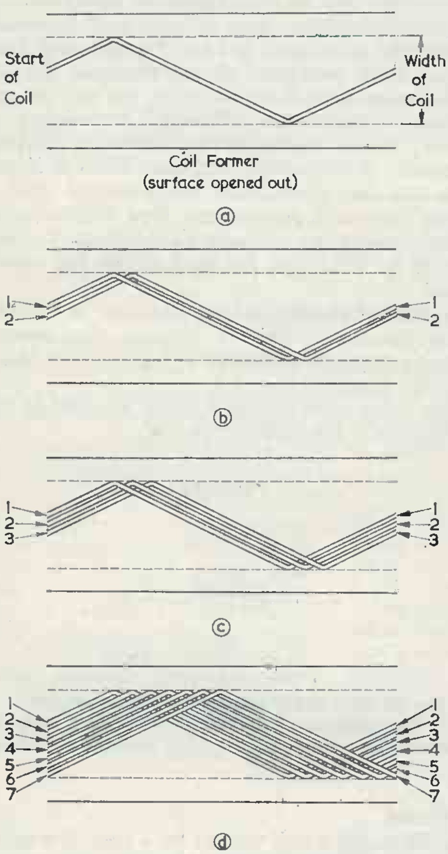


Fig. 71. The build up of a wave-wound coil, the former surface for one revolution being shown opened out flat. In (a) we see the first turn of the coil, and in (b) and (c) the second and third turns. The distinctive wave-winding pattern begins to become noticeable in (d), which shows the first seven turns

Fig. 74. In this diagram, intermediate cheeks separate portions of the coil, and the overall effect is similar to that given by the separate pies of Fig. 72.

The three methods of winding coils discussed here represent the most frequently encountered techniques used for inductors having large numbers of

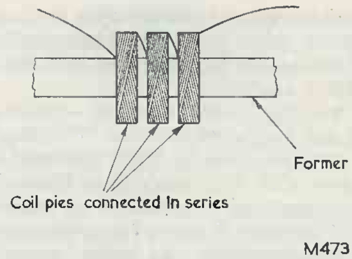


Fig. 72. The self-capacitance of a wave-wound coil may be reduced by splitting the winding into separate "pies"

turns. Coils having a small number of turns are usually wound in single-layer form and may have their turns touching or spaced. If a high mechanical stability is required, the coils may be wound into a spiral groove cut in a ceramic former.

Winding Wires

Most winding wires for practical inductors consist basically of a copper conductor which is covered with some means of insulation. Enamel is the insulation usually employed and this is available in a number of different categories; these including *oil-based*, *synthetic* and *polyester*. The oil-based enamels are obtained from natural sources, whilst the synethetic enamels fall in the category of plastic resins. The recently introduced polyester enamels are also of plastics origin.[4] Speaking in general terms, the synthetic enamels are tougher mechanically than the oil-based enamels, and the polyester enamels are tougher than the synthetic enamels.[5] Both synthetic and polyester enamels have better heat resistant and solvent resistant qualities than the oil-based enamels. Two

[4] Polyester resins are known by such trade names as Mylar and Terylene, etc.

[5] As an example of usage, the layer-wound coil of Fig. 68 (*b*) could well employ wire covered with an oil-based enamel because the wire in this coil is not subjected to arduous condition during winding. However, a random-winding may require a synthetic enamelled wire. This is because there will be a higher degree of abrasion between turns, to which the tougher synthetic enamel would stand up better.

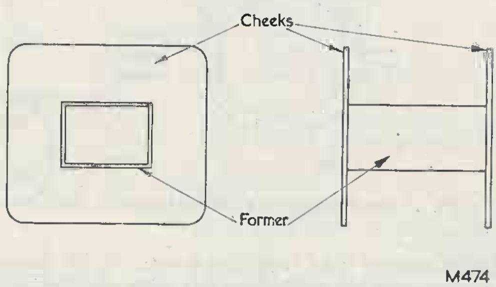


Fig. 73. A typical bobbin with cheeks to retain the winding wire. A former with a rectangular cross-section is illustrated, but any other shape may, of course, be employed

different thicknesses of enamel over the copper wire are available with oil-based enamels, and four different thicknesses are available with the synthetic and polyester enamels.

Other winding wire enamels commonly encountered are polyurethane and "Polyflux". Polyurethane enamels melt at fairly elevated soldering temperatures with the result that the ends of the coil do not have to be cleaned of enamel before soldering. "Polyflux"[6] melts, for soldering purposes, at lower temperatures. In other respects, polyurethane enamels have similar qualities to the synthetic enamels, and "Polyflux" to the oil-based enamels.

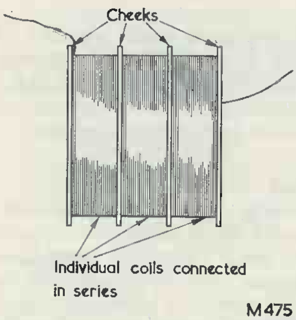


Fig. 74. The self-capacitance of a random-wound coil may be reduced by winding it in sections separated by cheeks, as shown here

Winding wires may also have a cotton, silk or rayon covering over the basic conductor (which is usually enamelled), a single or double lapping of the appropriate fibre being applied as required. Nowadays, rayon ("art-silk") is most frequently employed, as it is cheaper than cotton or silk. The following abbreviations describing such coverings are often met: s.c.c. (single cotton covered), d.c.c. (double cotton covered), s.s.c. (single silk covered) and d.s.c. (double silk covered). It may be generally assumed that s.s.c. and d.s.c. apply to rayon as well as to silk.

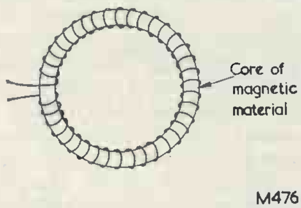


Fig. 75. A toroid wound on a core of magnetic material

Layer-wound and random-wound coils almost always employ enamelled copper wire, the thickness and type of enamel being that judged best to withstand the winding process and subsequent conditions in service. Fibre covered wires (i.e. cotton, silk or rayon) are generally used for wave-winding because the thin filaments of fibre extending from the surface tend to lock with each other and hold the wire in position during winding. (Also, the relatively large bulk of the fibre covering increases spacing between conductors and thereby reduces self-capacitance.)

Impregnation

After winding, coils with relatively large numbers of turns may be impregnated to prevent subsequent deterioration due to the ingress of moisture. The usual impregnants are wax or varnish. It is posssible to "pot" the completed coil by impregnating it with an epoxy resin or similar plastics material, the latter continuing around the outside of the coil so as to completely embed it. "Potting" techniques are, however, rather expensive for domestic electronic equipment. A somewhat inefficient form of impregnation can be given with wave-wound coils by painting these with polystyrene dope whilst winding, the dope having the secondary advantage of causing the turns to adhere in position during the winding process.

The self-capacitance of an inductor is increased by impregnation. This is because the dielectric constant of any impregnant is higher than that of the air it displaces.

Single layer coils having a small number of turns are frequently left unimpregnated.

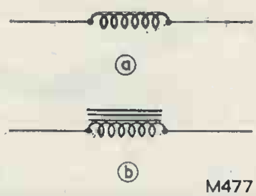


Fig. 76 (a). The circuit symbol for an inductor (b). The presence of a magnetic core (see text) is indicated by adding parallel lines, as illustrated here

The Toroid

Fig. 75 shows a coil wound on a ring of magnetic material, the latter forming the core for the coil. Such a coil is known as a *toroid*, the name applying also if the coil has no core.

Toroids, as such, are very infrequently encountered in normal radio work, and they are introduced here only for the sake of completeness. The two-ended coils we have considered up to now are differentiated from toroids by being described as *solenoids*.

Inductor Symbols

As with our discussion of practical inductors, we cannot review inductor symbols in great detail at this stage. This is because there are some points concerning the inductor which we have not yet encountered. Nevertheless, the basic symbols may be given.

[6] "Polyflux" is manufactured by Concordia Electric Wire and Cable Co. Ltd.

Fig. 76 (*a*) shows the circuit symbol for an air-cored inductor, whilst Fig. 76 (*b*) gives the symbol for an iron-cored inductor in which the magnetic material is a homogeneous metal (soft iron) or metal alloy. The reason for making this distinction is that some magnetic materials employed as coil cores are not a metal or metal alloy but consist, instead, of particles of metal in an insulated bonding medium or of ferrites,[7] and that these are given a different symbol.

Inductors in Series and Parallel

Provided that there is no coupling between their magnetic fields, inductors in series and parallel have the same relationships as are given with resistors. Thus, if two or more inductors are connected in series, the total inductance is equal to the sum of the individual inductances. Similarly, when two or more inductors are connected in parallel, we get:

$$\frac{1}{L}=\frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{L_3}+\ldots\ldots$$

where L is the total inductance and L_1, L_2, L_3, etc., the individual inductances.

If only two inductors are connected in parallel the formula simplifies to:

$$L=\frac{L_1 L_2}{L_1+L_2}$$

Next Month

In next month's article we shall carry on to time constant, after which we shall introduce the subject of alternating current.

[7] Ferrites are non-metallic magnetic materials having ceramic-like physical properties.

RASTER DEFLECTION

By J. M. WINSOR

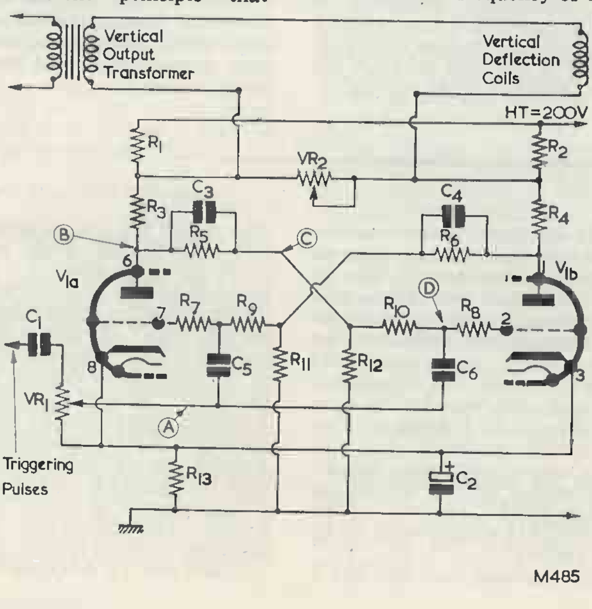
This article, sent to us by a contributor in New South Wales, Australia, describes an ingenious suggested method of making the line structure of a television picture less visible. We have not carried out any tests on the circuit and can therefore offer no guarantee on its operation in practice, and it is presented purely as an experimental project.—Editor.

THE PURPOSE OF THE CIRCUIT IS to render the line structure of a television raster less visible, or invisible. It has this object in common with "spot wobble" which is a well-known technique, but the present circuit uses an entirely different principle that appears to perform much better than "spot wobble", in that the latter tends to produce a blurred effect like a fine interference pattern.

The principle of the present circuit which may be called "Raster Deflection", is that the raster is shifted up and down at a frequency of 12½ c/s, each shift being made at the completion of each television picture. The raster is shifted by an amount equal to half the distance between two adjacent lines in the complete picture.

The effect is that the raster appears to be composed of twice the normal number of lines, and hence the gaps between lines become filled. Thus, the visibility of the line structure is greatly reduced.

This technique is more likely to be of practical interest in Britain than in Australia, since the British 405-line standard has fewer lines in the television picture.



M485

Components List

Resistors (10% unless otherwise stated)

R_1	1Ω ½ watt
R_2	1Ω ½ watt
R_3	27kΩ 1 watt 5%
R_4	27kΩ 1 watt 5%
R_5	2.7MΩ ½ watt
R_6	2.7MΩ ½ watt
R_7	820kΩ ½ watt
R_8	820kΩ ½ watt
R_9	1MΩ ½ watt
R_{10}	1MΩ ½ watt
R_{11}	390kΩ ½ watt 5%
R_{12}	390kΩ ½watt 5%
R_{13}	4.7kΩ ½ watt
VR_1	100kΩ potentiometer
VR_2	100kΩ potentiometer wire-wound

Capacitors

C_1	0.001μF
C_2	25μF, 25 w.v. electrolytic
C_3	0.1μF, 200 w.v. } matched within 10%
C_4	0.1μF, 200 w.v. } matched within 10%
C_5	470pF
C_6	470pF

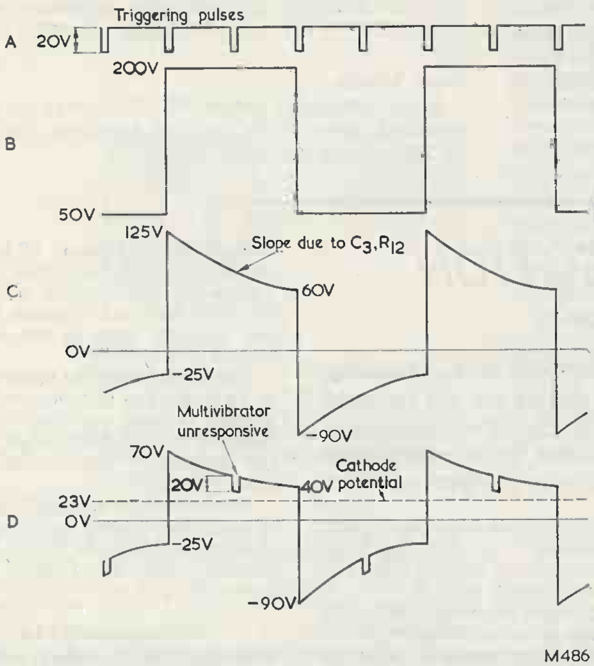
Valve

V_1 ECC82

Operation

The basis of the circuit (Fig. 1) is a bistable multivibrator which is triggered by pulses of field frequency (50 c/s), derived from the vertical timebase, for example from the anode of the blocking oscillator if such is used.

The triggering pulses are preferably of negative-going polarity, and should be of at least 30 volts amplitude.



The multivibrator does not act as a binary counter, but contains timing elements of resistance and capacitance (notably C_3, R_{12} and C_4, R_{11}), such that it is unresponsive to every second triggering pulse. Hence, one cycle of the multivibrator action is completed on every fourth triggering pulse, the resulting frequency being 12½ cycles per second.

A portion of the current flowing through each half of the multivibrator is diverted to flow through the vertical deflection coils as shown in the diagram. It has been assumed, for design purposes, that the total resistance of the vertical coils and output transformer secondary is about 10Ω, and that a current waveform of 1mA peak-to-peak maximum amplitude is required to shift the raster by one-half a line-spacing.

Potentiometer VR_1 controls the amplitude of the triggering pulses, and hence the locking stability of the multivibrator. VR_1 is adjusted to produce a stable division by four. Potentiometer VR_2 controls the amplitude of the current waveform produced in the deflection yoke. VR_2 is adjusted for minimum visibility of the lines.

The circuit is very stable in operation, and VR_1 and VR_2 may be replaced by fixed resistors of suitable value.

Fig. 2 shows the waveforms to be expected, the letters corresponding with those in Fig. 1. Voltages are approximate. The current flowing through R_{13} should be approximately 5mA, giving a cathode potential of some 23 volts.

Flicker

It may be thought that the relatively low switching speed of 12½ c/s may give rise to undesirable flicker effects. Here, a comparison may be made with a normal interlaced raster. In this case the interline flicker frequency is 25 c/s whereas the overall flicker frequency is 50 c/s. Although a 25 c/s flicker is very objectionable, the interline flicker frequency is not normally discernible because the eye prefers to respond to the overall flicker frequency.

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Radio Topics

(continued from page 143)

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Something Settled

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There is much else in this report of interest which we have no space to detail in "News and Comment." We would, however, advise interested readers to obtain a copy of this report from H.M.S.O.

Shipboard Television Systems

Comprehensive shipboard t.v. systems, still a comparatively new feature in the field of entertainment for passengers and crew, are naturally suitable only for the larger passenger vessels in which they are a practical proposition. Such a system has been installed on board the Shaw Savill line's new passenger vessel *Northern Star*. Launched on 27th June, 1961, by Queen Elizabeth the Queen Mother at Vickers-Armstrongs (Shipbuilders) Ltd. naval yard, Walker-on-Tyne, the *Northern Star* commenced her maiden voyage recently. The new liner's television system has been designed and engineered by Marconi's Wireless Telegraph Co. Ltd. with the Marconi International Marine Communication Co. Ltd. acting as agents in negotiating the order.

The installation provides for the off-air reception of television broadcasts employing the 405-line system used in Great Britain, the 525-line system used on the North American continent, and the 625-line system as used in Australasia and the greater part of Europe.

Standard television receivers are utilised in various parts of the ship, and wherever alternative programmes are available viewers can change from one channel to another by using the normal channel selector switch on the receiver. So, while in the vicinity of the United Kingdom, reception of either the B.B.C. or I.T.V. programme can be selected by the viewer. Elsewhere the same channel switch will select any local station operating in Band I or III. *Northern Star* passengers will have, for example, a choice of nine T.V. programmes while at Sydney, New South Wales. Flexibility in the choice of programmes to be received on either the 405-, 525- or 625-line systems is quite substantial. Up to thirteen channels are available on 625 lines, and two channels on 525- and 405-line systems respectively.

All incoming programmes pass through the central television control room for processing before being distributed to the receivers. The processing equipment includes two Marconi Vidicon camera chains which also form the basis of the closed-circuit installation.

For internal programmes on a closed circuit, entertainment is derived mainly from a library of 16mm films, and telecine projection is continuous without breaks between reels. Further facilities provide for insertion of still pictures or slides on 35mm film and also for showing extempore captions and announcements made up on caption boards.

This system combines operational simplicity, versatility and stability, with a picture presentation of a quality equal to that normally obtained ashore.

The *Northern Star* has also been fitted with a comprehensive range of Marconi Marine communications equipment and electronic aids to navigation.

London Taped

London is the first city in the world to be systematically surveyed for noise. The information obtained will be useful for town planning generally, and especially to architects when making provision for insulation in new buildings of all kinds in the central area.

Information about noise levels at selected sites throughout central London is also being recorded for use in particular town planning problems, such as assessing the noise effects of elevated motorways and heliports, and for siting hospitals and other buildings where noise may be detrimental to their use.

The London Noise Survey is being conducted by the Building Research Station, of the Department of Scientific and Industrial Research, and the London County Council. Two vans, with equipment which includes TR52/2 professional tape recorders supplied by E.M.I. Electronics Ltd., are sampling noise levels for 100 seconds once an hour over a 24-hour period at each of 540 points, distributed at 500-yard intervals on a rectangular grid over central London. The work has continued since early in 1961 and more than 350 sites have already been monitored.

Noises are automatically recorded on magnetic tape every hour on the unattended tape recorders. At the end of the 24-hour period, the tape is taken to the Building Research Station at Garston for analysis on an E.M.I. type TR90 tape recorder.

Normal method of calculating the loudness of noise from a frequency analysis of the noise into octave bands would be unpractical for the London Noise Survey because the necessary computations would take too long. Instead, the magnetic tapes are played back through a weighting network which attenuates the low frequencies and slightly accentuates the high frequencies. The resulting levels can be converted into loudness levels by multiplying by a factor and adding a constant.

Sites being monitored range from busy thoroughfares to a point in the middle of Hyde Park. Noisiest spot so far tested was in the Strand.

Parallel with this objective noise survey, a subjective survey has been carried out by the Central Office of Information. Two thousand people have been asked how noise affects their lives. Half of them live near enough to one or another of the 540 points being monitored by E.M.I. tape recorders for interesting comparisons to be made between the

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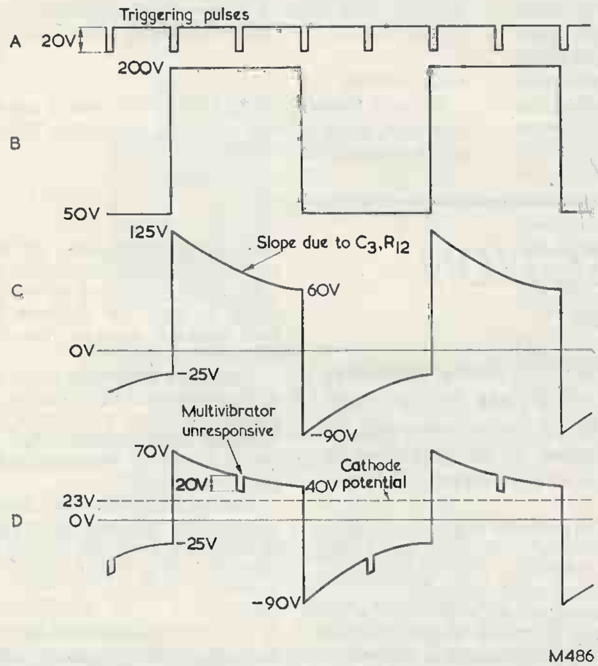

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There is much else in this report of interest which we have no space to detail in "News and Comment." We would, however, advise interested readers to obtain a copy of this report from H.M.S.O.

Shipboard Television Systems

Comprehensive shipboard t.v. systems, still a comparatively new feature in the field of entertainment for passengers and crew, are naturally suitable only for the larger passenger vessels in which they are a practical proposition. Such a system has been installed on board the Shaw Savill line's new passenger vessel *Northern Star*. Launched on 27th June, 1961, by Queen Elizabeth the Queen Mother at Vickers-Armstrongs (Shipbuilders) Ltd. naval yard, Walker-on-Tyne, the *Northern Star* commenced her maiden voyage recently. The new liner's television system has been designed and engineered by Marconi's Wireless Telegraph Co. Ltd. with the Marconi International Marine Communication Co. Ltd. acting as agents in negotiating the order.

The installation provides for the off-air reception of television broadcasts employing the 405-line system used in Great Britain, the 525-line system used on the North American continent, and the 625-line system as used in Australasia and the greater part of Europe.

Standard television receivers are utilised in various parts of the ship, and wherever alternative programmes are available viewers can change from one channel to another by using the normal channel selector switch on the receiver. So, while in the vicinity of the United Kingdom, reception of either the B.B.C. or I.T.V. programme can be selected by the viewer. Elsewhere the same channel switch will select any local station operating in Band I or III. *Northern Star* passengers will have, for example, a choice of nine T.V. programmes while at Sydney, New South Wales. Flexibility in the choice of programmes to be received on either the 405-, 525- or 625-line systems is quite substantial. Up to thirteen channels are available on 625 lines, and two channels on 525- and 405-line systems respectively.

All incoming programmes pass through the central television control room for processing before being distributed to the receivers. The processing equipment includes two Marconi Vidicon camera chains which also form the basis of the closed-circuit installation.

For internal programmes on a closed circuit, entertainment is derived mainly from a library of 16mm films, and telecine projection is continuous without breaks between reels. Further facilities provide for insertion of still pictures or slides on 35mm film and also for showing extempore captions and announcements made up on caption boards.

This system combines operational simplicity, versatility and stability, with a picture presentation of a quality equal to that normally obtained ashore.

The *Northern Star* has also been fitted with a comprehensive range of Marconi Marine communications equipment and electronic aids to navigation.

London Taped

London is the first city in the world to be systematically surveyed for noise. The information obtained will be useful for town planning generally, and especially to architects when making provision for insulation in new buildings of all kinds in the central area.

Information about noise levels at selected sites throughout central London is also being recorded for use in particular town planning problems, such as assessing the noise effects of elevated motorways and heliports, and for siting hospitals and other buildings where noise may be detrimental to their use.

The London Noise Survey is being conducted by the Building Research Station, of the Department of Scientific and Industrial Research, and the London County Council. Two vans, with equipment which includes TR52/2 professional tape recorders supplied by E.M.I. Electronics Ltd., are sampling noise levels for 100 seconds once an hour over a 24-hour period at each of 540 points, distributed at 500-yard intervals on a rectangular grid over central London. The work has continued since early in 1961 and more than 350 sites have already been monitored.

Noises are automatically recorded on magnetic tape every hour on the unattended tape recorders. At the end of the 24-hour period, the tape is taken to the Building Research Station at Garston for analysis on an E.M.I. type TR90 tape recorder.

Normal method of calculating the loudness of noise from a frequency analysis of the noise into octave bands would be unpractical for the London Noise Survey because the necessary computations would take too long. Instead, the magnetic tapes are played back through a weighting network which attenuates the low frequencies and slightly accentuates the high frequencies. The resulting levels can be converted into loudness levels by multiplying by a factor and adding a constant.

Sites being monitored range from busy thoroughfares to a point in the middle of Hyde Park. Noisiest spot so far tested was in the Strand.

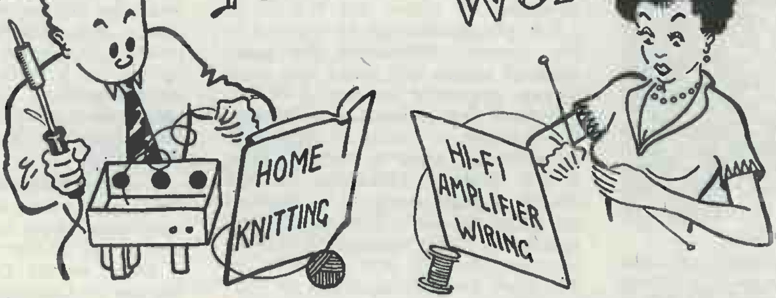
Parallel with this objective noise survey, a subjective survey has been carried out by the Central Office of Information. Two thousand people have been asked how noise affects their lives. Half of them live near enough to one or another of the 540 points being monitored by E.M.I. tape recorders for interesting comparisons to be made between the recorded noise levels and the residents' subjective reactions.

Molecular Electronics

Another step forward in the miniaturisation of electronic circuits has been reported from the U.S.A. with the development of "molecular electronics", sometimes termed "solid state" electronics. Molecular electronics uses no separate components, no wiring. Instead, an entire circuit consists of a very small piece of pure crystallised silicon or germanium, whose molecules have been "lined up" in a desired arrangement during manufacture of the crystal. A few atoms of tin, zinc or phosphorus—"impurities"—are then introduced into the silicon. Because of the interaction of the atoms, a minute slice of this substance amplifies or controls electrical signals, just as do valves, transistors, resistors and capacitors. The slices are sandwiched together, combining a number of circuits into a single small cube. Each circuit separately is smaller than a sliver cut from a grain of rice—100 million of them will fit into a cubic foot of space!

Molecular circuits will make possible the development some day of a miniature computer as compact as the human brain, which will be able to perform some of the functions of the brain. It will have a "memory", be able to command other machines to carry out certain tasks, recognise errors, and exercise a certain degree of judgment, much like the human computer, the brain. With such possibilities on the horizon, it is no wonder that technologists believe the potentials of miniaturisation to be limited only by man's imagination.

IN YOUR WORKSHOP



This month Smithy the Serviceman, aided by his able assistant Dick, finds time during a busy period to discuss mains transformers, half-power soldering iron circuits and u.h.f. tuners

"BUT THAT'S RIDICULOUS!"

Smithy the Serviceman, bent over the chassis he was repairing, sighed to himself as his assistant's voice carried across the Workshop.

"It just can't be!"

Smithy ignored the further comment. His assistant must learn to sort out his own faults for himself.

"It's impossible!"

Smithy decided he would sweat it out. He gritted his teeth.

"It's quite fantastic!"

With a sinking heart, Smithy realised that he was gradually being hooked. Already, he was beginning to lose interest in the chassis on his bench.

"It's practically preposterous!"

Smithy crashed his soldering iron down on its rest with unnecessary force, got up from his stool and turned round towards his assistant. Dick was crouched over a sound receiver with his ear pressed tightly against the cabinet in the manner of a water engineer checking the mains.

"For goodness' sake, Dick," exploded Smithy. "What's the trouble now? And don't get your hair oil all over the tuning scale—you know how these plastic dials are attacked by solvents."

Dick turned an innocent eye towards the Serviceman.

"Hullo," he remarked blandly. "What's up?"

"What's up," said Smithy, frowning, "is that you've just about run the gamut on synonymous expressions for some penomenon you don't understand, and that you're just about sending me round the twist in the process."

"I wouldn't know about that," replied Dick artlessly. "But I must admit that I *have* got a fault which is troubling me a bit. You may have heard me muttering to myself about it."

"This is the fifth time this morning," said Smithy bitterly, "that you've pulled me away from my bench to help you clear a snag. What is it this time?"

Mains Hum

"Nothing very much," replied Dick, "just a little case of hum I've encountered."

"What happened?"

"Well, the set came in with a complaint of mild but annoying hum. I switched it on and it worked O.K. There *was* a slight hum, but, quite honestly, it was so low that I would probably have considered it satisfactory but for the complaint."

"That's something which can often happen," remarked Smithy. "When you've got a set in the average repair shop, which usually has a fairly high background noise level, you tend to forget that some set-owners like to play their receivers at low volume in really quiet surroundings. Even very low hum can be annoying to some people under these circumstances. What did you do first?"

"After having confirmed that the hum was there," said Dick, "I checked to see whether its level varied with the volume control."

"Very sensible," commented Smithy. "If it had, the hum would have been introduced prior to the volume control or in the volume control circuit itself. Did you have any luck?"

"No," said Dick, "the volume control made no difference at all. I next had a quick butcher's at the works. Everything seemed all right, and so I followed this by slapping a little extra test capacitance across the h.t. electrolytics. And then rather a peculiar thing happened."

"Go on."

"Well," said Dick, "at the instant of applying my test electrolytic across the reservoir capacitor the hum suddenly increased momentarily. It then went back to its old level."

A gleam came into Smithy's eye, but he made no comment.

"This puzzled me," continued Dick, "and so, on a hunch, I pulled out the rectifier valve. Don't ask me why I did this—it was, I suppose, just an easy way of changing the circuit conditions around the reservoir capacitor which might have led me on to something."

"Fair enough," said Smithy. "What was the result?"

"That's what's got me baffled," replied Dick. "The hum went down a little bit but that's all. It's still there, and the set hasn't even got a rectifier in it!"

Smithy fixed his assistant with a stern and stony gaze.

"If the set hasn't got an h.t. rectifier," he remarked drily, "it would appear that its a.f. circuits aren't working. Correct?"

"That's right."

"And if the a.f. stages aren't working," continued Smithy, "might we not safely assume that the hum isn't coming from the speaker?"

"I suppose so," said Dick, reluctantly.

"In which case," Smithy carried on remorselessly, "would not the basic rules of logic cause us to arrive at an alternative conclusion?"

"Well, yes," remarked Dick brightly, "if you put it that way."

Smithy cast his eyes to the ceiling.

"Then what", he asked, "might that conclusion be?"

Dick assumed an expression indicative of intense concentration, and Smithy waited patiently. Suddenly, Dick's jaw dropped open.

"What you mean," he said excitedly, "is that the hum is coming from something quite different than the speaker."

"Of course I mean that," exploded Smithy. "Although it's taken me about five minutes to get it over to you! Without wasting any further time I'll tell you that the hum is almost certainly coming from a mains transformer. I will, however, concede in your favour the fact that it's often quite difficult to pin-point the source of low-level hum."

"We get so many a.c./d.c. chassis these days," broke in Dick, "that I'd almost forgotten that mains transformers existed!"

Smithy looked inside Dick's receiver.

"This one has a mains transformer anyway," he remarked. "Pass over something I can dig at it with."

Obediently, Dick handed Smithy a thin Paxolin tube, and the Serviceman applied it to various parts of the transformer. Suddenly, the hum ceased.

"There you are," said Smithy triumphantly, "a classic case of lamination buzz!"

Lamination Buzz

Smithy removed the Paxolin tube from the transformer, whereupon the hum became evident, as before.

"Well, that's cured *that* little job," said Dick with great satisfaction. "Whereabouts was the buzz occurring?"

"The leg of one of the 'E' laminations," said Smithy, "had come unstuck and was flapping about in the breeze. (Fig. 1 (*a*).) I just held it down with that insulated rod."

"I'm not quite certain," confessed Dick, "why a loose mains transformer lam should cause buzz, anyway."

"The effect is quite simple," explained Smithy. "All the lams, or laminations rather, are magnetised in the same manner as the a.c. cycle proceeds; and so they tend to repel each other. The repulsion is strongest when the a.c. is at its peak and is weakest when the a.c. passes through the zero current point. Laminations are made of fairly springy metal, with the result that any loose ones vibrate at 100 c/s."

"Shouldn't that be 50 c/s?"

"No," said Smithy firmly, "100 c/s The 50 c/s a.c. passes through two peaks in each cycle and so the loose lamination suffers maximum repulsion twice per cycle. Therefore, it vibrates at 100 c/s which is, incidentally, well within audible range. If the loose lamination vibrates without striking anything it generates a quiet but audible hum. More frequently, it strikes the lamination below it, whereupon it gives quite an audible noise. In that case, actually, it's more like a buzz than a hum."

"I suppose the cure," said Dick, "is to try and damp the lam down in some way."

"That's one way of clearing the snag," commented Smithy, "provided you don't have to go to a lot of trouble in doing so. A simpler method consists of bending the lamination leg out and cutting it off. (Fig. 1 (*b*).) This completely clears the trouble, but you have to be

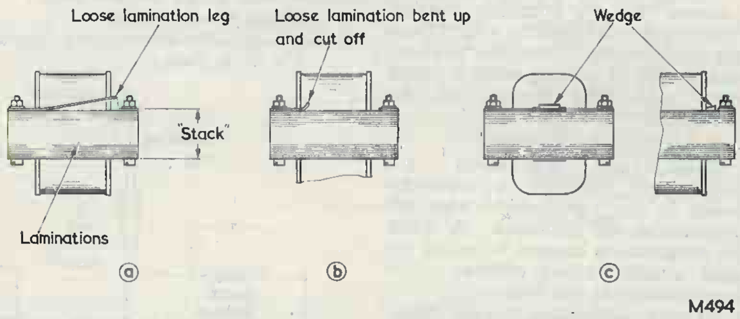


Fig. 1 (a). A loose lamination leg in a mains transformer may cause an audible hum or buzz

(b). The loose leg may be clamped down to eradicate the buzz, but it is frequently simpler to bend the leg up and cut it off, as shown here

(c). A loose lamination inside the former may sometimes be secured by inserting a small wooden wedge

careful that the laminations underneath are held tightly in place. Otherwise they'll start working loose also."

"How did you know it was transformer lamination buzz," queried Dick, "even before you knew the set *had* a mains transformer?"

"You said that the hum went up momentarily," explained Smithy, "when you added extra capacitance across the reservoir capacitor. The sudden increase in current taken from the h.t. secondary as the new capacitor charged up would cause an increase in primary current and an increase in the hum. That's also why the hum went down when you pulled out the rectifier valve, because you were then removing the h.t. load from the transformer and decreasing primary current."

"What would happen if we took *all* the valves out?"

"There would be no secondary currents at all," replied Smithy. "But there would still be a hum from the laminations. And the primary would then be passing what is called the 'magnetising current' of the transformer."

" 'Magnetising current'?"

"That's right," said Smithy. "It's the current required to overcome losses in the transformer when all secondaries are unloaded. A check on magnetising current is one of the tests usually carried out on mains transformers at the factory."

"That's interesting," said Dick. "I didn't know that before. Are all cases of lamination buzz as easy as this to clear?"

"Not always," replied Smithy. "Sometimes they're quite difficult. This is especially true if the loose lamination is inside the former (Fig. 1 (*c*).) In this case, it's usually the end of the centre leg of an 'E' lamination which has worked loose, and the normal method of cure is to insert a small wooden wedge into the end of the former. Don't bash it in too hard, or you may wreck the former. It's a good plan to apply a little shellac varnish, or something similar, to the wedge and laminations afterwards, in order to hold the wedge in place. Occasionally, the whole stack of lams vibrates at 100 c/s, but this usually infers that the transformer is seriously overloaded. The fault to look for then is a short-circuited heater supply or something like that. And, of course, you must switch off a transformer in this condition as quickly as possible, in case it burns out."

There was a frown on Dick's face.

"I've heard that word 'stack' before," he remarked. "I seem to remember someone talking about a '2 inch stack'."

"That would be right," said Smithy. "You refer to a 'stack of lams' or 'stack of laminations' and you also use the word 'stack' to describe its depth. (Fig. 1 (*a*).) A 2 inch stack of lams would be 2 inches deep."

Dick fell silent, and Smithy turned round to him suspiciously. Dick's expression made Smithy suddenly realise that his assistant was, as happened every now and again, in process of being visited by his Muse, and that some lines of doggerel would shortly be forthcoming.

"Here we are," exclaimed Dick after a moment. "Just listen to this, Smithy!:

Never let tranny buzz hold you back, Jack,
That loose lam you must find and attack, Jack,
You next wedge the lam back,
And you finally smack
Some shellac on that stack 'cause it's slack, Jack!"

and I'm wondering if you can help me clear this up, too."

"*Another* problem?" queried Smithy. "Dash it all, I've spent most of this morning on your problems already!"

"But this is an interesting one," Dick persisted. "I'm trying to dream up a scheme for running my soldering iron at half-current if I don't need it for long periods."

"I've got rather a knobby idea for that," said Smithy, "if you're using an iron which runs straight off the a.c. mains."

"It does," confirmed Dick. "Anyway, let me give you my own schemes first. These consist either of inserting resistance in series with the iron when I don't need it, or of using a step-down transformer. The resistance idea (Fig. 2 (*a*)) seems to me to be the better, despite the fact that heat has to be dissipated. In practice, you could use an ordinary mains electric light bulb as the series resistor, and this will give you the further advantage that it will glow dully when it's switched in, thereby telling you that the iron is on but running at half-current."

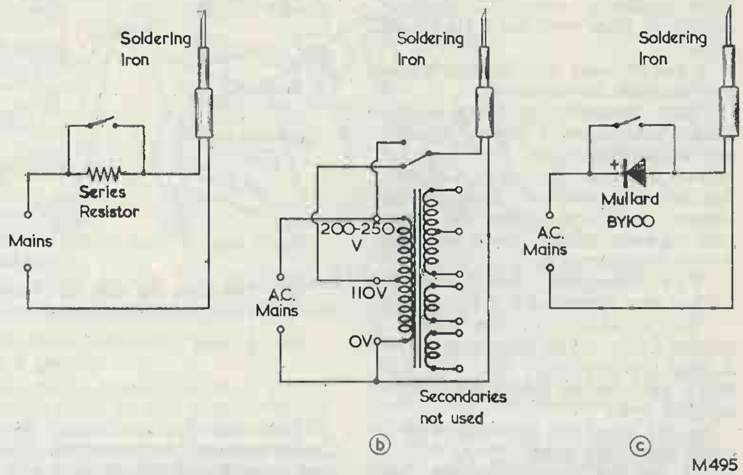


Fig. 2 (a). To run a soldering iron at half-power when it is not required for long periods, series resistance may be inserted. The resistance could be conveniently provided by an electric light bulb
(b). An alternative idea consists of using a discarded mains transformer
(c). Smithy's scheme consists of inserting a silicon h.t. rectifier in series with the iron. It is immaterial which way round the rectifier is connected

Half-current Soldering Iron Operation

Despite his somewhat testy mood, Smithy chuckled.

"That's not too bad," he commented. "I've heard you churn out worse."

"I'm glad you liked it," said Dick modestly. "Incidentally, I've got another little problem on my hands,

That's not a bad idea," remarked Smithy judicially.

"Also," continued Dick enthuthiastically, "you would simply have to choose an electric light bulb having the same power rating as the iron to give you half-current running. Thus, a 50 watt bulb in series with a

50 watt iron would cause half the normal current to flow through the iron."

"Hold it a minute," said Smithy. "You're way off the beam, there! Don't forget that ordinary domestic light bulbs have something like a 10:1 resistance ratio between the hot and cold conditions. A 250 volt 50 watt bulb will have a resistance around 1,250Ω when it's hot, but it will be nearer 100Ω when it's cold. Intermediate temperatures will, of course, give intermediate resistances. For half-current working with your 50 watt iron you'd need a bulb somewhere around 20 watts, and you'd have to check the voltage across the iron experimentally after you'd put it in circuit."

"Won't the iron resistance change also?"

"Not much," said Smithy. "The resistance of conventional mains soldering irons remains pretty constant from the cold to the hot condition. Indeed, I've occasionally used mains soldering irons as dropper resistors, during experiments, if they happen to have the resistance I need. Which is, by the way, a useful tip to bear in mind."

"I must remember that one," said Dick. "Anyway, my second idea was to use a transformer for running the iron at half-current. (Fig. 2 (*b*).) This is not quite as expensive as it sounds, especially if you have a few junked trannies lying around with 110 volt taps in the primary. A 50 watt 250 volt iron will have the same resistance as the bulb you just mentioned—1,250Ω. If, as you say, the soldering iron resistance stays reasonably constant, this will correspond to a current only slightly more than 100mA at 110 volts, and the primary of a standard receiver mains transformer should stand up to this quite happily. In fact, many of the soldering irons we use these days are only rated at 20 watts or so."

Smithy stroked his chin reflectively.

"Well," he remarked eventually, "your mains transformer idea isn't bad, and it has the advantage that you don't have to dissipate heat. But it still seems to me to require too much space and messing around."

"All right," said Dick, stung. "I've told you my ideas. Let's hear some of your own!"

"What you want," pronounced Smithy gravely, "is a component which will cause the iron to run at half-power and will take up no more space than a 1 watt resistor. Also, it should dissipate no heat."

"And where," asked Dick, sarcastically, "can you find a component with such magical qualities as this?"

"In our spares cupboard, for a start," replied Smithy. "I'm referring to a common-or-garden TV silicon h.t. rectifier."

"Hey?"

"That's right," grinned Smithy. "You simply shove the silicon h.t. rectifier in series with the a.c. supply to the soldering iron, with the result that the latter receives current on alternate half-cycles only. (Fig. 2 (*c*).) It doesn't matter which way round you connect the rectifier, as it will still only pass current half the time."

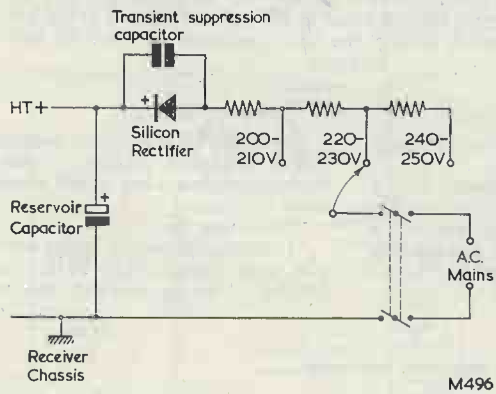


Fig. 3. A basic television h.t. rectifier circuit using a silicon rectifier. The transient suppression capacitor would normally have a value around 1,000pF. The heater circuit is not shown

Silicon Rectifiers

"Can such a rectifier stand up to a load like a soldering iron?"

"Of course it can," said Smithy. "A good choice of rectifier would be the Mullard BY100. The BY100 has a maximum average forward current of 550mA up to 50°C, this reducing to 450mA above this temperature. Therefore, even a 100 watt soldering iron could run quite happily if fed via a BY100. Also, there is a maximum recurrent peak rating of no less than 5 amps, and a maximum surge rating of 50 amps with this rectifier, so it should stand the soldering iron load quite well."

"I've often heard that the trouble with silicon rectifiers is that they can't stand high inverse voltages."

"That *has* been a limiting factor in the past," agreed Smithy, "but new rectifiers with higher peak inverse voltages are being developed all the time. The p.i.v. for the BY100 is 800 volts recurrent, or 1.25kV transient. If the BY100 is used in a half-wave rectifier circuit direct from the mains, as it is in a TV set (Fig. 3) the maximum p.i.v. will be 2.8 times the highest mains r.m.s. voltage. If we say that the highest mains r.m.s. voltage is 250, this gives us a p.i.v. of 700 volts. So the BY100 is O.K. for use in TV half-wave rectifier circuits because its rated p.i.v. is 800 volts."

"I'm beginning to get with this," said Dick excitedly. "In the TV rectifier circuit the p.i.v. is 2.8 times the mains r.m.s. voltage because of the presence of the reservoir capacitor. But, when you're putting the rectifier in series with a soldering iron there is no reservoir capacitor, so the p.i.v. applied to the rectifier drops to 1.4 times the mains voltage."

"You've got it," said Smithy. "And don't forget that, in the soldering iron instance, the small size of the BY100 makes it delightfully simple to fit on to the tags of a panel-mounting toggle switch. (Fig. 4 (*a*).) The switch gives you half-power and full-power, and the assembly takes up little more space than the switch on its own. If you use a three-position switch, such as the Bulgin S790, this single switch can give you 'Full-Heat', 'Half-Heat' and 'Off'." (Fig. 4 (*b*).)

"I'm dashed," said Dick impressed. "You learn something new every day! Tell me, Smithy, how is it that these tiny little silicon rectifiers can pass such heavy currents without overheating?"

"It's because," explained Smithy, "they have fantastically low forward resistances. It's the voltage dropped across a rectifier when it is conducting which causes heat to be generated, and the heat corresponds to the product of this voltage and the current. The very low forward resistance of a standard silicon rectifier, which is usually a fraction of an ohm, doesn't permit a high voltage to be dropped across it and so very little heat is generated. The BY100, for instance, only drops 1.5

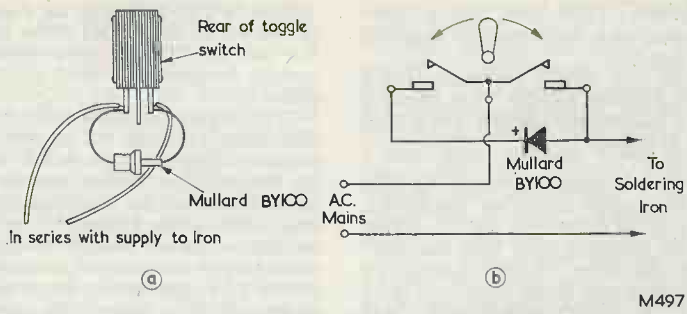


Fig. 4 (a). A BY100 silicon rectifier may be conveniently fitted to the tags of a panel-mounting toggle switch

(b). With the Bulgin rocker-action switch type S790 (shown here in ideogram form) three switch positions are possible. When the arm is to the right the mains voltage is applied direct to the iron. When it is to the left the BY100 is connected in series. The iron is switched off when the arm is central

volts at a forward current as high as 5 amps.

A sudden thought crossed Dick's mind.

"Have you actually checked a BY100 in series with a soldering iron," he asked suspiciously, "to see if the idea works?"

"I haven't tried it with a soldering iron," confessed Smithy. "But I *have* carried out a test which is much more exhaustive."

"What was that?"

"I connected one in series with a 100 watt electric light bulb," said Smithy. "To be truthful, this was rather a naughty thing to do because, at reduced temperature, the bulb filament would show a much lower resistance than that it has at full voltage. Anyway, the arrangement worked quite satisfactorily. The bulb dropped to half-brilliance with the rectifier in circuit and, after I'd disconnected the mains, I found that the rectifier was still cool."

"Why disconnect the mains?"

"Because," replied Smithy, "my method of checking for temperature rise is to apply my sensitive finger tip to the rectifier, and the cathode of the BY100 is common to its metal case!"

"I suppose you've got a point there," conceded Dick. "Incidentally I've noticed, in TV circuits, that silicon rectifiers often have capacitors connected across them."

"That's true enough," agreed Smithy. "Such capacitors usually have values around 1,000pF. Their function is to bypass any high transient voltages which might find their way into the mains and which could cause the rectifier to break down. These transients would be caused by switching inductive loads nearby, such as sewing machine motors or, even, channel-changing motors in the set itself."

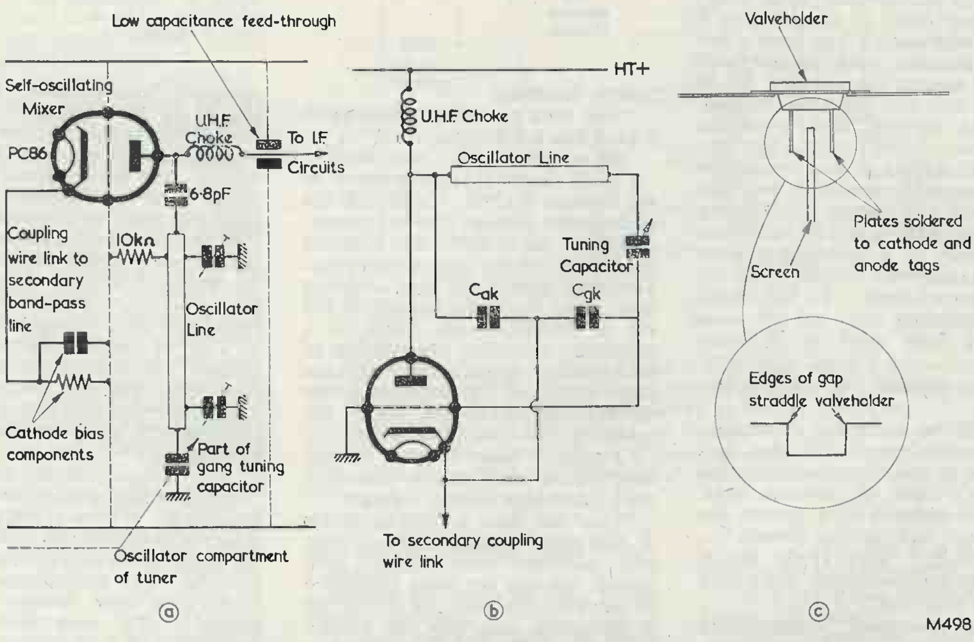


Fig. 5 (a). The oscillator circuit in a basic u.h.f. tuner (described in the June 1962 issue)

(b). The oscillator can be reduced to Colpitts form, as shown here

(c). The C_{ak} can be increased by adding metal plates to the cathode and anode tags of the valveholder. The rectangular gap in the screen appears at the valveholder only, the remainder of the screen continuing fully up to the underside of the chassis

Smithy paused for a moment.

"And now," he remarked, "I must get back to my bench again. To work, I hope, for the rest of the morning without any further interruptions."

But his comments fell on deaf ears, and he saw that Dick was, once more, in the throes of poetic invention. Smithy hoped it wouldn't take too long.

"How about this, then?" said Dick, his brow clearing.

"If, with an iron too hot you're encumbered,
Just pop in a BY100.
All you require
With this rectifier
Is a switch; and you're no longer lumbered!"

Back to U.H.F.

In spite of his previous remarks, Smithy chuckled as Dick's verse came to an end.

"You seem to be in good form this morning," he remarked, as he walked back to his bench, "some of those lines even scan!"

"I have my moments," replied Dick cheerfully. "Incidentally, I was hoping you'd explain something else to me."

"Sorry," said Smithy firmly, "but I've got a whole pile of work to get through and I just can't afford to spend any more time nattering."

"But this is important," protested Dick.

"I can't help that," replied Smithy, resolutely picking up his soldering iron.

"It's about u.h.f."

Smithy's hand faltered.

"What about u.h.f.?"

"It's just that I've got one or two queries which I've collected since our last session on u.h.f. tuners,* and I was hoping that you would answer them for me."

Smithy put his soldering iron back on the bench.

"I must admit," he remarked reluctantly, "that I find u.h.f. rather a fascinating subject at the moment. If your queries are quick ones, I *might* be able to spare a few moments in answering them."

"The first one," responded Dick quickly, "has to do with the frequencies covered by Bands IV and V."

"I see," said Smithy. "Well, Band IV is 470 to 582 Mc/s and Band V is 606 to 960 Mc/s. Which is what I told you when we had the previous session on u.h.f. tuners. You may recall that, at that time, I described the basic u.h.f. tuner and showed you how all the circuits worked."

"That's right," confirmed Dick. "And you also said that present tuners appear to have a range from 470 to 800 Mc/s or so."

"As you say," replied Smithy, ruminatively. "Off the cuff, I think that 800 Mc/s is still round about the correct maximum figure, although it may have been raised due to development work by some manufacturers. Anyway, all this raises an interesting point which was recently covered in the Pilkington Committee Report. The Report stated that the whole of Band IV is available in the United Kingdom for television, but that Band V is not wholly available. The range 606 to 614 Mc/s may possibly be reserved for radio astronomy. Also, at the time of the publication of the Report, no allocation between television and other services had been decided upon for the range 790 to 960 Mc/s.

"It sounds", said Dick, "as though the question of the maximum frequency which can be used for TV is still in the melting pot."

"It would seem so," agreed Smithy. "But don't forget that, as I said last time, these are still early days yet."

"Another thing that has puzzled me," continued Dick, "is the u.h.f. oscillator circuit. (Fig. 5 (*a*).) In our earlier discussion you explained that the oscillator line appears in a Colpitts circuit, and has a cathode tap given at the junction of the C_{ak} and C_{gk} of the triode. (Fig. 5 (*b*).) However, I can't help feeling that the C_{ak} must ve very small."

"It *is* small," said Smithy, "and would, I'd assume, be considerably less than 1pF. Anyway, I'm glad you brought up this point because I've since found that, in some tuners, the C_{ak} is augmented by a small physical capacitor in parallel. (Fig. 5 (*c*).) In some Continental circuit diagrams I've seen, the additional capacitor is shown as a trimmer."

"It would have to be a very *small* trimmer," commented Dick.

"Indeed it would," agreed Smithy. "But it normally wouldn't look like a conventional trimmer at all. A typical tuner obtains the additional capacitance across the C_{ak} by ensuring that the screen between cathode and anode of the valve does not continue right up to the bottom of the oscillator, leaving a rectangular gap approximately ¼ by ½in. Small metal plates are then soldered to the cathode and anode tags of the valveholder and the additional capacitance appears between these."

"But those plates would give the effect of a fixed capacitor," protested Dick. "Where does the trimmer come in?"

"The plates can act as a trimmer quite easily," replied Smithy. "In which case, you change the capacitance by bending them closer to, or

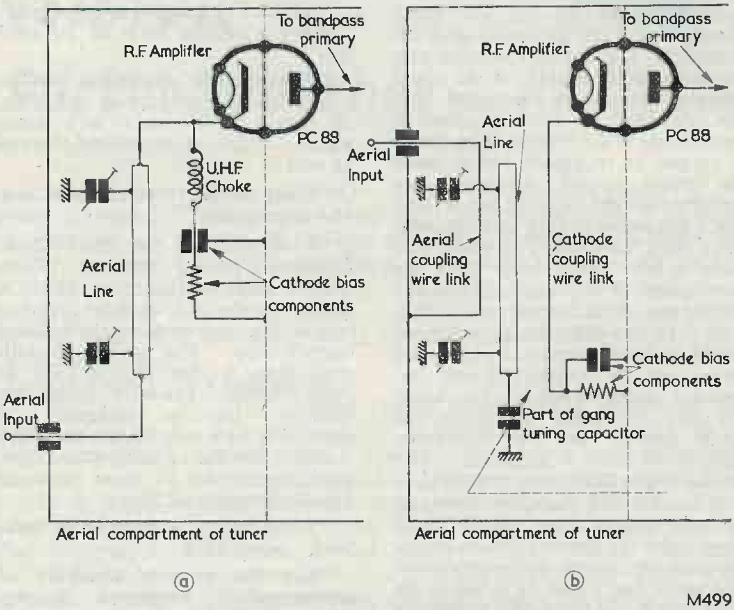


Fig. 6 (a). An aperiodic u.h.f. aerial input circuit (b). A tuned aerial input circuit in which links couple the low impedance aerial input and cathode circuits to the resonant line

* "In Your Workshop", June 1962 issue.

further away from, each other."

"That's going to be a difficult job for the serviceman," said Dick critically.

"I doubt," commented Smithy, "if the serviceman would be expected to touch them. The plates would be set up at the tuner factory using special equipment. The serviceman would then be well advised to leave them severely alone."

"Fair enough," said Dick. "Have you bumped into any other new things about u.h.f. tuners since our last session?"

"Not a great deal," admitted Smithy. "I think we covered the whole ground pretty thoroughly then. There is one point, nevertheless. I said, previously, that the aerial input circuit would normally be untuned, because of the heavy damping given by the low input impedance of the grounded-grid r.f. amplifier. The circuit I showed you consisted, quite simply, of the aerial going straight into the aerial line, the other end of which coupled to the cathode of the triode. (Fig. 6 (*a*).) A couple of trimmers would make the aerial circuit resonate very broadly over the required range; and that's the entire tuning arrangement. Since then, however, I've heard that some u.h.f. tuners may have an extra gang of the tuning capacitor tuning the aerial line as well. (Fig. 6 (*b*).) In this case, the aerial circuit would probably require two coupling wires, one to couple the low impedance aerial input to the aerial line and the other to couple the aerial line to the low impedance cathode of the r.f. amplifier. The second wire could have the cathode bias resistor and capacitor sitting at the end remote from the cathode, whereupon the whole cathode circuit becomes very simple and inexpensive. The aerial line would be tuned in the same way as the band-pass secondary line is tuned. As per our previous session."

"I'm with it," said Dick. "The trimmer at the tuning capacitor end of the line is adjusted at the high frequency end of the band being covered and the trimmer at the other end is adjusted at the low frequency end of the band."

"You've got it," said Smithy approvingly.

"With all the low impedances involved," remarked Dick, "won't the aerial tuned circuit still tune broadly?"

"Probably it will," replied Smithy. "You'll need to couple both the aerial and the cathode pretty tightly to the aerial line to get an adequate transfer of energy into the r.f. amplifier, and this will probably damp the tuned circuit quite a bit."

"What's the advantage then?"

"The main advantage of an aerial tuned circuit," replied Smithy, "is that it cuts down second channel interference. The output of the u.h.f. tuner is at standard receiver i.f., which is slightly short of 40 Mc/s. So, second channel interference may be given by stations having carriers spaced away from the required carrier by nearly 80 Mc/s. 80 Mc/s spacing sounds a lot, but it isn't all that much when you're dealing with signal frequencies of the order of 800 Mc/s. If the aerial tuned circuit is selective enough to reduce second channel interference by only 10dB then it may well have started to earn its keep."

"10dB?" commented Dick. "That's a voltage ratio of 3:1 isn't it?"

"Near enough," confirmed Smithy. "The tuned aerial circuit will also, of course, give you a little more signal strength on the desired channel as well."

"What do the resonant lines look like in practice?"

"It depends on the tuner manufacturer," replied Smithy. "You need a large surface area which is highly conductive at u.h.f., and a typical line may employ silver-plated copper strip. The advantage with strip lines is that they're easy to mass-produce. The strip shapes, for instance, can be stamped out accurately by a very simple tool, and it is also possible to pierce accurately-positioned holes in them with an equally simple tool."

"What do you want holes in them for?" asked Dick.

"For the accurate soldering of components," explained Smithy. "A manufacturer producing u.h.f. tuners will want all connections to the lines to be made at exactly the right points. Wire-ended components may be connected by passing the wires through the holes which have previously been pierced, whereupon each connection is bound to be at the right point along the line. You solder the wire to the line as well, of course."

"Could a manufacturer use other types of line?"

"Oh yes," said Smithy. "He could use silver plated wire or silver plated tubing if he wanted to. The latter would offer nearly twice the surface area as a round wire of the same diameter. In these cases, connections to the lines would probably be positioned accurately by using soldering jigs during production."

"This all sounds quite fascinating to me," commented Dick.

"Television tuner units *are* fascinating when you study them seriously," said Smithy. "They employ principles that are so uniquely their own that they are almost entirely separate from the remainder of television engineering."

"Is there anything else of interest concerning u.h.f. tuner lines?"

"There's one other thing," replied Smithy. "Since the lines are silver-plated you don't *have* to use copper underneath, since the u.h.f. currents travel in the plating anyway. Because of this, some tuners may have oscillator lines consisting of silver-plated Invar."

"Invar?"

"That's right," said Smithy. "Invar is a trade name for an alloy of iron, nickel, manganese, carbon and silicon which has an extremely low coefficient of linear expansion with heat. It's very useful for such things as high grade clock movements and surveying instruments, where the length of a piece of metal has to be accurately maintained."

Dick looked puzzled.

"I don't see what its application is in this case," he remarked.

"If," said Smithy, "you use silver-plated Invar for the oscillator line, the length of that line will remain very nearly constant despite changes in its temperature. The result is that oscillator drift in the tuner due to increase of temperature becomes reduced."

"Well, I'm dashed," exclaimed Dick. "I hadn't looked at it in that light! Incidentally, isn't Invar rather a peculiar name?"

"Not at all," said Smithy. "As I said, it's a trade name. So far as I know, it's short for 'invariable'."

"I see," said Dick.

"And that," commented Smithy, "really must bring our latest discussion on tuners to an end. I *must* get on with some work of my own."

"Okeydoke," said Dick, equably. "Many thanks for the gen!"

Peace at Last

The Workshop settled down to its usual calm, with Smithy concentrating on the chassis in front of him, and Dick putting the finishing touches to the set which had originally caused him to ask for Smithy's help.

With a satisfied grunt, Dick finally put the back on his receiver and carried it over to the rack. Vaguely, Smithy heard him deposit the set and, after a moment's examination of the remaining stock in for repair, walk back to his bench with another receiver.

Complete silence followed and, with a sigh of relief, Smithy applied his full attention to his own job. So engrossed did he become that it was several minutes before he realised that Dick was talking to himself again.

"But that," said Dick, "is ridiculous!"

Cover Feature

The "Clymax" 6-TRANSISTOR Printed Circuit Pocket Superhet

Described by **E. GOVIER**

THE "CLYMAX" 6-TRANSISTOR PRINTED CIRCUIT pocket superhet has been expressly designed for the home constructor who requires an efficient receiver at reasonable cost which may be constructed with the minimum amount of time and trouble. Consequent upon this, as the title of this article implies, the whole assembly is built upon a printed circuit board which is clearly marked out, thus avoiding any possible errors and saving much time in the building process.

The receiver, when completed, is contained in an attractive plastic case of modern styling, as may be seen from the heading illustration above.

The superhet design ensures that this is much more than a purely "local station" receiver, reception being possible at any location. The "Clymax" covers the medium-waveband and the B.B.C. Light programme on long-waves, no wavechange switch being necessary due to the fact that the wavechange control is built into the tuning capacitor.

Circuit

From Fig. 1 it will be seen that this is a perfectly straightforward superhet design. Mullard transistors are used throughout, the new alloy diffusion type AF117 being employed in both the mixer and i.f. stages.

A ferrite rod aerial assembly is incorporated this being tuned by one section of the 2-gang tuning capacitor, the other section of which tunes the oscillator winding of OT_1. The i.f. frequency is 470 kc/s, TR_2 and TR_3 being the i.f. transistors whilst TR_1 is the mixer/oscillator. Rectification is carried out by the germanium diode D_1 (OA70) the resultant a.f. being taken, via volume control RV_1, C_{11} and R_9, to the base of the driver stage TR_4 (OC78D). The driver transformer T_1 is connected to the push-pull output stage, a matched pair of OC78s, and from thence into a high flux 3in speaker. Negative feedback is applied, via R_{14}, to the base of TR_4. To avoid overloading on strong signals, a.g.c. is applied, via R_{21} and the secondary of IFT_1, to the base of TR_2.

Construction

The printed circuit board has a legend on one side which clearly indicates the positions of all the components. The volume control is already fitted to the board as it is thought that some constructors may find this operation somewhat difficult. Fig. 2 shows the methods of fitting both capacitors and resistors to the printed circuit board. All components should be inserted through the board from the legend side, the wire lead-outs being trimmed and soldered on the copper side. Fig. 3 shows the legend side of the board, on which each number corresponds to a particular item in the process of construction.

In Fig. 3 it will be noted that some designations appear more than once, for example, Item 1 is shown twice. This means that Item 1 requires two 4.7Ω resistors to be fitted, one each in the positions indicated.

Item 1. Obtain two 4.7Ω resistors and mount vertically to the printed circuit board.

Item 2. Mount two 100Ω vertically to the board.

Item 3. Mount into position two 470Ω resistors vertically.

Item 4. Obtain three 1kΩ resistors and secure vertically to the board.

Item 5. Vertically mount two 2.7kΩ resistors.

Item 6. Vertically secure one 10kΩ resistor.

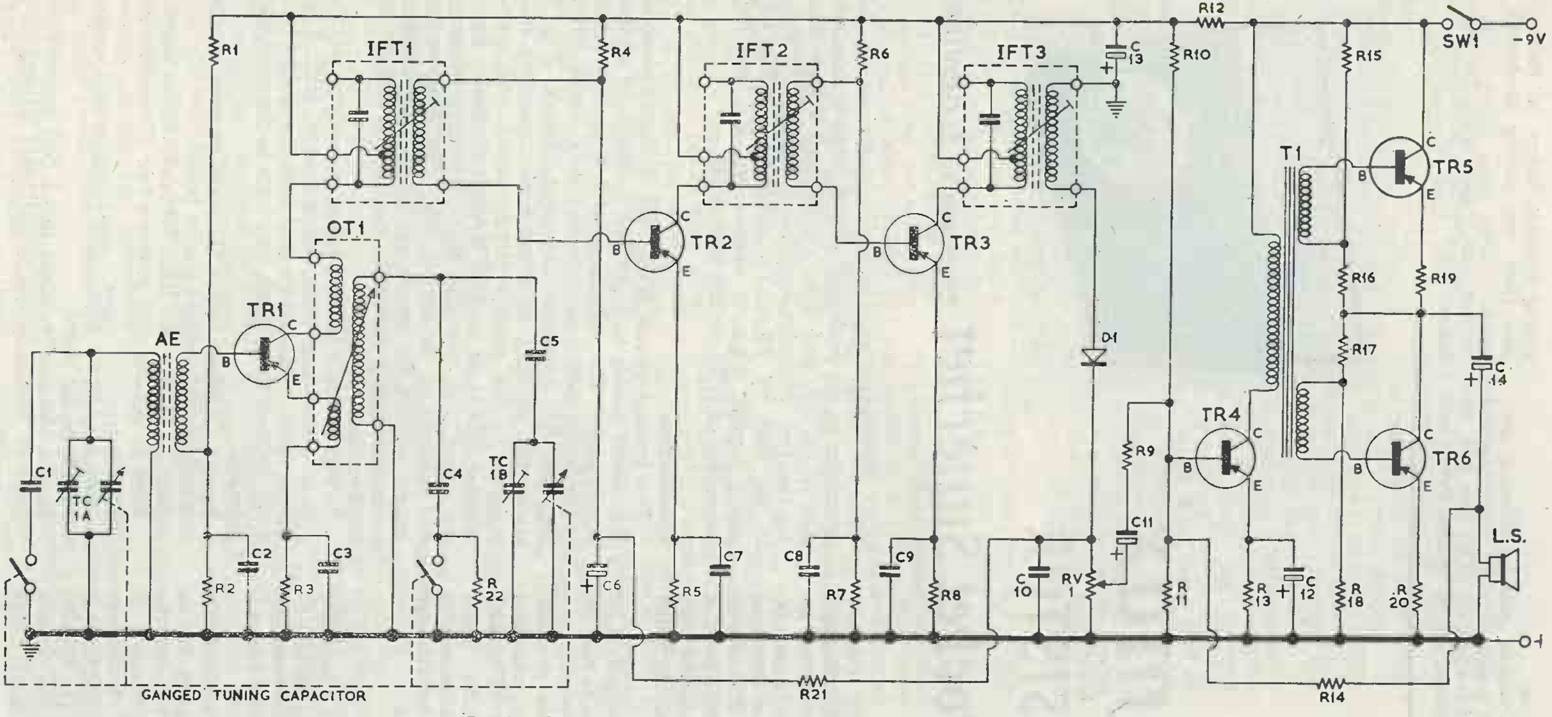


Fig. 1. Circuit of the "Clymax" 6-Transistor Printed Circuit Superhet

Components List

Resistors

R_1	33kΩ
R_2	6.8kΩ
R_3	1kΩ
R_4	56kΩ
R_5	680Ω
R_6	22kΩ
R_7	4.7kΩ
R_8	1kΩ
R_9	1kΩ
R_{10}	47kΩ
R_{11}	10kΩ
R_{12}	470Ω
R_{13}	470Ω
R_{14}	220kΩ
R_{15}	2.7kΩ 5%
R_{16}	100Ω 5%
R_{17}	2.7kΩ 5%
R_{18}	100Ω 5%
R_{19}	4.7Ω
R_{20}	4.7Ω
R_{21}	8.2kΩ
R_{22}	150kΩ

Capacitors

C_1	1,250pF
C_2	0.1μF
C_3	0.04μF
C_4	165pF
C_5	220pF
C_6	5μF, 2.5 w.v.
C_7	0.1μF
C_8	0.1μF
C_9	0.1μF
C_{10}	0.01μF
C_{11}	2μF, 10 w.v.
C_{12}	25μF, 6 w.v.
C_{13}	64μF, 10 w.v.
C_{14}	64μF, 10 w.v.

Transistors

TR_1	AF117
TR_2	AF117
TR_3	AF117
TR_4	OC78D
TR_5	OC78D
TR_6	OC78D

Speaker

35Ω

Battery

Vidor T6004 9V

Tuning Components

TC_{1a}, TC_{1b} } All included in twin-gang tuning capacitor

Wavechange switch (Clyne Radio Ltd.)

Miscellaneous

Ferrite Rod and Aerial Coil (Clyne Radio Ltd.)

OT_1 Oscillator Coil (Clyne Radio Ltd.)

Cabinet, Printed Circuit Board (Clyne Radio Ltd.)

IFT_1, IFT_2, IFT_3 (Clyne Radio Ltd.)

T_1 Driver Transformer (Clyne Radio Ltd.)

RV_1 Potentiometer, 5kΩ with switch SW_1

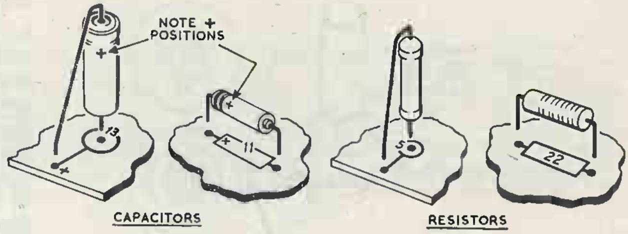


Fig. 2. Showing the various methods of fitting components

Item 7. Mount one 47kΩ resistor in the vertical position.

Item 8. Next, secure vertically one 220kΩ resistor to the board.

Item 16. The driver transformer should now be fitted, see Fig. 4. Note the position of the green spot on the transformer bobbin and ensure that this spot is adjacent to Items 2 and 5, as shown.

Item 10. Fit one 0.01μF capacitor vertically.

the soldering process. This procedure should be adopted when fitting the remainder of the transistors.

Item 15. Obtain two OC78 transistors and secure these to the board as previously described.

Item 17. Connect the red speaker lead to hole 17 leaving the other end free for the time being.

Item 18. Solder the black speaker lead to hole 18 leaving the other end free.

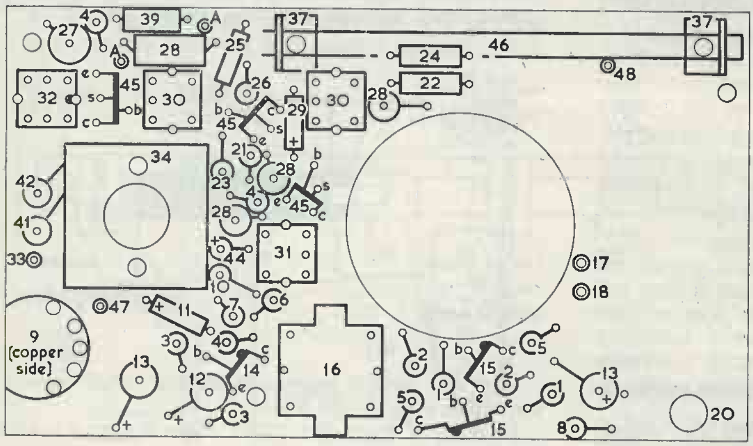


Fig. 3. Legend side of the printed circuit board

Item 11. Obtain one 2μF 10V capacitor and mount horizontally to the board, noting particularly the polarity (+) marking on both the component and the board. (Refer to Figs. 2 and 3.)

Item 12. Fit vertically one 25μF 6V capacitor, again noting the polarity markings both on the component and the board.

Item 13. Obtain two 64μF 10V capacitors and mount vertically, noting very carefully the polarity markings on the board. One has the sign + within the circle whilst the other marking indicates that the capacitor should be mounted in the reverse manner. (See Fig. 3.)

Item 14. Obtain one OC78D transistor (note the D suffix). Refer to Fig. 5 showing the transistor lead-out connections. Trim the lead-outs to approximately one inch in length and fit insulated sleeving to all three lead-out wires. Insert e of the transistor to e on the board and so on. Grip the ends of each transistor lead-out wire with a pair of long-nosed pliers, as near to the end of the wire as possible, in order to form a heat shunt during

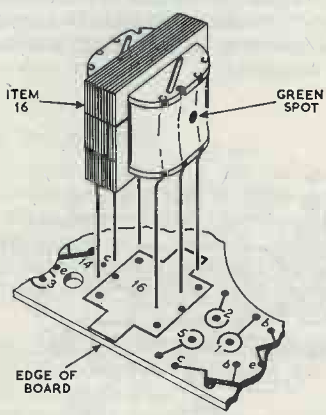


Fig. 4. Showing the correct location of the driver transformer T_1

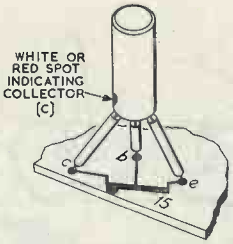


Fig. 5. Connections for the OC78 and OC78D transistors

Item 21. Connect one 680Ω resistor in the vertical position.

Item 22. Obtain one 4.7kΩ resistor and secure in the horizontal position.

Item 23. Connect the 8.2kΩ resistor vertically.

Item 24. Secure the single 22kΩ resistor in the horizontal position.

Item 25. Solder into position the 33kΩ resistor horizontally.

Item 29. Noting polarity, mount horizontally the 5μF 2.5V capacitor.

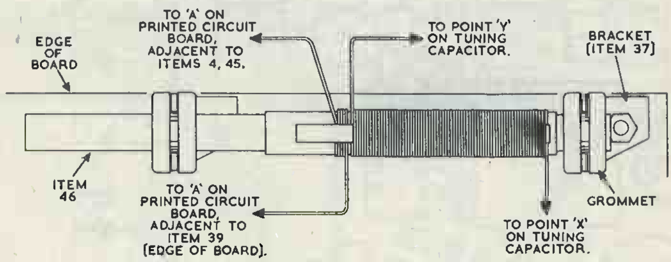
Item 30. Dealing next with the i.f. transformers, note that these have five pins on the base plus two further pins on the screening can and can therefore only be fitted in one position. Item 30 is that having the orange spot as the identification mark.

Item 31. This i.f. transformer has a black spot as the identification mark—*do not confuse this with Item* 30.

Item 32. Red spot oscillator coil. This coil has six pins on the base plus two on the screening can. Note that it can be fitted in two differing positions, only one method of fitting being correct. Ensure that the red spot on the base corresponds with the white spot on the legend side of the printed circuit board (adjacent to S of Item 45). Check carefully before soldering into position.

Item 34. Variable twin-gang tuning capacitor. Fit this component with reference to Fig. 6. Use two 6BA x ⅛in screws (Item 35). Mount the capacitor on the legend side of the board using fixing screws fitted through from the copper side.

Fig. 7. The ferrite aerial coil assembly



Item 26. Mount the single 56kΩ resistor vertically (see Fig. 3).

Item 39. Obtain one 6.8kΩ resistor and mount horizontally.

Item 44. Noting polarity, mount the OA70 germanium diode vertically.

Item 27. Vertically mount one 0.04μF capacitor.

Item 28. Obtain four 0.1μF capacitors and solder into position, as indicated, one horizontally and three vertically.

Item 41. Solder into position the 165pF capacitor. (See Figs. 3 and 6.)

Item 42. Obtain the 220pF capacitor and solder into position.

Item 33. Referring to Fig. 6, fit a lead between point 33 on the board and point Y on the tuning capacitor.

With reference again to Fig. 6, fit Item 40 (150kΩ resistor) and Item 43 (1,250pF capacitor).

Fit the aerial brackets (Item 37) of which there

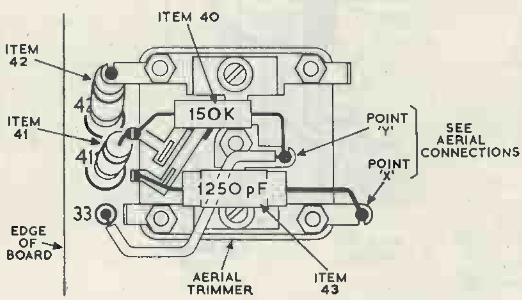


Fig. 6. Tuning capacitor assembly

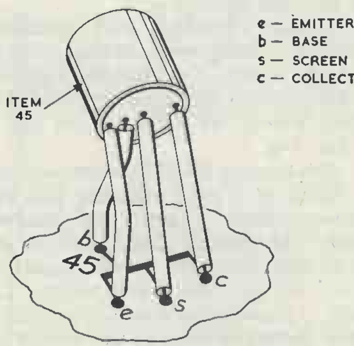


Fig. 8. Connections for the AF117 transistors

are two, using two 6BA x ¼in screws and nuts to secure the brackets into position. (See Fig. 7.)

With reference to Fig. 7, fit the rod aerial (Item 46) using rubber grommets (Item 51), as shown.

Solder the connections from the aerial coil on the rod aerial to the various points indicated on the printed circuit board. (See Fig. 7.) Examine the leads carefully and ascertain that they are located correctly before soldering.

Item 45. Obtain three AF117 transistors and trim the lead-outs to approximately one inch in length. Fit insulated sleeving to each lead-out and identify these lead-outs from Fig. 8. Solder into position each transistor, using pliers as a heat shunt, as described previously.

With reference to Fig. 9, fit the positive (+) battery clip (Item 49) to the battery red lead (Item 48). Fit the negative (−) battery clip (Item 50) to the black battery lead (Item 47). Insert these leads into the board and solder into position. The red lead fits to hole 48 and the black lead to hole 47.

Fit the speaker insulation ring (Item 63), which is a paper washer, over the loudspeaker magnet casing.

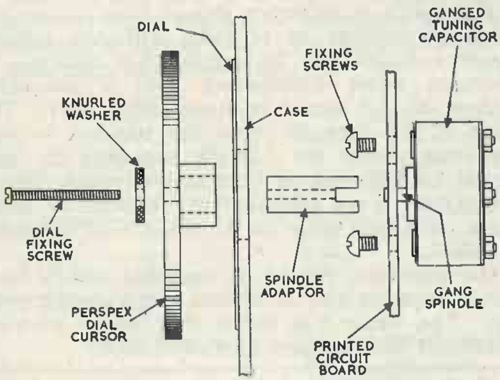


Fig. 10. Exploded view of the dial assembly

Solder the lead (Item 17) to one loudspeaker tag and the other lead (Item 18) to the other loudspeaker tag, routing these leads through the loudspeaker cut-out in the board.

Obtain the perspex tuning knob (Item 54) this being in the form of a dial cursor, and on the rear of this, using a needle or similar pointed object in conjunction with a ruler, score a line from the centre to the outside edge *on one half of the cursor only*. This line will then become the station pointer mark.

Construction of the receiver is now complete.

Alignment

The receiver alignment should be carried out before actually fitting the assembly into the cabinet.

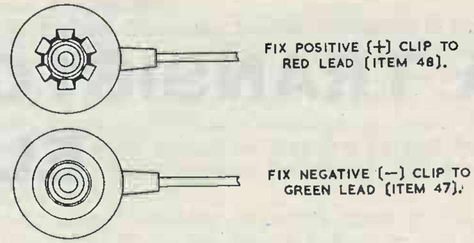


Fig. 9. The battery clips

Connect the Vidor T6004 battery to the battery leads. A testmeter may be inserted into one lead in order to check the current drain, which should be approximately 10 to 15mA under no-signal conditions.

Fit the printed paper dial and dial cursor into position temporarily (see Fig. 10).

Using a signal generator (inductive coupling to the ferrite rod aerial) switch on the receiver and fully mesh the tuning capacitor (550 metres approximately) *not on the long-wave band.*

Tune the i.f. stages to 470 kc/s reducing the output from the signal generator as necessary. Alter the generator to 540 kc/s and adjust the oscillator coil for maximum signal.

Set the signal generator to 1.6 Mc/s and fully open the tuning capacitor. Close both the trimmers on the tuning capacitor and then turn back approximately half of one complete turn. Adjust the oscillator trimmer for maximum signal, reducing generator output as required.

Adjust the aerial trimmer for maximum signal.

Tune the receiver to the B.B.C. Light programme (249 metres medium-wave) and readjust the aerial trimmer for maximum signal.

Rotate the dial in order to obtain the B.B.C. Light programme (1500 metres) on the long-wave band, and adjust the aerial coil on the ferrite rod for maximum signal. It will now be necessary to remove the dial assembly.

Completing the Assembly

Place the loudspeaker into the cabinet ensuring that the insulating paper ring is fitted over the rear of the loudspeaker. Insert the board into the cabinet and secure into position using the three 6BA x ¼in fixing screws provided. Clip the back of the cabinet into position and fit the chrome handle.

Affix the printed paper dial into the correct position on the cabinet front and refit the dial assembly as shown in Fig. 10.

Check the rotation of the tuning capacitor.

The "Clymax" receiver is now complete.

A TRANSISTORISED ELECTRONIC ORGAN

Part 2

By **S. ASTLEY**

This is the second in a series of four articles describing a transistorised electronic organ. Apart from the fact that transistors are employed, thereby reducing heat dissipation and assembly time, the organ has the further advantage that it is fully polyphonic on both manuals and pedals, that it employs no elaborate solenoid switches, and that all pitches and voicing are selected by electronic means

The Power Unit

THE TRANSISTOR POWER REQUIREMENT FOR THE complete electronic organ is only 30 to 35mA at 9 volts, and this is provided by a simple mains-operated stabilised power unit.

It must be emphasised that it is essential to start operations with the correct stabilised supply, as described here. On no account should a battery or an unstabilised supply be employed for the organ as these will give varying voltages with the risk of consequent frequency drift. The first unit to construct is the stabilised power supply.

The circuit of the power supply is given in Fig. 7 and, as may be seen, this consists of an OC72 or OC81 emitter-follower stabilised by a Mullard OAZ207 zener diode which applies a reference voltage to the base of the transistor. The 8 volt dial bulb acts as a fuse and is optional. In the event of an accidental short-circuit the bulb will light, giving an indication that the mains supply must be switched off immediately or the transistor will overheat.

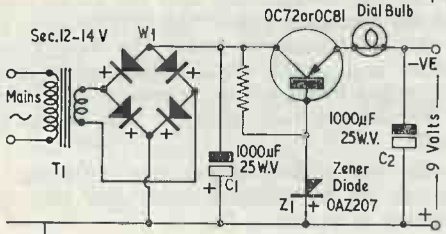


Fig. 7. The circuit of the stabilised power supply unit

The mains transformer should have a nominal secondary voltage of 12 volts, although slightly higher voltages may be employed if desired. A television boost transformer with a secondary voltage of 13.5 would be quite satisfactory. The value of R_1 depends upon the rectified voltage appearing across the 1,000µF capacitor C_1, and should be adjusted so that approximately 10mA (the current is not critical) flows through the zener diode. A typical value for R_1 would be of the order of 2.7kΩ.

The transistor should be provided with a heat sink by securing it to the chassis with a small copper clip. The writer has found that under working conditions the transistor runs quite cool.[1]

[1] The power dissipated in the transistor (i.e. the current flowing through the collector-emitter circuit multiplied by the voltage appearing across these two electrodes) should preferably be kept below some 80mW for the OC72. For a 35mA load this infers that the maximum voltage across collector and emitter should not exceed 2.3 volts.—*Editor.*

Components List
(Fig. 7)

Resistors

R_1	See text

Condensors

C_1	1,000µF 25 w.v. Electrolytic
C_2	100µF 25 w.v. Electrolytic

Miscellaneous

TR_1	OC72 or OC81
T_1	Mains transformer (see text)
W_1	Bridge rectifier (see text)
Z_1	Zener diode OAZ207 (Mullard)
Dial bulb	8V 0.15A

The rectifier employed by the writer was an 18 volt bridge type with a current rating of 500mA.

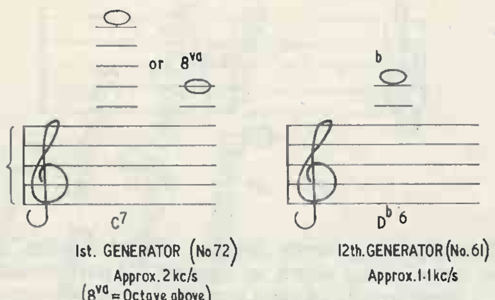
The components required for the power unit are not large and it should be possible to accommodate them on a chassis measuring 4in square or less.

The Generators

The waveform used for organ purposes is all important. The writer would suppose that there are three basic waveforms: sine, square and sawtooth. As was mentioned in Part 1 of this series (published in last month's issue) many instruments use sine and, by borrowing from other generators, produce the desired tones. Sometimes up to twelve generators are used to produce one particular tone colour. This is an excellent system and is used in the Hammond organ, but, as it necessitates some ten or more pairs of contacts per key, it is difficult for the amateur. The sine waves may be generated electro-magnetically or by means of valves, and tones are formed by the additive process.

The square wave has a pleasing tone, characteristic of the clarinet or bassoon, but as its harmonic content is mainly odd (i.e. 3rd, 5th, etc.) it is not readily suitable for tone forming and would become monotonous after a time.

The sawtooth, as used in the writer's instrument, has a very large number of harmonics and, by a subtractive system of filters, it is possible to imitate a wide range of instruments.



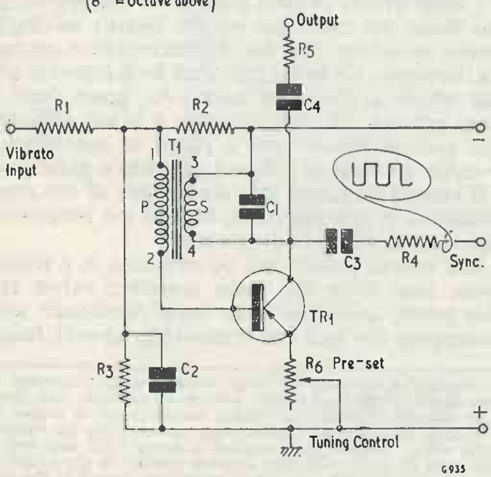


Fig. 8. The circuit for the 12 master oscillators

Master Oscillators

The highest frequency master oscillator is tuned to C^7. See Fig. 2 and Table 1 (both published in last month's issue). In Table 1, this generator is No. 72. Eleven further master oscillators for the octave down to D♭6 are required as well, these having the same circuit as that for C_7 and being tuned in the same manner by means of a pre-set variable resistor.

The master oscillator circuit is given in Fig. 8. In this circuit C_1 is the tuning capacitor and *must* be a mica type, preferably moulded mica, to guard against frequency drift. R_2 and R_3 temperature stabilise the transistor. C_4 is given a small value, at 500pF, to prevent pulling. R_5 assists in this direction and also provides attenuation. C_3 and R_4 form a network to carry a pulse for locking the first frequency divider. R_6 controls frequency, and may be mounted on a separate panel with the eleven similar variable resistors for the other master oscillators, thereby allowing tuning from a readily accessible position.

Vibrato is fed into R_1. As there will be twelve R_1's (one for each oscillator) all of these must be connected to the vibrato unit before the correct effect can be obtained. The transistor should be an XB101 or XB102,these types having been chosen, after trial with many alternatives, because of their excellent stability against temperature rise. The simple expedient of placing a soldering iron near the transistor will check the stability. If a transistor tester is available a leakage (Ico) over 10mA should not be tolerated, at least for the master oscillators.[2]

Within wide limits, the transformer employed in the circuit of Fig. 8 is not critical as regards turns, but it is important to ensure that the same type is employed in all twelve master oscillators or the amplitude of adjacent notes will vary. The writer

[2] The writer has found that many cheap transistors (e.g. Japanese types) which amateurs may obtain have leakages much higher than the figures quoted here. A simple instrument which would be of considerable advantage to the constructor is described in "Making a Simple Transistor Tester", by Gordon J. King, *The Radio Constructor*, March 1962.

Components List
(Fig. 8)

Resistors

R_1	47kΩ $\frac{1}{4}$W
R_2	33kΩ $\frac{1}{4}$W
R_3	2.2kΩ $\frac{1}{4}$W
R_4	270kΩ $\frac{1}{8}$W
R_5	270kΩ $\frac{1}{8}$W
R_6	3kΩ W.W. pre-set

Capacitors

C_1	0.005 to 0.001μF Mica (see text)
C_2	0.05μF miniature 150 w.v.
C_3	0.005μF miniature 150 w.v.
C_4	500pF

Miscellaneous

TR_1	XB101 or XB102
T_1	See text

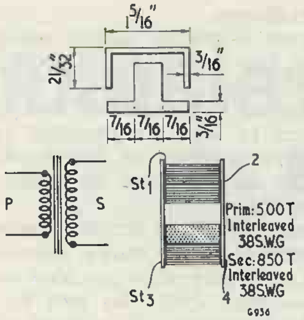


Fig. 9. Details of a suitable master oscillator transformer.

found t.v. vertical blocking oscillators quite suitable. He has also checked a driver transformer as employed in transistor personal portables (the primary being used as a secondary and the total secondary as a primary) and this gave excellent results. For those with patience, a suitable transformer may be home-wound as shown in Fig. 9, this consisting of a primary of 500 turns of 38 s.w.g. wire and a

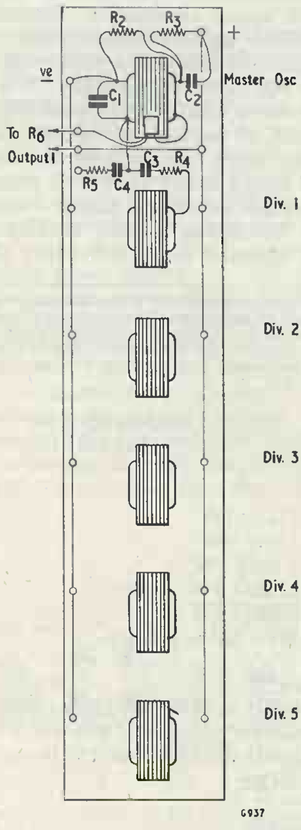


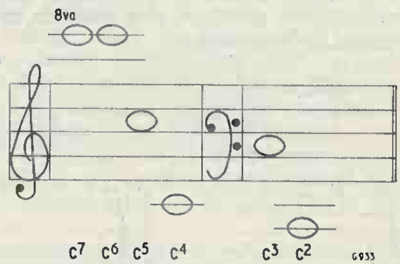
Fig. 10. The layout of master oscillator and frequency dividers for a note unit

secondary of 850 turns of 38 s.w.g. wire wound on a $\frac{5}{16}$in stack of silicon iron laminations having the dimensions illustrated. It is important that the windings are wound tight and evenly. They should, preferably, be impregnated.

The transformer employed in the circuit must be such that the required note is obtained without the value of C_1 falling below 0.001μF. If C_1 falls below this value, and added resistance in the emitter circuit does not produce the required frequency, the transformer must be discarded. The reason for this is that a high value of C_1 swamps shifts in circuit values elsewhere, and thereby reduces frequency drift.

No metal chassis is necessary for the master oscillators. The writer mounted each master oscillator and its five dividers on Paxolin boards measuring 8 x 2in, as shown in Fig. 10. For those who wish, twelve identical printed boards could be made up instead. An attractive mounting for the master oscillators and dividers might be given by Veroboard, although the writer has not used this himself.[3] It should be pointed out that modern miniaturised components can assist in making each board extremely light and small.

The first board will be a C board consisting of six C's in octaves down to C^2:



The remaining eleven boards will be similar, with six notes going down in octaves. Apart from the C's, there are six of each note in the complete organ, and these are provided by the boards having the master oscillators and five dividers. There are seven C's, however, C^1 being provided by a separate small unit which is described later. As, apart from C^1, there are only 12 notes to tune, it is not difficult to beat each oscillator with a piano or accordion, or to enlist the help of a friend who has a good "ear".

It should be noted that the output of the master oscillators is not sawtooth, but, as the frequency is high, this is of no consequence.

The boards should not be mounted in a position where heat from the main amplifier valves rises. This point, combined with those mentioned above concerning C_1 and the transistors, should help to

[3] Veroboard, reviewed in "Radio Topics" in the November 1961 issue of *The Radio Constructor*, consists of synthetic resin bonded paper material to which are bonded parallel strips of copper 0.1in wide, holes for component leads being pierced along the centre line of the strips. Veroboard is supplied in sheets 4.8in wide and 18in long, with 21 strip conductors running parallel to the longer side. The manufacturer and a source of supply are quoted at the end of this article.

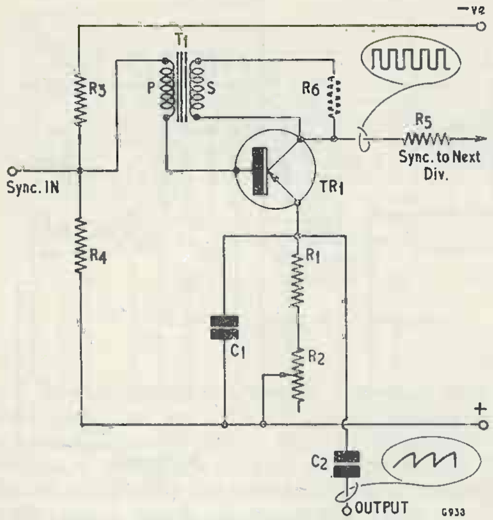


Fig. 11. The circuit of the frequency dividers. C_1 and C_2 have different values according to the range of notes handled

Components List
(Fig. 11)

Resistors

- R_1 3kΩ to 20kΩ (see text)
- R_2 5kΩ miniature pre-set potentiometer (Egen)
- R_3 33kΩ ¼W
- R_4 3.3kΩ ¼W
- R_5 270kΩ ⅛W
- R_6 See text
- TR_1 XB101, OC71, or any general purpose transistor
- T_1 See text

Unit	Div. 1	Div. 2	Div. 3	Div. 4	Div. 5
C_1—C–G♯	0.05	0.1	0.25	0.35	0.5
—G♮–D♭	0.1	0.25	0.5	1	1.25
C_2—C–G♯	500pF	0.001	0.005	0.01	0.1
—G♮–D♭	500pF	0.005	0.01	0.1	0.25

Note: The values for C_1 are for guidance only. See text. All paper capacitors are miniature low working voltage types. C_1 C_2 values are in µF unless otherwise stated.

preserve long term tuning stability. (If greater temperature compensation were required, R_3 of Fig. 8 could be replaced by a suitable temperature sensitive resistor.)

Frequency Dividers

The circuit for the frequency dividers is given in Fig. 11. In this diagram the transformer is identical to that used in the master oscillator. It will be noted that there is no tuning capacitor across either of the transformer windings; the circuit oscillates at a frequency dependent upon the winding self-capacitances.

Due to the high value of bias, TR_1 is cut off and C_1 slowly discharges until the arrival of a pulse which causes TR_1 to conduct and charge C_1. The time TR_1 is cut off is dependent upon the time constant of C_1 and R_1 plus R_2, and in our case a division of 2 is required. Some improvement could, no doubt, be obtained with synchronising by the addition of a pulse shaping circuit employing diodes, etc., but the writer preferred to keep components to a minimum, and the lock is, in practice, quite good. If desired, it can be improved by adding a resistor, R_6, across the transformer secondary, an average value being 10kΩ. If R_6 is too low the sync for the next stage will be poor. R_6 is entirely optional.

As with the master oscillator, the leakage current of the divider transistors should be low.

The components list for Fig. 11 gives the values for C_1 and C_2 for the different dividers, divider No. 1 being that which immediately follows the master oscillator. The values given for C_1 are those required

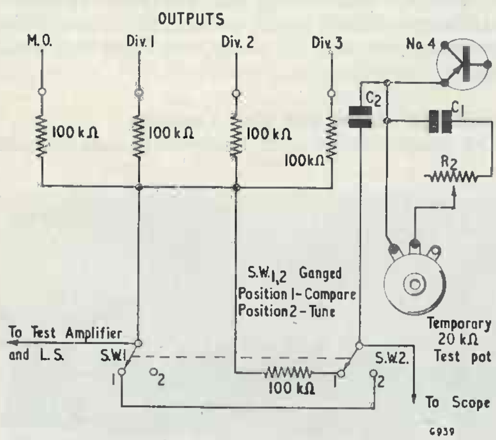
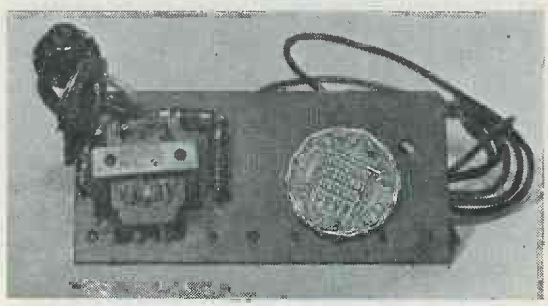
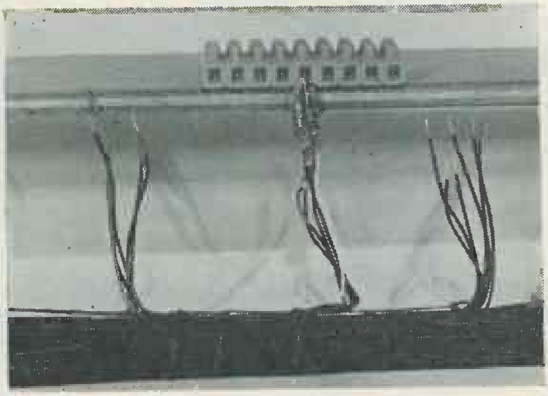


Fig. 12. Typical set-up for finding the value of R_1. In this instance, the divider is No. 4. The frequency being produced may be checked by beating with the finished dividers and cross-checking the waveform with the oscilloscope



A prototype master oscillator showing how small this unit can be made. A standard transistor driver transformer is employed



Illustrating how connections may be made to the distribution board terminal blocks

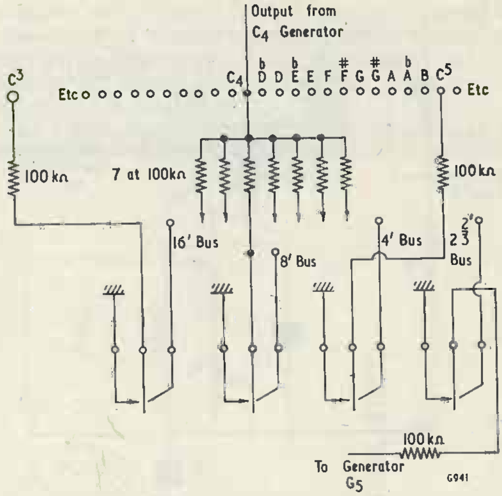


Fig. 14. The circuits switched by Middle C on the Solo manual. Also shown are the isolating resistors required by C4 generator

with the writer's transformers. The value for R_1 is found experimentally. When R_1 plus R_2 are too low in value no division takes place and the circuit can function as a variable oscillator. If an oscilloscope is available this can be used to indicate that a sawtooth is appearing at the output terminal. When the divider is working correctly it is possible to observe a definite division taking place as R_2 is turned, division going in steps from 2nd, 3rd, 4th, 5th, etc.

Although a series capacitor and resistor are employed in the sync feed from the master oscillator, only a single 270kΩ resistor is used for sync coupling between dividers.

The author's method of finding the value of R_1 consisted of using a test set-up such as that shown in Fig. 12. R_2 is set to mid-position and a temporary 20kΩ potentiometer substituted for R_1. The latter is then adjusted until a division of 2 is obtained, after which its value is measured and the nearest standard value of fixed resistor connected in the R_1 position. R_2 is then finally set up. If more than 20kΩ is required for R_1, the value of C_1 should be increased. When R_2 is set to the mid-position of the lock-in range it should be found possible to vary the master oscillator over 1½ tones up or down without the divider falling out of lock. This also ensures that a really vicious amount of vibrato can be applied to the master oscillator without the divider falling out of synchronism. The whole procedure is very simple and speedy if a test rig such as that of Fig. 12 is used for each unit as it is completed. No "queer" value capacitors and resistors are necessary, and the only thing to watch is that the unit is not working as a variable oscillator, and that it is definitely dividing.

It is worth mentioning that the pulse present at the divider collector could be used for a string tone. The writer has not, however, explored this possibility.

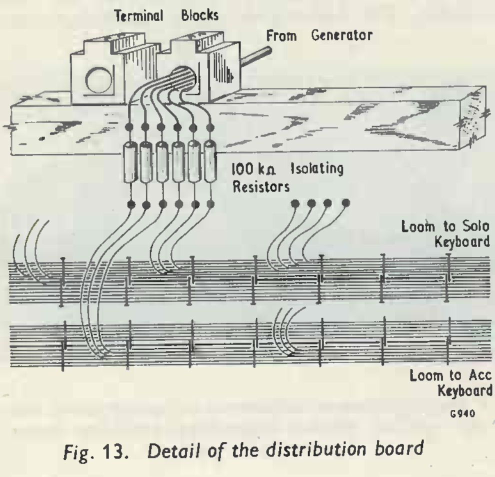
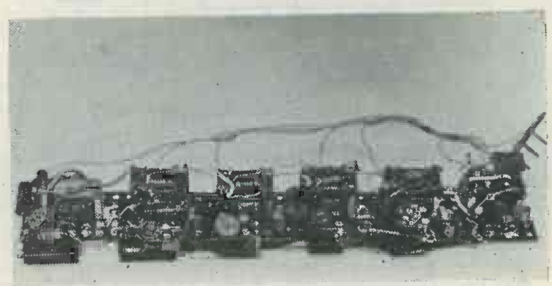


Fig. 13. Detail of the distribution board

Distribution Board and Key Contacts

The output from each completed note is taken



A master oscillator and set of dividers. The master oscillator is on the right. The left-hand transformer is identical to the others but has no tagboard

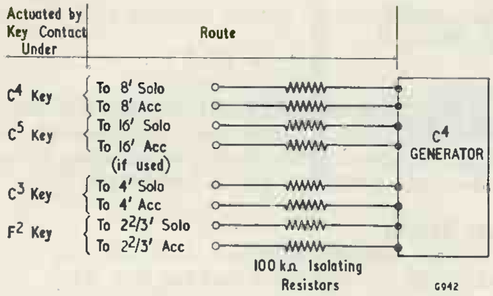


Fig. 15. The output routing of C^4 generator

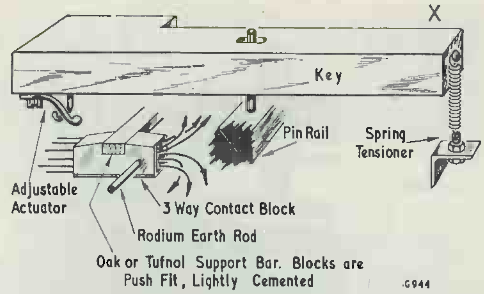


Fig. 17. Actuating the contact block. The contact block may alternatively be positioned at the point indicated by the cross

to a 72-way distribution board, and from here we route each note via a 100kΩ $\frac{1}{8}$ watt resistor to its respective key switches. Fig. 13 illustrates the manner in which the output of an individual note may be applied to the manuals, and, if applicable, to the pedal board. A single-way screw terminal block accepts the output from the note generator, and also holds the isolating 100kΩ resistors which are inserted between the note and each key contact. The leads from the resistors to the manuals are laced up into a loom, or harness.

Fig. 14 illustrates the connections at a typical key switch, as would be given by Middle C on the Solo manual. One 100kΩ resistor appears between C^4 generator and the key (which connects C^4 output to the 8ft bus), one 100kΩ resistor between C^3 generator and the key (16ft bus), one 100kΩ resistor between C^5 generator and the key (4ft bus), and one 100kΩ resistor between G^5 generator and the key ($2\frac{2}{3}$ft bus). At the same time the output from C_4 generator has to be applied to other keys. It requires a 100kΩ resistor for connection to the C^4 key on the Accompaniment manual (8ft bus). Two further resistors are required for the C^3 keys on both manuals (4ft bus). A further resistor is required for the C^5 key on the Solo manual (16ft bus), and two more for the F^2 keys ($2\frac{2}{3}$ft bus) on both manuals. Thus, seven 100kΩ isolating resistors are required for the output from the C^4 generator. These resistors are illustrated in Fig. 15, which also shows an additional eighth resistor to the Accompaniment manual for 16ft bus. The latter would be employed if the constructor decided to give the Accompaniment manual a 16ft bus.

The number of isolating resistors required for notes at the higher and lower ends of the range varies, and Fig. 16 shows two typical examples, as are given at the C^2 and B^6 generator outputs. The routing of other notes follows the procedure just outlined, and may be further ascertained by reference to Table 1.

It will be noted that each key, when at rest, causes the appropriate 100kΩ terminations to be short-circuited to chassis, thereby reducing generator breakthrough due to wiring capacitances. A further valuable result of this method of connection is that impedance to earth progressively increases as more keys corresponding to the same generator are pressed, thereby giving the effect of adding more ranks of pipes.

Fig. 4 (published in last month's issue) gives a simplified illustration of the type of key contacts used. On the Solo ahd Accompaniment manuals the writer employed commercial organ contact sets with a rhodium earth rod running the length of the contact blocks. The contact wires on the contact sets are gold plated and this is very desirable for a.f. keying as is employed in the writer's organ. Fig. 17 illustrates the manner in which the contacts are positioned relative to the key. They may alterna-

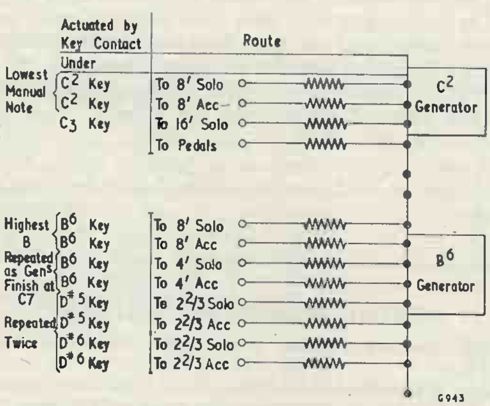


Fig. 16. Output routing for C^2 and B^6 generators

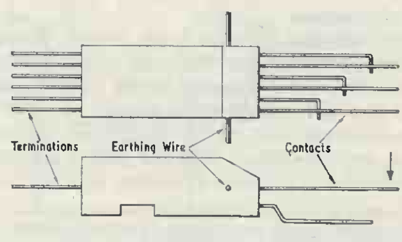
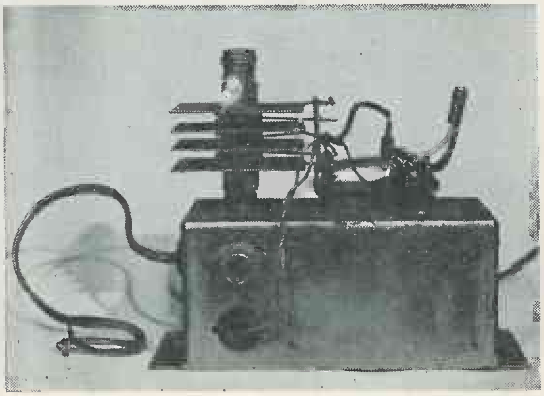


Fig. 18. The contact block employed by the writer. The straight wires are depressed by the key, contacting the angled wires



A prototype power supply unit. The zener diode is between the metal rectifier and the transistor (not fitted with a heat sink here), whilst the transformer is inside the box

tively be mounted at the rear upper edge, as indicated by the cross. Fig. 18 gives an illustration of the contact block.[4]

An alternative method of keying has been developed by Mr. A. Le Boutillier, Hon. Sec., Electronic Organ Constructors Society, and this is described in the Appendix at the end of this article. The keying developed by Mr. Le Boutillier allows a gradual build up when the key is pressed and thereby obviates key clicks. In the present instrument the 100kΩ isolating resistors act as click filters, and clicks are only very slightly evident on Flute stops high up in frequency.

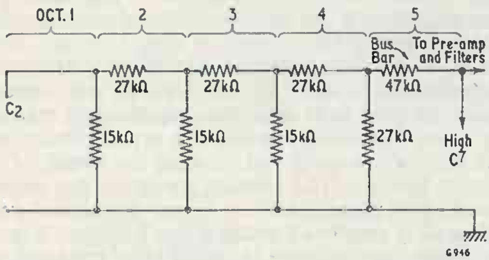


Fig. 19. The ladder attenuator used in each busbar

Busbar Attenuation

As the octaves descend, the lower notes will appear louder to the ear than the upper. Thus, as one runs down the scale, the lower notes would be stronger, and if a chord were played the left hand would overpower the right hand. To counteract this effect, approximately 5dB per octave attenuation is inserted in each busbar, as shown in Fig. 19. The attentuating sections appear between each B and C per octave.

Supplier

Veroboard is manufactured by Vero Electronics, South Mill Road, Southampton. It is available from some home-constructor stockists, including Henry's Radio Ltd., 5 Harrow Road, London, W.2.

Next Month

In next month's issue we shall carry on to the pedals, the pre-amplifiers and the stop tray.

(*To be continued*)

Appendix

Electrolytic Key Contacts

We are grateful to Mr. A. Le Boutillier, Hon. Sec., Electronic Organ Constructors Society, for the following description of electrolytic key switches, which is taken from the Society's Newsletter No. 4.

In electronic organs where the signal is keyed, two of the most formidable difficulties are given by contacts and key clicks. Electrolytic contacts appeared to be a solution to this and these were originally tried in the form of small brass dippers attached to Paxolin strips under the keys, these dipping into long copper troughs running the length of the keyboard and acting as busbars. The troughs contained a semi-conducting liquid, and gradual keying was obtained in this way.

Evaporation of the water in the troughs was the main objection, together with possible spillage when the organ was moved. Various liquids were tried in the troughs. Some of these, whilst satisfactory, were impracticable on account of their smell.

The latest development consists of having the troughs filled with foam rubber (available from Woolworths as draught excluder). The foam rubber is saturated with glycerine containing either by absorption (a natural process), or adding, about 10% of water plus a pinch of salt. In actual fact Bluecol anti-freeze was used and found satisfactory for a considerable length of time without "topping up".

The key contacts employed consist of 5BA bolts, but it is thought that 6BA with pointed ends may prove better, and the next keyboard to be tried by Mr. Le Boutillier is to be built on these lines.

(Mr. Le Boutillier has since informed us that the dippers showed slight signs of erosion from the electrolyte, and that an experimental keyboard is now under construction using graphite rods, i.e. the leads used in lead pencils, which should be a perfect answer.)

[4] Suitable contact blocks are available from the suppliers listed at the end of Part 1 of this series. Gold plated wire for the construction of contacts may also be available from these suppliers. Silver plated wire, found under most secondhand keyboards, is intended for high current keying and is not suitable for small current a.f. keying as is used here. (The author has, however, had fairly good results with silver plated wires sprayed with MS4 silicon Aero-Spray.)

PART II

PRACTICAL USES

Cathode Followers and Their Uses

By J. B. DANCE, *M.Sc.*

In this second article on the subject of cathode followers the uses of cathode followers will be discussed, particular attention being paid to their functions in radio receivers. Cathode followers are not used in small receivers where economy is important, or where power consumption must be kept to a minimum, because they cannot amplify; they have, however, a wide variety of uses in large receivers where optimum results are required. The home constructor will find that cathode followers are very useful in receivers because he will be able to add an extra valve as a cathode follower much more economically than can the manufacturer of commercial receivers. The performance of the cathode follower may be summarised as follows: (1) gain slightly less than unity, (2) high input impedance, (3) low output impedance, (4) low distortion, (5) wide frequency range, (6) the input and output are in phase, (7) the performance is stabilised by the negative feedback.

The component values suggested in the circuits in this article approach the optimum values, but it is not claimed that they are exactly optimum; much depends on the exact circuit details and the frequency being used.

R.F. Amplifiers

The two most important characteristics of r.f. amplifiers for use above 20 Mc/s are that they should generate low noise and that they should have a high input impedance. (The output impedance is not so important.) The first condition is satisfied by the use of a grounded grid triode, but grounded grid circuits have a low input impedance (a few hundred ohms). The signal itself must supply about one-tenth of the output power. The aerial is, therefore, loaded considerably by the circuit and the results are not nearly as good as might be expected from the low equivalent noise resistance of the triode.

This difficulty can be largely overcome by placing a cathode follower stage between the aerial and the grounded grid valve as shown in the circuit of Fig. 4. The input impedance of the cathode follower is very high and, providing the aerial is correctly matched to the receiver, a comparatively large signal voltage can be fed into the grid of the cathode follower. In the Fig. 4 circuit, the h.t. line supplies the input power required by the grounded grid stage and this power is controlled by the cathode follower. If the grounded grid valve were the first valve in the receiver, it would take so much power from the aerial that the signal voltage input to the grounded grid stage would be much lower than in the circuit of Fig. 4. An additional advantage of the cathode follower input circuit is that the loading on the aerial tuned circuit is very small and the Q and selectivity of this tuned circuit are, therefore, almost unaffected.

In order to achieve the best signal to noise ratio in the Fig. 4 circuit, it is necessary to use the valve with the lowest equivalent noise resistance (highest mutual conductance) for the grounded grid stage (V_2). The input impedance of the grounded grid stage is not a very important factor because the cathode follower stage has a very low output impedance and can supply the necessary input power to the grounded grid stage. Further details of such circuits can be found in articles by Longerich and Smith (*QST*, March 1955), T. W. Bloxham (*Short Wave Magazine*, September 1956) and by A. C. Edwards (*Short Wave Magazine*, May 1958). These authors use an EC91 cathode follower input stage followed by a triode-connected 6AC7 as a grounded grid r.f. amplifier. Other valves could be used in a similar circuit for a communication receiver if desired.

Cathode follower input stages followed by grounded grid triodes are also very useful as input stages for reception of f.m. transmissions on Band II. A 6J6 double-triode has been used but the circuit is reputed to have a tendency to instability. Owing to its very low noise, the circuit is useful for fringe area reception.

Oscillator Buffers

In short-wave receivers the conventional triode-hexode is often used as a multiplicative frequency changer. The main reason for this is that the

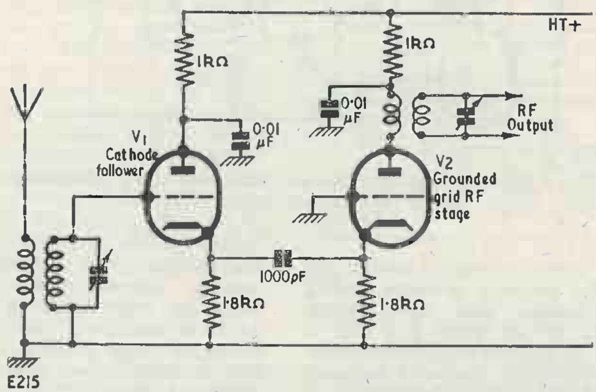


Fig. 4. A cathode follower feeding a grounded grid amplifier for use at the front end of a communications receiver. Trimmers and bandswitching are not shown

oscillator voltages are sufficiently isolated from the signal voltages to render pulling of the oscillator frequency on to the signal frequency almost negligible. In addition the circuit is fairly economical in components. It has the great disadvantage, however, that it is extremely noisy (equivalent noise resistance about 200,000 ohms). Similarly, heptodes are also very noisy as mixers. These types of oscillators are electron-coupled oscillators; that is, the signal and oscillator voltages are fed to separate grids of the mixer. The conversion conductance of most of these electron coupled oscillators is of the order of 0.3mA per volt at low frequencies, falling to much less than this at high frequencies. Other things being equal, the higher the conversion conductance, the lower the noise generated by the circuit.

The other common method of oscillator coupling involves feeding the oscillator and signal input voltages to the same grid and is known as additive frequency conversion because the signal and oscillator voltages are added together. A conversion conductance of at least 3mA per volt can be achieved by a suitable choice of valves. This method of coupling is not very widely used because, unless the ratio of i.f. to signal frequency is much greater than is normally used in a communications receiver, pulling will be very bad. The advantage of this method of coupling is that the high conversion conductance enables the circuit to generate very low noise.

One of the best solutions to the problem of designing a mixer stage which generates very low noise and yet which is not susceptible to pulling is the use of the circuit shown in Fig. 5. In this circuit one extra valve is required as a cathode follower buffer stage between the oscillator and the mixer. When suitable screening is used, the buffer stage effectively reduces the coupling from the signal circuits to the oscillator to a negligible amount. The loading of the oscillator by the cathode follower buffer is very small and this helps to increase frequency stability. The output of the buffer stage is cathode coupled into a 6AC7 low noise triode-connected mixer. If preferred, the circuit of Longerich and Smith (*QST*, March 1955) using a grounded grid mixer which is fed with signal input from another cathode follower could be used. This arrangement requires an extra valve and is less sensitive, but gives somewhat lower noise. A conventional valve amplifier can also be used as a buffer between the oscillator and mixer, but a cathode follower usually gives a better performance for most purposes. A single 12AT7 double-triode is suitable for both V_1 and V_2. The mixer (V_4) should be a low noise triode or triode-connected pentode. A suitable voltage stabiliser (V_3) is the VR105/30.

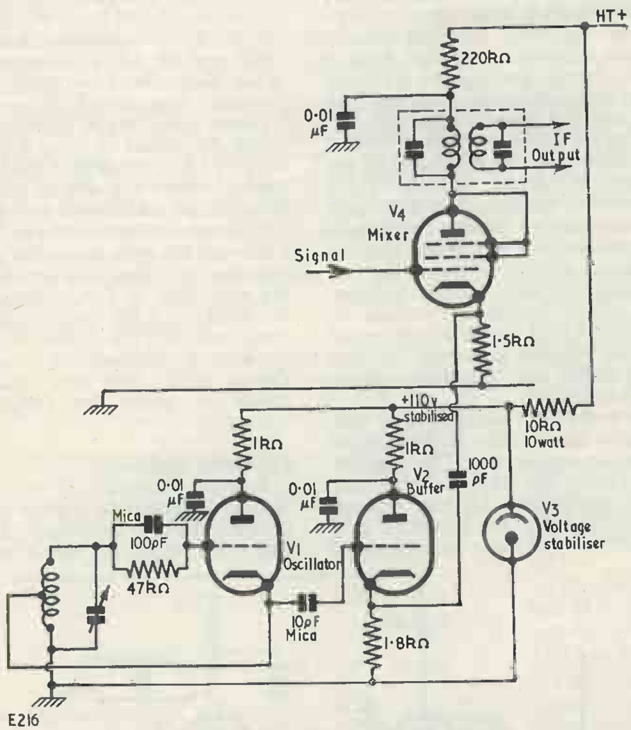


Fig. 5. A low noise frequency changer circuit employing a cathode follower buffer (V_2). Bandswitching is omitted

General Purpose Buffers

If it is desired to feed an r.f., i.f. or a.f. signal from one chassis to another or over longer distances by means of coaxial cable, it is not usually practical to merely connect the cable to the output of the unit. The common forms of coaxial cable have a capacity of about 10pF per foot; although cable can be obtained with a capacitance smaller than this, it is never possible to connect a length of it across a tuned circuit without completely throwing that circuit off tune. If, however, a cathode follower output stage is used as shown in Fig. 6 (*a*), any reasonable length of coaxial cable can be connected to the output of the cathode follower with barely any change in the loading on the tuned circuit.[1]

In a.f. circuits the output impedance of a unit is often quite high. If a long length of cable is connected to the output, the capacity of the cable will partially short-circuit high frequencies whilst leaving low frequencies almost unattenuated. This can be prevented by the use of a cathode follower output stage in the unit which feeds the signal to the connecting cable. A suitable circuit is shown in Fig. 6 (*b*). Such a stage has a low output impedance and the loading of the cable alters the output voltage at even the highest audio frequencies by a neglibible amount. The circuit is suitable for low levels, but if a cathode follower buffer for levels greater than a few volts is desired, the circuit of Fig. 8 (*a*) could be used if R_3 and C_3 were omitted.

[1] The output of the cathode follower can be approximately matched to the impedance of the coaxial cable by suitable choice of the cathode resistive load. Thus, if the output impedance of the triode of Fig. 6 (*a*) were 150Ω, a 150Ω cathode resistor (effectively in parallel) would cause the cathode follower to be approximately matched into 75Ω cable. If biasing requirements preclude the use of a single low-value cathode resistor, such a resistor could be inserted in the cathode circuit in series with a resistor giving the correct bias voltage, the latter being bypassed.—EDITOR.

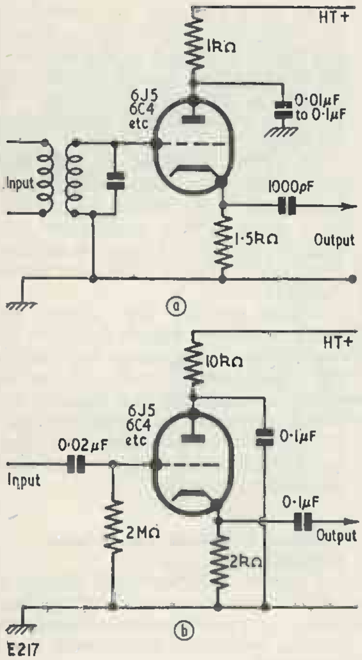


Fig. 6 (a). A typical cathode follower buffer stage for use at intermediate frequencies or radio frequencies up to at least 30 Mc/s. The optimum values of the capacitors vary somewhat with the frequency of operation (b). A typical audio frequency cathode follower stage

Cathode Follower Detectors

A cathode follower detector circuit (also known as an infinite impedance detector) is shown in Fig. 7. The cathode is bypassed to radio and intermediate frequencies but not to audio frequencies by C_3. The circuit is essentially an anode bend detector with 100% feedback at the modulation frequency. The anode current at zero signal is about 150 microamperes, but it rapidly increases when the input signal voltage becomes large. A meter in the anode circuit of a cathode follower detector is very useful when aligning a receiver. C_4 is used to block d.c. voltages and R_3 and C_5 filter r.f. from the audio output. If the value of C_3 is too small, the circuit can oscillate in the Colpitts manner. If, on the other hand, it is too large, high audio frequencies will be attenuated.

The cathode follower detector is very useful when it is important that the previous tuned circuit should not be appreciably loaded. The sensitivity is about the same as that of a diode detector, but much less than that of the leaky grid or anode bend detectors. It gives low distortion because of the audio frequency feedback and is comparable with the diode in this respect.

One of the major reasons why the cathode follower detector is not more widely used is the fact that most people consider that a.g.c. cannot be easily obtained from this type of detector. Whilst an extra diode could be employed in a separate circuit to rectify the i.f. for a.g.c. purposes, this would load the previous tuned circuit. A circuit which will provide amplified a.g.c. from a cathode follower detector was published in the October 1959 issue of *The Radio Constructor*; it requires one extra diode and a few resistors and capacitors.[2] Almost any small triode or triode-connected pentode can be used as a cathode follower detector.

Phase Splitters

Some phase splitters have equal loads in their anode and cathode circuits. They can therefore be considered as a combined cathode follower and conventional earthed cathode amplifier. Two such phase splitters are shown in Figs. 8 (*a*) and 8 (*b*). In Figs. 4 to 7, the same single resistor has been used for the cathode bias and the load; this is quite satisfactory at low levels, but at high levels it is important to use the correct load. Phase splitters normally operate at a fairly high level and therefore the bias and load resistors must be carefully chosen.

Fig. 8 (*a*) shows a method by which the necessary bias can be obtained whilst using the optimum value of load resistor. The cathode load is divided into two parts. The resistor (R_4) connected to the cathode provides the bias in conjunction with R_1. Both cathode resistors in series (R_4 and R_5) constitute the cathode load. The voltage developed across these two resistors is the same as that developed across the anode resistor, but opposite in phase. The anode load resistance must match the total cathode load resistance fairly accurately so that the amplitudes of the voltage in each output are nearly the same. R_3 and R_5 should therefore be components of 5% tolerance. R_4 need not be especially accurate.

An alternative phase splitter is shown in Fig. 8 (*b*). The first section of the 12AU7 is a normal audio amplifier and the second section is the phase splitter. The anode of the first triode is directly connected to the grid of the second triode. This places a positive voltage of the order of 100 volts on the grid of the second triode but a positive voltage of the same order is also present at the cathode owing to the high value of cathode load resistor used. The biasing is self-adjusting. If the grid becomes slightly more positive, the increased anode current will make the cathode more positive and the bias will be practically unchanged. The gain of the phase splitters themselves are both the same but the complete circuit of Fig. 8 (*b*) will give much more gain than the circuit of Fig. 8 (*a*) because of the extra amplifying triode section. The circuit of Fig. 8 (*b*) keeps phase shift to a minimum because of the direct coupling between the triodes; this is useful when negative feedback is being used.

The gain of the phase splitter itself in either circuit is slightly less than unity. The two output impedances are not equal, the output from the cathode being less than that from the anode. This does not, however, lead to the possibility of the amplitudes of the two outputs from the phase splitter being different.

Other Audio Uses

Cathode followers are very suitable as driver stages for any amplifier which draws grid current, such as Class B power amplifiers. Their low output impedance and low distortion are very important for this application. As such driver stages normally operate at a high level, care must be taken to use the correct bias and the correct load resistor.

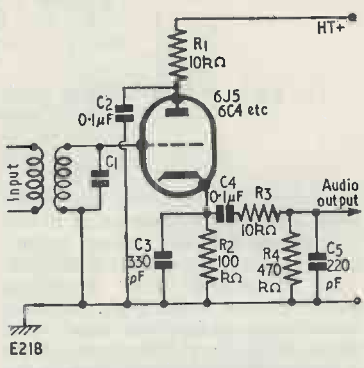


Fig. 7. A cathode follower detector circuit. The optimum values of resistors and capacitors depend on the input frequency and on the amount of high audio frequency attenuation which can be tolerated

[2] Page 184, "Amplified A.G.C. in Communications Receivers", J. B. Dance, *The Radio Constructor*, October 1959.

Cathode follower power amplifiers are not widely used despite their low distortion and low output impedance. This is because they require a high audio input voltage to feed them. It is not possible to obtain this voltage from a resistance-capacity coupled stage operating at normal h.t. voltages, but a step-up transformer can be used. The use of a transformer tends to introduce distortion, however, and one of the main reasons for attempting to use a cathode follower power output stage is to obtain low distortion. The transformer also introduces phase changes which might make the use of negative feedback much more more difficult. Attempts to obtain a large audio voltage to feed to the cathode follower output stage almost always lead to appreciable distortion.

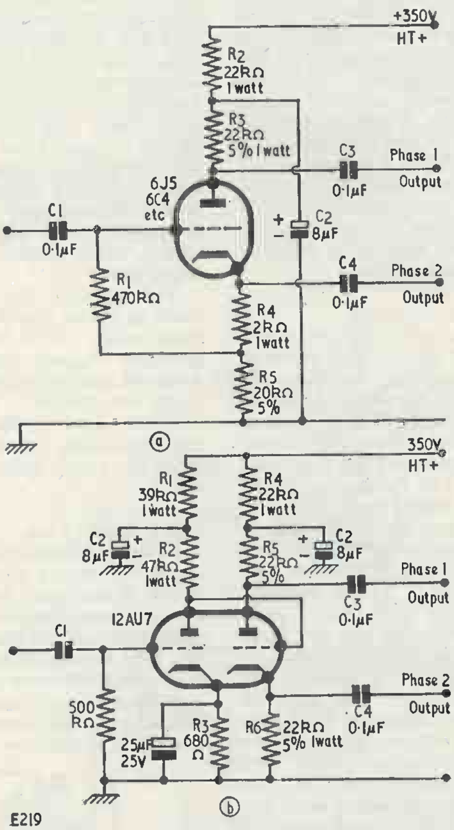


Fig. 8 (a). A phase splitting circuit and (b) an alternative phase splitting circuit

Power Supplies

If a variable voltage d.c. power supply is required, the simplest possible method would be the use of a variable series resistor or an adjustable potential divider. Both of these methods have the disadvantage that the output of the power supply will decrease rapidly in voltage as the output current increases for any one particular setting. In other words the regulation is very poor. In addition, the resistors required will be large, as they must be capable of dissipating a considerable amount of power.

The use of a cathode follower as shown in the circuit of Fig. 9 will overcome these difficulties. The circuit provides an output voltage which is variable from about 50 volts to about 240 volts d.c. at any current up to just over 50mA. The valve used must be capable of passing the maximum output current which will be required from the unit. It must also have a rated anode dissipation which is not less than the actual anode dissipation under any conditions.

As R_1 is adjusted, the potential of the cathode tends to follow that of the grid. A change in the setting of R_1 will therefore cause a proportional change in the output voltage. R_2 prevents excessive grid current from flowing.

If output voltages of less than about 50 volts are required, the lower end of R_1 should be returned to a point which is negative with respect to earth. A separate negative bias supply of about 100 volts is then required.

Owing to the low output impedance of the cathode follower, the regulation is little worse than that of the supply circuit itself. If the top of R_1 is connected to a separate h.t. supply instead of to the main supply, the regulation becomes excellent (very much better than the regulation of the main supply).

Cathode Followers for Volume Expansion

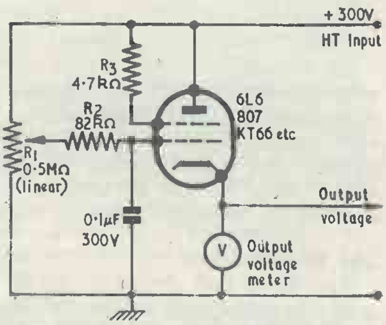
Cathode followers are useful in rather more unconventional applications, a typical example being the volume expansion circuit now to be described.

The average modulation level of any broadcast a.m. transmitter cannot be too low or the first-class reception area will be small. In order to prevent overmodulation it is, therefore, necessary to reduce the gain of the audio amplifier feeding the transmitter during loud musical passages ("volume compression"). If it is desired to reproduce the sound in a fairly large room at the receiving end so that it is as nearly as possible identical with the original, it is necessary to use a receiver containing an audio amplifier, the gain of which increases with the audio input level ("volume expansion" or "contrast expansion").

There are a number of methods by which the gain of an audio stage can be increased as the audio signal input increases. None of these circuits are perfect, as the characteristic of the volume expansion at the receiver is not likely to be exactly the opposite of the compression at the transmitter.

Principles of Circuit

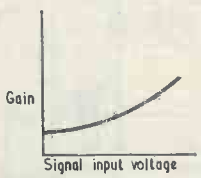
The circuit to be described (Fig. 11) employs a variable-mu pentode as a cathode follower (strapped as a triode) together with a single diode. This diode, V_1, rectifies a suitable fraction of the input voltage (tapped off VR_1) in order to provide a negative d.c. bias which is smoothed by R_3 C_3. This resistor and capacitor determine the time constant of the circuit. The negative bias is applied to the grid of the variable-mu valve, V_2, and alters its mutual conductance. In addition bias is provided by the flow of anode current through R_5. The larger the signal, the larger the negative bias provided by V_1 and the smaller the mutual conductance (g_m) of V_2.



E220

Fig. 9. A cathode follower which can be used in conjunction with a normal smoothed d.c. power supply, to provide a variable d.c. output voltage

The output impedance of a cathode follower (Z_{out}) is much smaller than (R_5+R_7) and, as Z_{out}



E221

Fig. 10. A typical volume expansion characteristic

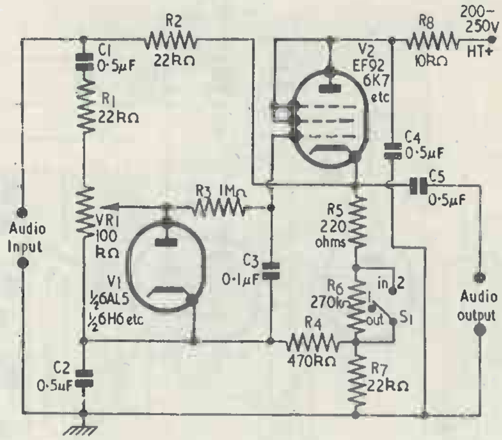
is virtually in parallel with these resistors, R_2 and Z_{out} form a potential divider. $Z_{out}=1/g_m$ for a cathode follower and therefore if g_m becomes smaller (with increasing audio input), Z_{out} will increase and the gain of the whole circuit will become larger, thus giving the desired volume expansion.

The switch S_1 is normally in position 2 so that R_6 is short-circuited. When S_1 is in position 1, the valve V_2 receives a fairly large positive voltage on its cathode and the expansion circuit becomes inoperative, the audio signal voltages merely flowing through R_2 to the output.

The resistor R_1 is incorporated in the circuit so that peak audio voltages are not short circuited through the diode V_1 when the slider of VR_1 is near the upper end of its track.

Practical Details

It is most important that the circuit shown in Fig. 11 should be inserted in the audio section of the receiver at a point at which the signal level is suitable. It could follow the detector if the latter is operating at a fairly high level and has a low output impedance (e.g. a cathode follower detector), but a stage of audio amplification will probably be required between the detector and the expansion circuit.



E222

Fig. 11. Circuit of the volume expander described in the text

The audio input voltage to the expansion circuit should be about 12 to 17 volts peak, but should not appreciably exceed 20 volts or distortion will occur.

The gain of the circuit is less than unity; that is, its use will cause a slight loss of volume, but many receivers will have enough spare audio gain to compensate for this. As the input voltage increases from 3 volts to 20 volts, the gain increases from about 1/25 to 1/6th.

When any contrast expansion is being used, it is unlikely that the best results will be obtained unless the listener is prepared to experiment somewhat. The setting of VR_1 and the receiver volume control should be adjusted until the most pleasing results are obtained.

The principle on which the circuit of Fig. 11 operates was first described by M. O. Felix in *Wireless World*.[3]

Conclusion

Cathode followers have a very wide variety of uses in radio receivers and industrial electronic equipment where economy of components is not of primary importance. Some of the uses of cathode followers have been discussed, but there are many others, e.g. the output stage of a crystal calibrator for a receiver, microphone input stages, and couplers in wide band amplifiers.

[3] Page 92, *Wireless World*, March 1944.

FOUR WAVEBAND A.M. TUNER

By A. A. BAINES

THE TUNER DESCRIBED IN THIS ARTICLE WAS built to provide a piece of equipment which, with a suitable amplifier, would give results superior to that offered by the conventional "4+1" a.m. receiver. The tuner provides reception on medium and long-wave bands, as well as on two short-wave bands (66–30 metres and 30–12 metres). A manufacturer's surplus coil pack was employed in the unit constructed by the writer, this being mounted, with all trimmers and associated components, on a heavy metal base measuring some nine by three and a quarter inches. It is appreciated that this pack will not be available to constructors, but the circuit may still be employed with individual aerial and oscillator coils, the coil manufacturer's recommendations being followed with regard to trimming and padding capacitance values. The circuit evolved by the writer includes an r.f. stage having an untuned anode load, this offering an improved signal-to-noise ratio.

The Circuit

The tuner unit circuit is shown in Fig. 1., and is of straightforward design. V_1 is the r.f. amplifier and is a high-slope 6BA6 valve. Anode coupling is taken through C_7 to the grid of the frequency changer V_2 which is a 12AH8. A point of interest here is that the screen-grids of V_1 and V_2 are

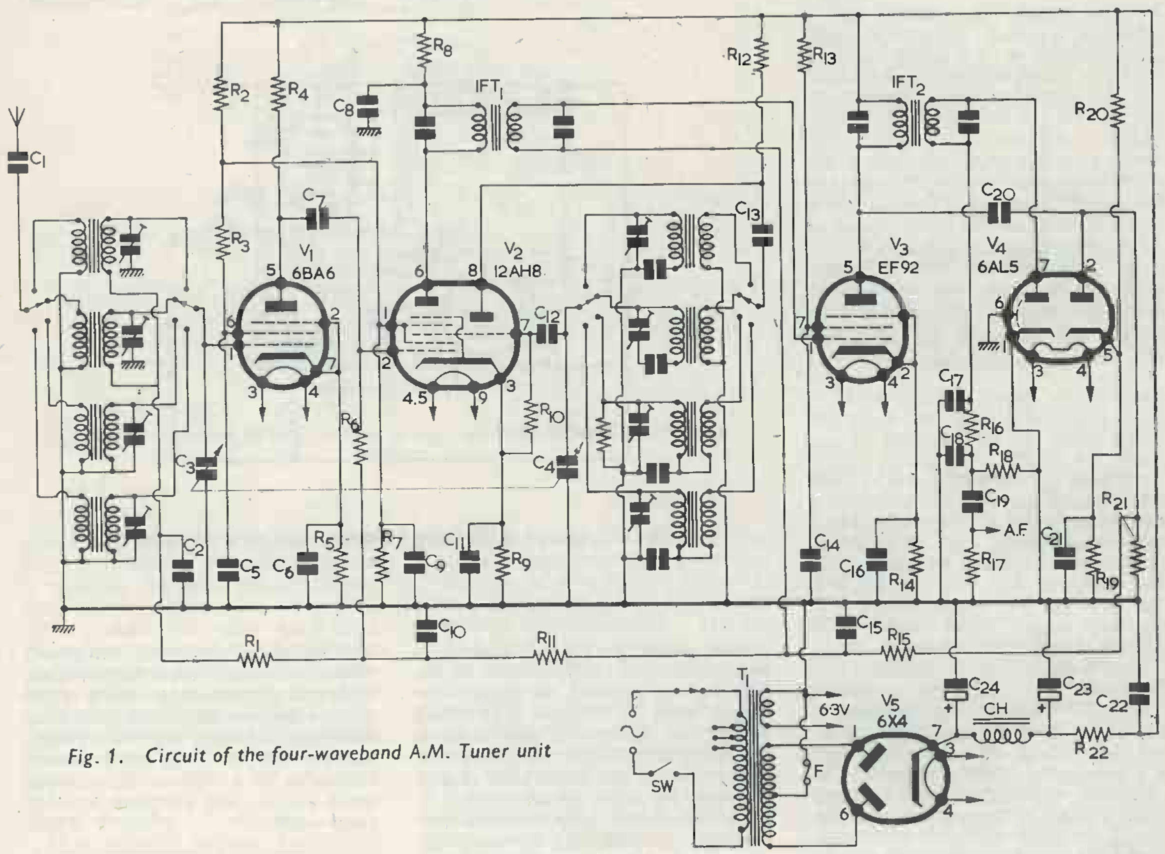
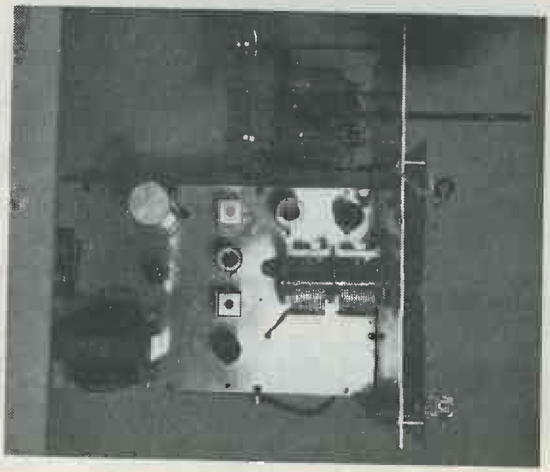


Fig. 1. Circuit of the four-waveband A.M. Tuner unit

potentiometer fed from the junction of R_2 and R_7, thus giving a stable feed which helps to overcome the effect of a.g.c. on the screen-grid voltage.

The output of the mixer section of the 12AH8 is tuned by I.F.T.$_1$, a miniature adjustable core transformer, the secondary of which feeds an EF92 acting as an I.F. amplifier in V_3 position. The second I.F. transformer is coupled to one half of a 6AL5, V_4, functioning as a diode detector, the other half of this valve being the a.g.c. diode which is fed through C_{20} from the primary of I.F.T.$_2$. A delay voltage is developed across R19 and the a.g.c. voltage itself is fed, via R_{15}, to the grids of V_3, V_2 and V_1 when on medium- or long-waves. No a.g.c. voltage is fed to V_1 on the short-wave bands. (It should be pointed out that this is due to the internal wiring of the coil pack employed, and that a.g.c. could be fed to V_1 on the short-wave bands—provided the requisite oscillator padding capacitors are employed—by returning the lower ends of the tuned coils to C_2 instead of to chassis.)

The usual i.f. filter is incorporated and the a.f. voltage is developed across the load resistor R_{17}. No volume control was used as such a control would normally be already present in the input



Above-chassis view of the A.M. Tuner

to the existing amplifier; if this was required, a 1MΩ log potentiometer could be fitted in place of R_{17}, the a.f. voltage being taken from the slider of this control. To avoid distortion on heavily

Components List

Resistors

(All ¼W except where otherwise stated)

R_1	220kΩ 20%
R_2	10kΩ 20%
R_3	1.5kΩ 20%
R_4	2.2kΩ 20%
R_5	68Ω 20%
R_6	1MΩ 20%
R_7	47kΩ 1W 20%
R_8	1kΩ 20%
R_9	220Ω 20%
R_{10}	47kΩ 20%
R_{11}	220kΩ 20%
R_{12}	27kΩ ½W 20%
R_{13}	27kΩ ½W 20%
R_{14}	220Ω 20%
R_{15}	470kΩ 20%
R_{16}	47kΩ 20%
R_{17}	1MΩ 20%
R_{18}	100kΩ 20%
R_{19}	10kΩ 10%
R_{20}	470kΩ ½W 10%
R_{21}	1MΩ 20%
R_{22}	1kΩ 2W 10%
V_1	6BA6
V_2	12AH8
V_3	EF92
V_4	6AL5
V_5	6X4

Capacitors

C_1	100pF
C_2	0.1μF 150 w.v.
$C_{3,4}$	500pF variable, two-gang
C_5	0.05μF 250 w.v.
C_6	0.01μF 150 w.v.
C_7	20pF
C_8	0.1μF 375 w.v.
C_9	0.05μF 250 w.v.
C_{10}	0.1μF 150 w.v.
C_{11}	0.01μF 150 w.v.
C_{12}	47pF
C_{13}	100pF
C_{14}	0.05μF 250 w.v.
C_{15}	0.1μF 150 w.v.
C_{16}	0.1μF 150 w.v.
C_{17}	100pF
C_{18}	100pF
C_{19}	0.05μF 375 w.v.
C_{20}	47pF
C_{21}	0.1μF 250 w.v.
C_{22}	0.5μF 375 w.v.
$C_{23,24}$	16+16μF 350 w.v. electrolytic

Miscellaneous

4 off B7G valveholders
1 off B9A valveholder
Coil pack—see text
2-gang 500pF capacitor
Dial and drive
Chassis—see text
1FT1 1FT2—465 kc/s I.F. transformers
T1—Mains transformer 250–0–250V. 70mA. 6.3V. 1.5A
Ch—60mA. 10H. choke
Sw—Mains on-off switch
F—Fuse 500mA

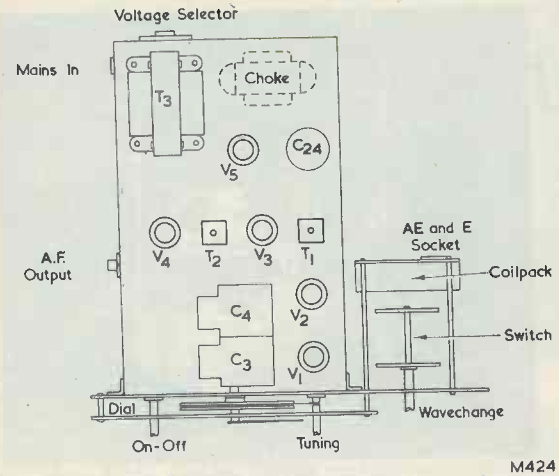


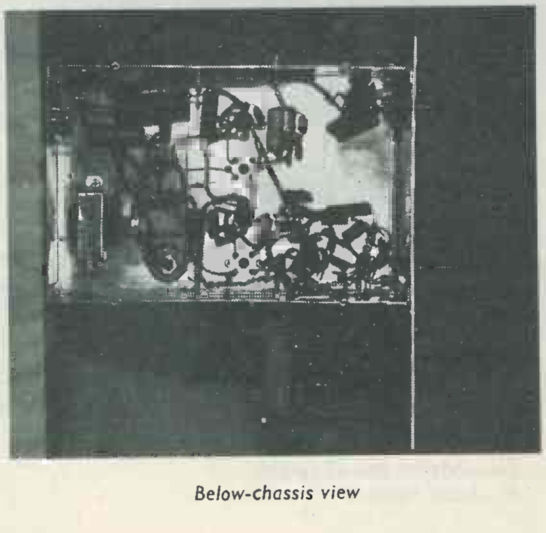
Fig. 2. Chassis layout

modulated signals, the input resistance of the subsequent amplifier should be at least 500kΩ.

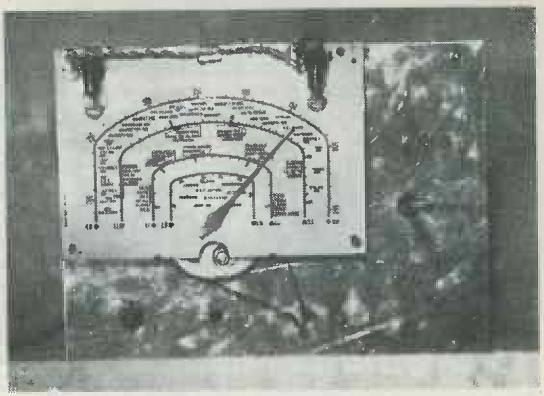
The power pack is conventional but, as the maximum anode voltage of the EF92 is 250 volts, a limiting resistor, R_{22}, with a decoupling capacitor, C_{22}, is inserted in the h.t. rail.

The circuit is amenable to modification if desired; V_1 and its associate components can be omitted if an r.f. stage is not required and in this event R_2 will become 22kΩ. The values of R_3, R_4 and R_8 can range from those specified up to 5kΩ. Likewise, the value of the decoupling capacitors is not critical and can be in the range of 0.01μF to 0.1μF;[1] of course, attention to their working voltages must be given. Values actually used in the writer's unit were 150 w.v. for a.g.c. and cathode decouplers, 250 w.v. for screen-grid decouplers and 375 w.v. for h.t. components.

[1] If a.g.c. is applied to V_1 on the short-wave bands, the value of C_2 may be critical for optimum tracking.



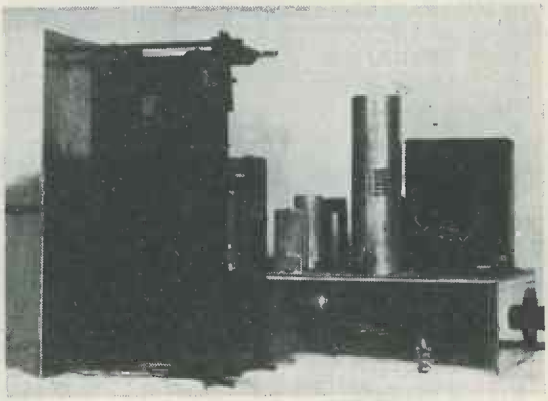
Below-chassis view



Front panel of the completed tuner unit

Chassis Layout

A suitable chassis layout for the tuner unit is illustrated in Fig. 2. As may be seen, the coil pack employed is mounted separately from the main chassis. When individual aerial and oscillator coils are employed, these could be mounted on a separate metal base taking up the same position as that for the coil pack used here.



View of the coil pack assembly

The Completed Tuner

The completed tuner gives an excellent selection of British and foreign stations, ease of tuning on the short-wave bands having been enhanced recently by the addition of a twin 25pF bandspread capacitor in parallel with the tuning capacitor; the bandspread capacitor being mounted below the chassis in line with the tuning capacitor and other controls so that a symmetrical front layout is preserved. This modification is not shown in the diagrams or photographs but its incorporation more than repays the small expenditure of time and money required.

The Advantages of Micro-Alloy Transistors

By C. M. SINCLAIR

Currently available to the home constructor through the usual retail channels are a series of micro-alloy p.n.p. transistors under the type numbers MAT100, MAT101, MAT120 and MAT121. Micro-alloy transistors offer a number of important advantages, and these are reviewed in this article

THE IDEA OF A UNIVERSAL TRANSISTOR—one that can be used in virtually any circuit—has always appealed to manufacturers and home constructors because of the simplicity it brings to design and construction. Until recently such an ideal has not been possible and a multitude of types has been needed to suit all requirements. However, now that the micro-alloy transistor has been released to the home constructor market this situation is completely changed, and since MAT's, as they are sometimes known, are remarkably low in price they may be used to advantage in all applications.

The MAT is made by an extension of the technique originally used with surface barrier transistors. The latter were excellent for use as low level r.f. amplifiers and at frequencies up to about 30 Mc/s, but they suffered from very low current gain and were limited to levels of collector current of only about 5 mA. Micro-alloy transistors, however, have extremely high levels of current gain, will operate at frequencies as high as 130 Mc/s and may be used with collector currents of 50mA. At the same time they will give good gain at incredibly low levels of collector voltage and current. For example, computer circuits have been built with them in which each MAT operates with only 0.005mW of power whilst conventional transistors require 5mW or 1,000 times as much.

Technical Specifications

Four different micro-alloy transistors are now on the market, types MAT100, MAT101, MAT120 and MAT121. The technical specifications for these are given in the Table.

From the Table it will be seen that the MAT100 and MAT101 types are specified at a collector voltage of 1.5V and a collector current of 0.5mA. The values of current gain and cut-off frequency achieved at these levels are remarkably high and these transistors were, in fact, specially designed for high performance at low power.

Types MAT120 and MAT121 are specified for operation at normal power levels for v.h.f. transistors and their exceptionally high cut-off frequencies make them very useful at higher frequencies as well as in low frequency, high current, high gain circuits. The MAT121 is particularly impressive because it has a guaranteed gain of more than 75 and a typical gain of 150.

Micro-Alloy Transistors in A.F. Circuits

MAT's have several advantages over conventional types and these may be briefly outlined as below:

(1) Extremely high gain.
(2) Ability to operate at very low levels of collector current and voltage and in simple direct-coupled circuits.
(3) Superb frequency response. MAT's are ideal for use in Hi-Fi circuitry.
(4) Complete freedom from drift or inconsistant performance.
(5) Very low noise level making them invaluable in pre-amplifier circuits.

Fig. 1 shows the circuit diagram of a conventional, small signal, a.f. amplifier stage. With the component values shown the collector current will be 1mA and any MAT may be used, although since the MAT100 and MAT120 are cheaper they may be preferable. It can be shown that whereas with an ordinary a.f. transistor this circuit would give a power gain of about 20dB or 100 times, the MAT100 will give a gain of 34dB (2,500 times) and the gain with the MAT101 will be 40dB (10,000 times). It will be seen that the MAT'S result in an extremely high

Absolute Maximum Ratings

Storage temperature	−65° to 85° C.
Junction temperature	85° C.
Collector voltage	−6V
Collector current	−50mA
Total dissipation at 45° C.	25mW
Lead temperature	230° ± 5° C.

Electrical Characteristics

		MAT100	MAT101
A.F. current gain hfe. At (VCE=1.5V, Ic=0.5mA)	Min.	25	75
	Typical	50	100
	Max.	75	250
		MAT100	MAT101
Cut-off Frequency fα at (VCE=1.5V, Ic=0.5mA)		60 Mc/s	60 Mc/s
VCE Sat. (Minimum Collector voltage) at Ic=1mA		0.04V	0.04V
Price		7s. 9d.	8s. 6d.
		MAT120	MAT121
A.F. current gain hfe. At (VCE=6V, Ic=4mA)	Min.	25	75
	Typical	50	150
	Max.	75	250
Alpha Cut-off Frequency fα at (VCE=6V, Ic=4mA)		120 Mc/s	120 Mc/s
VCE Sat. (Ic=6mA)		0.05V	0.05V
Price		7s. 9d.	8s. 6d.

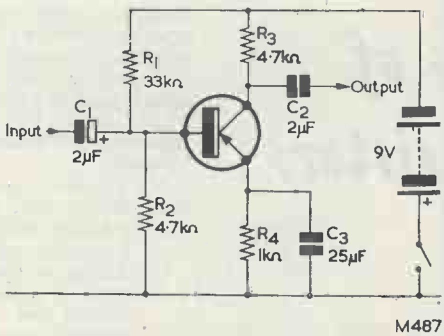


Fig. 1. Single a.f. amplifier stage

improvement, and whilst some a.f. transistors may be slightly cheaper than the MAT's, two stages would be required using such transistors to achieve the gain of a single MAT101 stage. Thus the use of the MAT101 results in a considerable saving as well as a reduction in the number of components, together with an improvement in frequency response and noise factor. This circuit is typical of those used in the a.f. pre-amplifier and driver stages of radios and amplifiers, and a MAT may be used in any circuit of this type.

The very low power capabilities of MAT's are well illustrated in the circuit of Fig. 2 which has a total consumption of only 0.5mA from a 1.3V or 1.5V battery. The collector currents of TR1, TR2 and TR3 are 0.1mA, 0.2mA and 0.25mA respectively. The circuit is made possible by the fact that a MAT will work with a collector voltage of as little as 0.04, which is very much lower than that required by any other type of transistor. The overall power gain is 80dB or 100 million times. Other types of transistor might work in this circuit but the gain would be very much lower.

A high impedance magnetic earpiece may be used in place of R_3, and C_4 will then be unnecessary. Also, a high impedance microphone can be connected between the base of TR1 and the junction of R_5 and R_6, whereupon C_1 and R_4 should be omitted and R_5 increased to 33kΩ.

To achieve a very low noise level in any transistor it is necessary to use a low collector current but with conventional transistors this results in low gain. With a micro-alloy type, however, a collector current of only 0.1mA may be used and the gain will still be very high. A microphone pre-amplifier is a typical example of a circuit that requires low noise and high gain. Normally two or three transistors are required in a fairly elaborate and carefully designed circuit. The circuit of Fig. 3, however, uses a single MAT101 in an extremely simple circuit which has a power gain of 35dB. It may be used to feed directly into a valve or transistor power amplifier.

MAT's may be used in class A output stages wherever the transistor dissipation does not exceed 25mW. Their particular advantages in this case are their very high gain and improved efficiency due to the low bottoming voltage. They are particularly advantageous when a very low battery voltage is used because their high gain is maintained up to 50mA collector current.

Micro-Alloy Transistors in R.F. Circuits

The advantages of MAT's in medium wave and long wave receiver circuits are particularly noticeable.

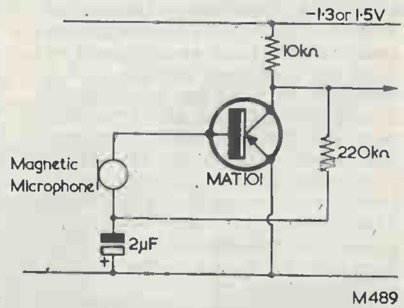


Fig. 3. Low noise high gain microphone pre-amplifier

A typical MAT100 has a current gain of 50 at 1 Mc, and the MAT121 has a gain of well over 100 at this frequency. This type of gain can also be achieved by the recently introduced alloy diffused transistors, such as the OC171. These are excellent transistors for many applications, but they will not operate with less than about 1.3 volts across the collector and the emitter, and their gain reduces sharply as the collector current is reduced below about 1mA. The MAT types, however, will operate with only 1/20th of a volt across the collector and emitter and their r.f. gain is still excellent at only 1/10th mA. They will also provide high r.f. gain with collector currents as high as 50mA.

Using micro-alloy transistors in a conventional 6 transistor superhet can result in an immense improvement in performance. They may be used in a conventional circuit without changing the component values, except that any neutralising components used in the i.f. stages of the original receiver will become

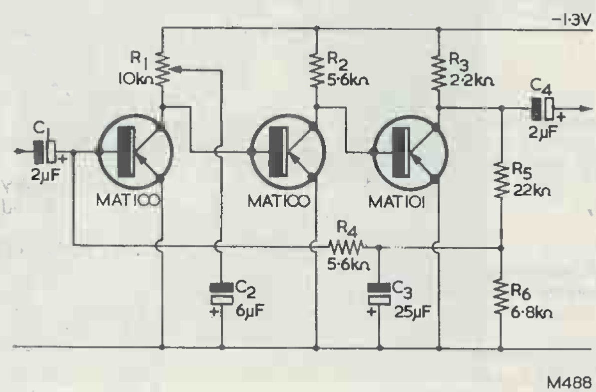


Fig. 2. Very low consumption subminiature amplifier

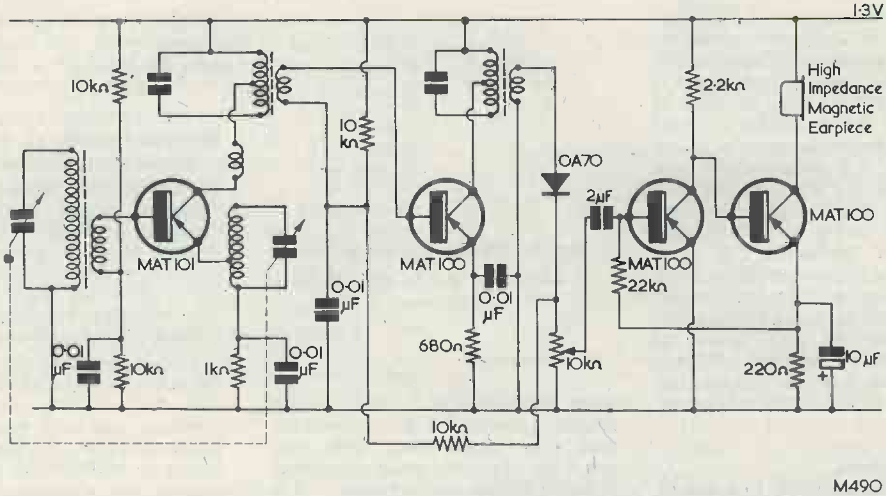


Fig. 4. Very low voltage superhet. Any matching set of tuning capacitor, ferrite aerial, oscillator coil and i.f. transformers may be used

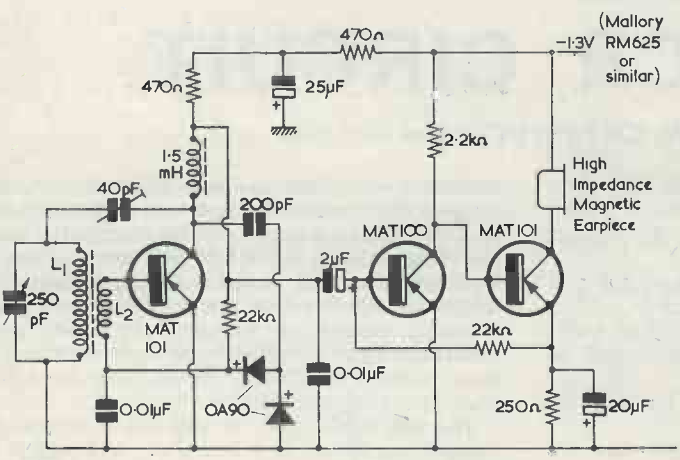


Fig. 5. Very low voltage subminiature reflex receiver M491

completely unnecessary. For the first stage, which is the frequency changer, the MAT101 should be used. The i.f. transistors and the first a.f. stage may all be replaced by MAT100's or, if the ultimate in gain and sensitivity is required, by further MAT101's. The push-pull output transistors may also be replaced by MAT100's, but in this case it will be necessary to select two for similar values of current gain.

When a very small superhet is required, it is desirable to use a low supply voltage to minimise the dimensions of the battery, and to keep the size of the electrolytic capacitors to a minimum. With Alloy or Alloy-diffused transistors at least 6 volts is normally required but with micro-alloy transistors only 1.3V need be used, this being obtainable from a single mercury cell. A circuit for such a receiver is shown in Fig. 4. Four transistors are used, one MAT101 and three MAT100's, in a fairly conventional circuit, except for the very low voltage and current consumption. The battery used may be an RM625 which will power the set for about 150 hours. The sensitivity may be increased by using MAT101's in place of the three MAT100's. Precisely the same circuit may be used with a six volt battery by replacing the MAT101 by an MAT121, and the MAT100's by MAT120's. The earpiece should then be replaced by a high impedance loudspeaker. The sensitivity of such a radio may be quite as good as that of a six transistor superhet.

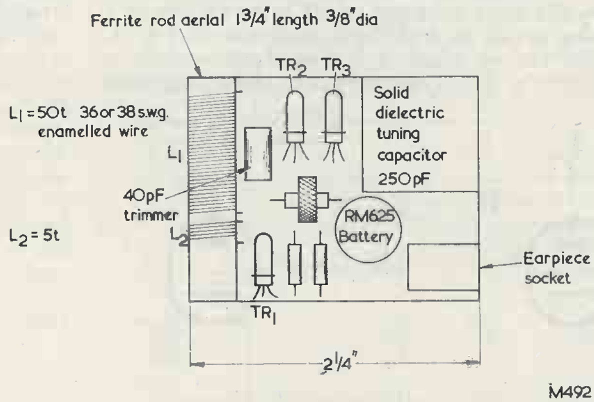


Fig. 6. Suggested layout for subminiature reflex receiver

Micro-alloy transistors are particularly effective in reflex receivers because the sensitivity of such radios depends upon high gain in the r.f. transistor. MAT's may be used in conventional reflex circuits or their low voltage properties may be taken advantage of in a circuit of the type shown in Fig. 5. This set will give an extremely good performance and may be built into a very small case if the layout shown in Fig. 6 is followed. The impression should not be given, however, that MAT's can only be used in unusual circuits. Such circuits are only given to illustrate their exceptional abilities, and in practice they can improve the performance of any circuit of normal design.

VHF Applications

The very high cut-off frequencies of the MAT120 and MAT121 make

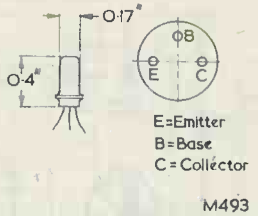


Fig. 7. Physical dimensions and connections of MAT transistors

them ideal for use in radio control circuits, and v.h.f./f.m. receivers, particularly since they cost very much less than any other transistors of comparable performance. The MAT121 makes an excellent r.f. amplifier or frequency changer in conventional f.m. receiver circuits and the MAT120 is equally good as a 10.7 Mc/s l.f. amplifier.

Physical Details

Micro-alloy transistors are comparatively small in size, being only 0.4in in height by 0.2in overall diameter. Both the can and the leads of each MAT are gold plated to give protection from corrosion and to make soldering swift and simple. The positions of the emitter, base and collector leads are shown in Fig. 7.

Those constructors who are devoted to the art of miniaturisation will find MAT's ideal for their purpose, not only because of their small size, but also because of their ability to provide high gain in simple circuits and with low power dissipation.

THE CR CIRCUIT

By T. W. CARREYETT, *Grad.Brit.I.R.E.*

A RESISTOR-CAPACITOR COMBINATION OF SOME kind or other can be found in use in almost every electronic circuit. Some of the reasons for this are:

(*a*) It is normally cheaper to use a capacitor as a reactive component instead of a coil
(*b*) A capacitor is quite often smaller than a coil
(*c*) On the whole, higher "Q" values can be obtained with capacitors
(*d*) The capacitor offers a means of blocking off any unwanted d.c. component.

All these factors offer greater advantages than the equivalent LR circuit.

One can think of many applications of the CR circuit, the most common of all being its use as a coupling device in amplifiers, as shown in Fig. 1. Another use to which it is put is decoupling as shown in Fig. 2. Combinations of capacitance and resistance are found in many other circuits, these ranging from smoothing and tone controls to filters and timebases. Various combinations of C and R are often included in the feedback loops of negative feedback amplifiers. All this goes to show that the simple CR combination is a very important circuit. Probably because of its simplicity, many people unfortunately skip over some of its important theoretical aspects and, by so doing, lose sight of its many practical applications.

The CR circuit may be assessed in terms of its frequency response to a sine wave, although it may also be assessed by its response to a square wave. One of the aims of this article is to discuss these methods of assessment so that one can see how they are related.

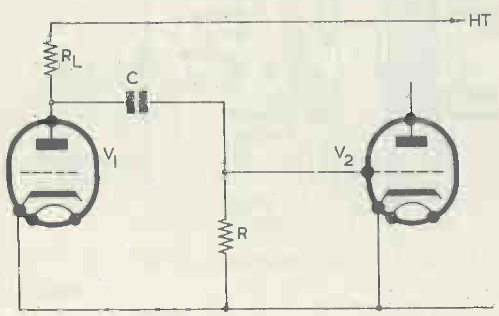


FIG.1 M330

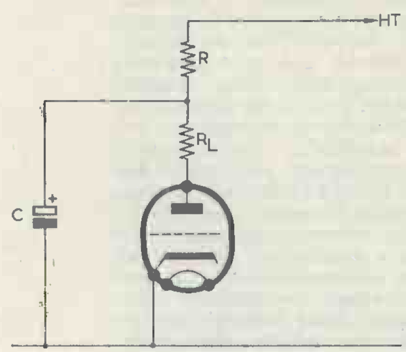


FIG.2 M331

Simple CR Coupling in A.F. Amplifier

Returning to Fig. 1 it is seen that R and C represent the coupling between two stages of an amplifier. The job of the capacitor is to pass on the signal and at the same time stop the d.c. supply (found at the anode of V_1) from being fed to the grid of V_2. Let us now take typical values, as found in an average a.f. amplifier, of 0.01μF for C and 470kΩ for R. Fig. 1 is now redrawn as Fig. 3, whilst Table 1 shows the values of reactance of C for different frequencies in the audio spectrum. As frequency is reduced so the value of Xc increases. At a particular frequency, f_o, Xc will be equal to R. This frequency, which is known as the turnover frequency, can easily be found for if Xc=R, or $\frac{1}{\omega c}=R$, then

$$\omega=\frac{1}{RC} \text{ and } f_o=\frac{1}{2\pi RC}$$

Substituting values,

$$f_o=\frac{10^5}{6.28\times 470\times 10^3\times 0.01}=36 \text{ c/s}.$$

So at 36 c/s Xc=R=470kΩ.

From Fig. 3 it is seen that R and C form a potential divider across R_L, so that the output voltage E_2 to the grid of the next stage will be $\frac{R}{\sqrt{R^2+Xc^2}}$. (This ignores any effects from R_L.) If Xc is small in comparison to R, as occurs from 1 kc/s up, then $\frac{R}{\sqrt{R^2+Xc^2}}$ approximates to $\frac{R}{R}$ or unity, therefore the loss due to Xc can be neglected.

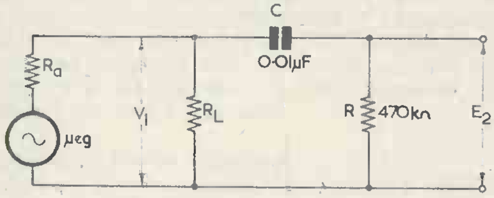


FIG.3 M332

When the frequency is decreased, an increasing loss is built up across Xc, and at 36 c/s Xc is equal to R. At this frequency, f_o, the output voltage across R has dropped by 30% of the mid-frequency voltage. At first sight this might appear questionable, because if Xc=R then surely equal voltages must be developed across Xc and R. This is true but, since Xc is a reactive component, the voltage developed across it has a 90° phase shift with respect to the voltage developed across R. When Xc=R then, from $\frac{R}{\sqrt{R^2+Xc^2}}$ (which represents the output voltage)

$$\frac{R}{\sqrt{R^2+Xc^2}}=\frac{R}{\sqrt{R^2+R^2}}=\frac{R}{R\sqrt{2}}=\frac{1}{\sqrt{2}} \text{ or } 0.707.$$

Table 1

	$Xc=\frac{1}{\omega c}$	f
	1.59k	10 kc/s
	15.9k	1 kc/s
	159k	100 c/s
f_o	470k	36 c/s

In other words the output voltage across R has dropped by 30%. Another popular way of expressing this low frequency loss introduced by the capacitor is by giving the coupling loss in decibels. For the example given, the loss expressed in decibels is found from (dB)=20 $\log_{10}$ (voltage ratio). Here the voltage ratio, when Xc=R, is $\frac{1}{\sqrt{2}}$, therefore the loss in dB is given by 20 $\log_{10}(1\sqrt{2})=-20\log_{10}(\sqrt{2})=1-10\log_{10}2=3$dB.

One important fact to be borne in mind when deciding on the frequency for the 3dB loss point is that if 3 similar coupling stages are used then the total loss for the amplifier at the turnover frequency will be 3×3dB=9dB.

Simple CR Coupling in a Pulse Amplifier

Having had a look at the CR network as a coupling device in an a.f. amplifier let us now look at it as a coupling device for a square wave instead of a sinewave, Fig. 4 (*a*).

Since it is only the response of the CR network which is of interest, Fig. 4 (*b*) can simulate the

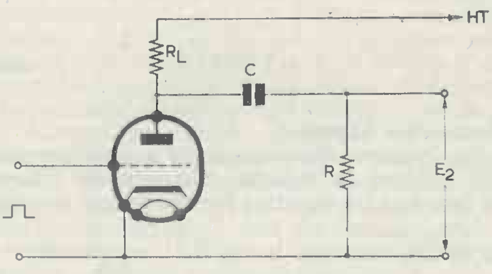


FIG.4a

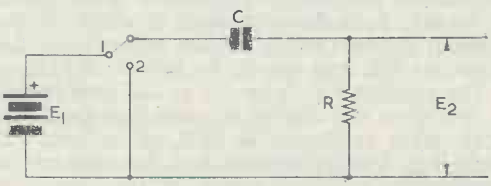


FIG.4b M333

square wave conditions quite well. Fig. 5 shows typical input and output waveforms for a CR circuit where the time constant is much shorter than the duration of the applied pulse. The first part (or leading edge) of the pulse appears undistorted in the output, since the capacitor, being uncharged, offers a virtual short circuit path. The current, having completed the loop, tries to continue circulating, but the capacitor starts to store some of the charge and continues doing so until fully charged. From Fig. 5 we see that the capacitor is fully charged by the time the trailing edge of the pulse appears. Therefore, when the charge is switched off and the capacitor is connected across R (by switching to position 2 in Fig. 4 (*b*)) it discharges, sending a current circulating in the reverse direction. The square wave is not fully transmitted through the CR circuit and the distortion is introduced by the capacitor. In consequence, a few moments spent on looking into the effects of a charge applied to a capacitor might be helpful in understanding the origin of this distortion.

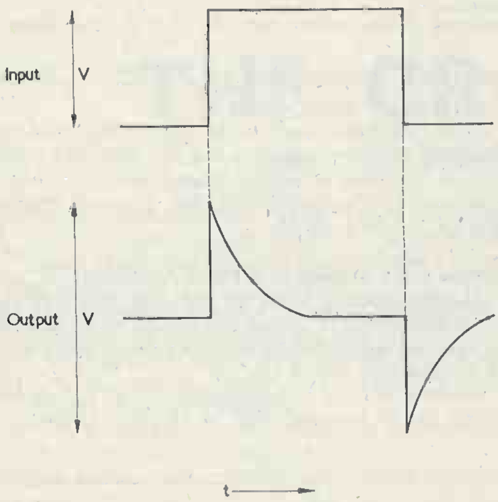


FIG.5 M334

Charge on a Capacitor

Fig. 6 shows the response of a capacitor (as in Fig. 4 (*b*)) to an impulse. The response follows a set law, and the equation for the voltage developed across the capacitor is $ec = E\,(1 - \varepsilon^{\frac{-t}{CR}})$ where t is the time in seconds, C is the value of the capacitor in farads, R is the resistance in ohms, E is the applied voltage and ε is the exponential 2.718. When $t = RC$, then $ec = E\,(1 - 1/\varepsilon) = E\,(0.632)$.

The product RC is known as the time constant, T, and gives the time in seconds that the CR network takes to charge to 63% of its final value. From Fig. 5 it can be seen that the discharge time response is a mirror image of the charge time response. Because of the shape of the response, the

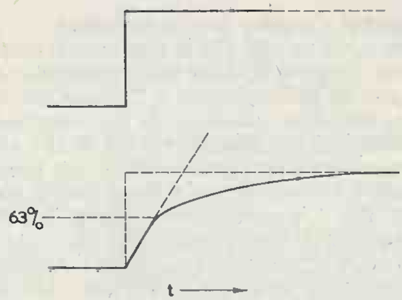


FIG.6 M335

form of circuit shown in Fig. 4 is known as a differentiation circuit since it tries to differentiate the input pulse when a suitably small time constant is chosen. Fig. 7 shows the results found in the output when a square wave is applied to CR circuits having various time constants. In (*a*) we see the effect of a time constant which is small compared to the applied pulse duration. Here CR would be about 0.02 of the duration. In (*b*) CR is approximately 0.25 of the duration, and in (*c*) it equals the duration. In (*d*) CR is about 10 times the pulse duration. From these waveforms one can understand why designers of pulse equipment are interested in time constants. If a pulse output has to be transmitted through a CR differentiation circuit and if an undistorted output is required, then the time constant of the CR circuit assumes the greatest importance.

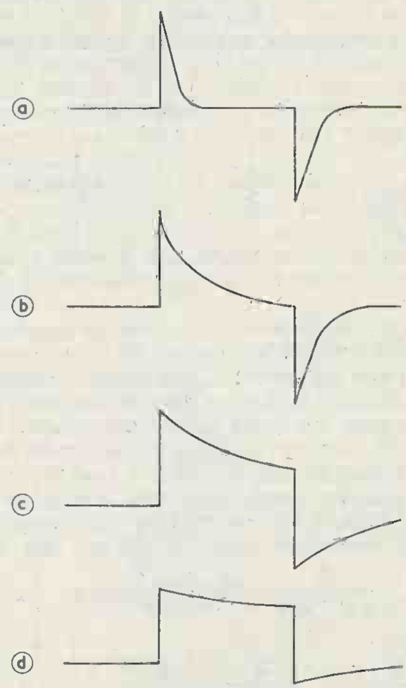


FIG.7 M336

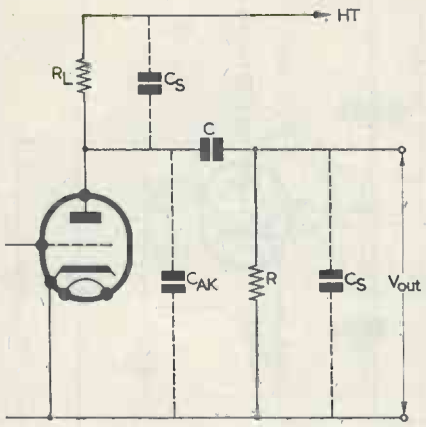


FIG.8a

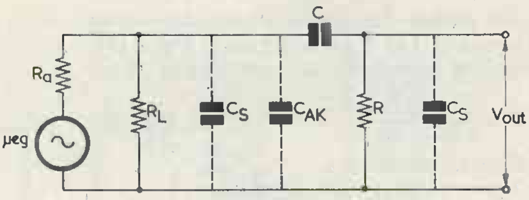


FIG.8b

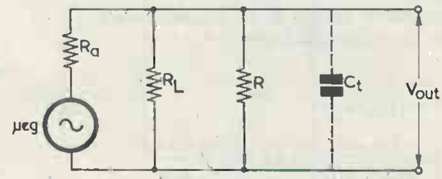


FIG.8c

M337

Square Wave Test for A.F. Amplifiers

How and why is it that the time constant appears in audio frequency amplifier testing? The answer is that some authorities argue that although the response of an a.f. amplifier may be happily assessed by sine wave testing, such testing does not tell the whole story. As the amplifier is used for amplifying speech and music, and as these types of signal contain many square wave shapes, it seems only fair in a comprehensive test to check the amplifier on a square wave as well as with a sine wave. Accepting this argument, it would be reasonable to say that a square wave test should provide a valuable assessment of an a.f. amplifier. However, caution must be taken when analysing the results of a square wave test since this will show all irregularities for the combined frequency and phase response; and some forms of phase distortion, unless recognised, may rather upset one's assessment.

Screen-Grid Circuit Distortion

At very low frequencies in a pentode amplifier, say around 15 c/s and below, the effect of the screen-grid circuit must be taken into consideration. At higher frequencies the screen-grid can be regarded as being held at a constant h.t. potential via the screen resistor, whilst having a low impedance path to earth at signal frequency via the decoupling capacitor. These conditions are fairly constant and can quite often be forgotten once set suitably but, at very low frequencies, where the impedance of the decoupling capacitor rises, the situation alters. Signal currents, now without the low impedance path to earth, start to develop voltages across the screen-grid resistor. These then rob the anode of its full amplitude swing and produce a low frequency loss. This problem does not normally arise in the case of the average a.f. amplifier as few of these are designed to have a response extending below 15 c/s, with which frequency trouble in the screen-grid circuit is probable.

Relationship between T and f_o

Let us return for a moment to the turnover frequency equation, where the response is 3dB down when $f_o=\frac{1}{2\pi CR}$. Since CR=T, then $f_o=\frac{1}{2\pi T}$ or $\omega_o=\frac{1}{T}$ and $T=\frac{1}{\omega_o}$, where ω_o is equal to the turnover frequency multiplied by 2π. From this equation one can see how the time constant and the turnover frequency are related, and one can also see that, having chosen values for C and R, the time constant and the turnover frequency can be determined.

High Frequency Loss

So far, only low frequency loss has been discussed, but it will be found that a similar set of conditions apply to the high frequency end of the spectrum. Fig. 8 (*a*), (*b*) and (*c*) illustrates this. Working from Fig. 8 (*a*) to Fig. 8 (*b*) and (*c*), it can be seen that the total stray capacitance, Ct, is found to be in parallel with the output voltage. This circuit can therefore be thought of as one operated by current excitation, whereas the low frequency circuit operated by voltage excitation. To find the high frequency loss with respect to the mid-band frequency* we must firstly find the current values at both frequencies. At the mid-band frequency the coupling capacitor will have negligible reactance, and the effects of the stray capacitance will be very small, so that the coupling impedance as far as the signal is concerned is equal to R. The signal current through the coupling circuit at the mid-band frequency is therefore $Imf=\frac{e}{R}$.

At the high frequencies the total stray capacitance

*The mid-band frequency is that at which gain is at a maximum —*Editor*.

across R will reduce the signal amplitude. The equivalent circuit of Fig. 8 (*a*) is drawn in Fig. 8 (*b*), and the coupling impedance as seen in Fig. 8 (*c*) will now be $\frac{Xc_tR}{\sqrt{R^2+Xc_t^2}}$. The ratio of the two currents will therefore be

$$\frac{Imf}{Ihf}=\frac{e}{R}\times\frac{Xc_tR}{e\sqrt{R^2+Xc_t^2}}=\frac{Xc_t}{\sqrt{R^2+Xc_t^2}}$$

(for accurate assessment R should take into account the parallel resistances across it of R_a and R_L).

This may also be expressed as:

$$\frac{Imf}{Ihf}=\frac{1}{\sqrt{1+(R/Xc_t)^2}}$$

$$=\frac{1}{\sqrt{1+(\omega C_tR)^2}}\text{ since } Xc_t=\frac{1}{\omega c_t}$$

$$=\frac{1}{\sqrt{1+(\omega/\omega_o)^2}}\text{ since } C_tR=\frac{1}{\omega_o}$$

$$\text{and }\frac{Imf}{Ihf}=\frac{1}{\sqrt{1+(f/f_o)^2}}\dagger$$

The high frequency loss can be found from

$$dB=20\log_{10}\text{(current ratio)}$$

Therefore, the high frequency loss is given by

$$dB=20\log_{10}\frac{1}{\sqrt{1+(f/f_o)^2}}$$

$$=-20\log_{10}\sqrt{1+(f/f_o)^2}$$

$$=-10\log_{10}[1+(f/f_o)^2]$$

As previously discussed the turnover frequency, f_o, will be given when $Xc_t=R$, where Xc_t is the total stray capacity. Also, the high frequency time constant will be $T_{hf}=RC_t=\frac{1}{\omega_{hf}}$ by similar reasoning to that previously discussed.

In a wide band amplifier, one popular method of correcting for high frequency loss is by means of a series inductance as shown in Fig. 9. At the higher frequencies the reactance of the inductance increases, thus increasing the gain of the stage and counteracting the loss given by the stray capacitance.

Conclusions on Discussion

From the discussion so far two points have become clear. The first of these is that for a good low frequency response in an amplifier a large time constant is required from the CR in the coupling circuit. In deciding on a practical value for the coupling capacitor C, it should be borne in mind that if a large signal voltage is available to C, and if C is given a very large value in order to increase the time constant, then at extremely low frequencies motor-boating or oscillation of some sort may occur.

Secondly, a very small time constant is required from C_tR for good high frequency response. It is

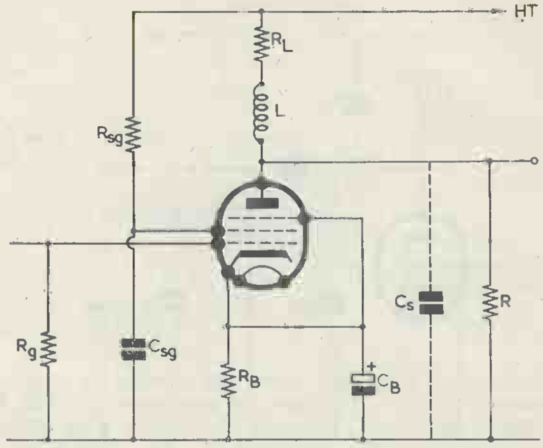


FIG.9 M338

therefore very necessary to keep stray capacitances down to a minimum. This can best be achieved by using a component layout which provides the shortest wiring runs possible. Careful positioning of all grid components is essential, and it is preferable to use low capacitance valveholders. All these factors will help in obtaining good high frequency response.

The reasoning which has been discussed on time constant and turnover frequency is a valuable designer's tool which can be applied to many circuits. To round off this discussion let us work out a practical example.

Bass Equalisation

Fig. 10 shows a popular form of circuit found in tape playback amplifiers. Here, equalisation of the bass frequencies for operational speeds of 7½in per second takes place by means of frequency selective feedback, this being introduced in the anode follower circuit (V_2).

The equalisation is provided by CR in the feedback loop. There are, of course, other methods of providing equalisation, but since this combines the necessary equalisation in a negative feedback amplifier a greater margin of stability and an easy method

Table 2

	f (c/s)	loss (dB)
f_o/f_o	1580	3
$f_o/2$	790	6.9
$f_o/4$	395	12.3
$f_o/8$	197	18.1
$f_o/16$	98	24
$f_o/32$	49	30.1

†Where f is the high frequency and f_0 the turnover frequency—*Editor*.

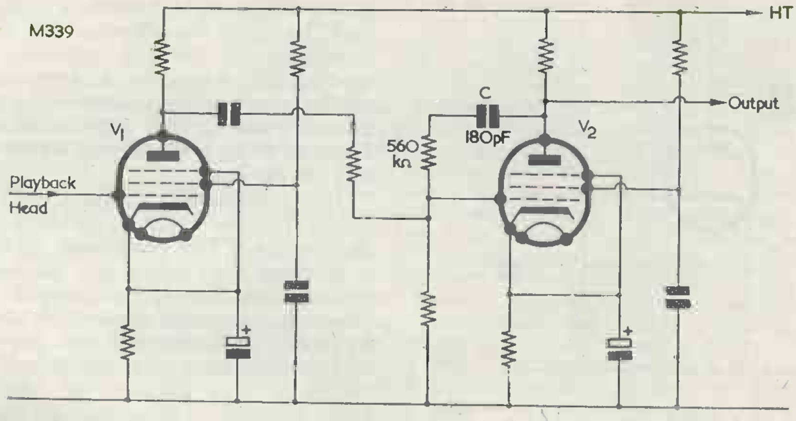


FIG.10

of preselecting the input and output impedance are provided at the same time, hence its popularity. Let us then work out the response of this equalisation with values we would be likely to find in practice. The turnover frequency f_o is found from $f_o=\frac{1}{(2\pi CR)}$. Taking values from the circuit we obtain

$$f_o=\frac{1}{6.28\times180\times10^{-12}\times560\times10^3}=1.58 \text{ kc/s}$$

at this frequency the CR circuit will present a loss of 3dB. To find the loss given by the CR network at lower frequencies we can proceed as follows.

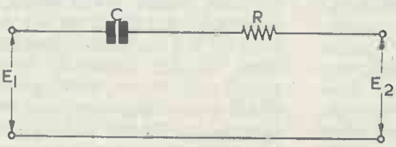


FIG.11 M340

With reference to Fig. 11 we firstly find the voltage ratio with respect to the mid-band frequency so,

$$\frac{E_{mf}}{E_{hf}}=\frac{R}{\sqrt{R^2+X_c^2}}$$

$$=\frac{R}{\sqrt{R^2+(1/\omega C)^2}}$$

$$=\frac{1}{\sqrt{1+(1/\omega CR)^2}}$$

$$=\frac{1}{\sqrt{1+(\omega_o/\omega)^2}}$$

$$\text{since } CR=\frac{1}{\omega_o}$$

Therefore, the loss in dB is given by

$$dB=20\log_{10}(\text{voltage ratio})$$

$$=20\log_{10}\frac{1}{\sqrt{1+(f_o/f)^2}}$$

$$=-10\log_{10}[1+(f_o/f)^2]$$

We have found previously that, when a frequency f equals the turnover frequency f_o, the loss is 3dB. Therefore, let us now check the equation derived.

From $dB=-10\log_{10}[1+(f_o/f)^2]$,
when $f=f_o$ then

$$dB=-10\log_{10}(1+1)$$
$$=-10\log_{10}(2)=-10\times0.3010$$

therefore, the loss is equal to 3dB, which checks with previous findings. Let us now investigate the loss in the low frequency spectrum an octave at a time, with respect to the turnover frequency, f_o. The frequencies in question will be $f_o/2$, $f_o/4$, $f_o/8$ and $f_o/32$, which correspond to frequencies of 790 c/s, 395 c/s, 197 c/s, 98 c/s and 49 c/s. To save space the results are given in Table 2. From this we can see that with reference to the turnover frequency, the loss of a CR network appears to increase by 6dB per octave. The frequency response of this network can now be plotted as shown in Fig. 12.

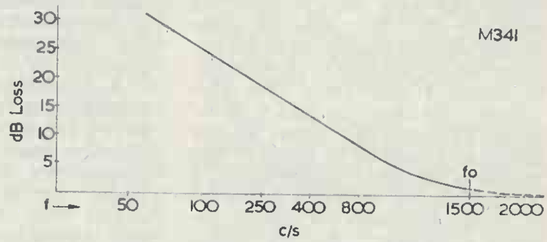


FIG.12

From the graph we can see that the CR network has a loss of 30 dB at 49 c/s. Now let us see how all this is put to work in Fig. 10, which we now reduce to Fig. 13. From Fig. 13 it can be seen that negative voltage feedback occurs between anode and grid. As is well known, the greater the quantity of negative feedback used in an amplifier the less will be the amount of available gain from it. In this example the loss of the CR network at 1.58 kc/s is 3 dB, whilst at higher frequencies the loss is reduced to nearly zero dB. So (in Fig. 13) at these higher frequencies the feedback signal is

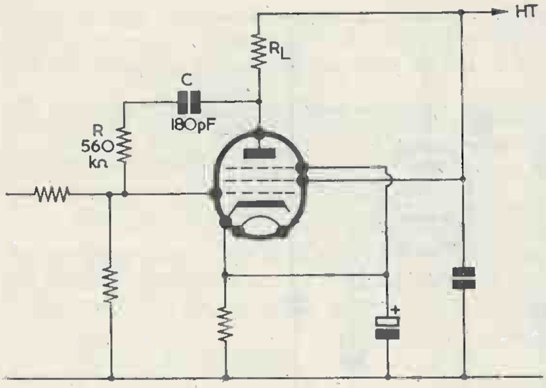


FIG.13 M342

not attenuated and the maximum reduction of gain is experienced. At frequencies below 1.58 kc/s the loss of the CR network has been shown to increase by 6 dB per octave. Therefore, as frequency decreases, the loss of the CR network increases which in turn reduces the amount of negative voltage fed back to the grid. This reduction in feedback increases the gain of the stage; so that gain is increased as frequency is lowered, and feedback becomes less effective due to the increasing impedance of the CR network. This form of equalisation will give a frequency response of similar shape to that shown in Fig. 12, where, in place of loss in dB, gain in dB would be read. Thus, at 49 c/s a 30 dB gain would be given instead of a 30 dB loss.

This equalisation characteristic can be said to conform to the C.C.I.R. playback specification for tape speeds of 7½in per second, so the last operation is to check that this is so. To meet the C.C.I.R. characteristic the playback amplifier should have a "frequency response curve that falls with increasing frequency in conformity with the impedance of a series combination of a capacitance and a resistance having a time constant of 100 microseconds". From this definition we can see that the frequency response of an equaliser can quickly be checked for conformity by means of calculating its time constant. In the example worked out, C is given as 180×10^{-12} and R as 560×10^{3}. The time constant is, therefore, $180 \times 10^{-12} \times 560 \times 10^{3}$, which is 100.8$\mu$S. This circuit will, therefore, equalise fairly well to the C.C.I.R. characteristic.

From the discussion in this article, it can be seen that the art of juggling with time constants is relatively easy, and that the time constant is a very useful and often a rewarding tool to wield.

Radio Topics . . .

WHATEVER THE PILKINGTON Committee had said, *somebody* would have been upset. Television is a subject in which it is impossible to avoid controversy. The reason, of course, is that television has now become what is probably the most effective mass communication medium in existence. I am, indeed, amazed at the number of people I meet these days who "haven't the time" to read a newspaper but who can spend several hours at a stretch in front of the television receiver. Incidentally, I don't think this denotes a falling-off in public standards—it merely denotes a *change*. At any event, television now has a vast captive audience and has become a strong force in consequence. Which is all the more reason why it should be administered with great care and with the utmost impartiality.

Violence

The appearance of the Pilkington Report engendered a great rash of headlines in the Press. What was probably the most witty of these appeared in the London *Evening News*, in which the subject was introduced as "The H Bomb," the letter "H" consisting of an H-aerial. Press reaction to the Report varied somewhat, but there was general criticism of its recommendations concerning the Independent Television Authority, and of its comments concerning the moral standard of the material which is broadcast by the independent television companies.

A considerable amount of the criticism was based on the fact that, since I.T.V. programmes are in many instances more popular than B.B.C. programmes, the independent companies are obviously giving the people what they want. It was also pointed out that the Committee accepted evidence from many bodies representative of persons who would require programmes of a higher level, but that it did not approach the man in the street. Although there is a lot of truth in this charge, what the Pilkington Committee said *had* to be said, and it is a good thing that it has come out into the open.

Many of the points made in the Report have to do with the excess of violence shown on our screens these days. This is, surely, a true statement of facts. For instance I, and many of my friends, have often been sickened by the too-familiar television scene of Teds breaking up some establishment or other, the whole presentation being put over with as much shock-effect as the producer can inject in it. My own locality has its small quota of Teds who wander aimlessly around in gangs and whose intelligence seems to be several degrees lower than submoronic. These oafs haven't the mental ability to work out projects of their own, so why should television demonstrate such projects for them? I should hasten to add that, by "Teds", I am not referring to all youngsters who wear the Edwardian rig—I am only referring to the small hard core of layabouts who delight in spoiling life for everyone else.

The Pilkington Committee also referred at length to the effects of violence on young children, quoting Bishop Cockin's statement that "most of what we might think is rather pernicious passes over a child's head, but brutality does not: it hits it."

This can be aptly followed by another quote, which is taken from the Report itself and which needs no further comment. "The [Independent Television] Authority recognise that impressionable children are still watching until 9 p.m., for they and the companies have agreed that hanging scenes must not be shown before 9 p.m. in case they lead children to experiment."

Technical Features

Let us leave the ethical questions raised by the Pilkington Report, and turn to its technical features. Even here, we find ourselves once more in the midst of controversy.

The major technical war which has been waging over the last few years concerns the desirability of changing over from 405 to 625 lines. I have already touched upon this matter several times in the past, and our last Radio Show Report (in the October 1961 issue) described the unhappy argument, glaringly evident at the Exhibition, which existed between set-manufacturers, with G.E.C. standing out on one flank for 405 lines and Pye carrying the banner on the other flank for 625 lines. However, the 405-line adherents have now been out-generalled because, like all European countries, the United Kingdom has undertaken to use 8 Mc/s channelling in the u.h.f. bands. This single fact knocks much of the stuffing out of the 405-line argument since it means that, despite their narrow 5 Mc/s bandwidth, it is impossible to get any more 405-line channels into Bands IV and V than 625-line channels.

Nevertheless, the Committee was cautious in its approach to the superiority of 625 lines over 405 lines as expressed in terms of improved picture, and took great care in handling the conflicting technical evidence passed on to it. Thus we find: "The improvement [with 625 lines] is to some extent a matter of subjective judgment; and the Radio Industry Council contended that the improvement would be marginal on the sizes of television screen likely to be required by the public. However, in giving oral evidence, the R.I.C. stated that the two main obstacles to the sale of sets with larger screens were the cost and bulk of the sets." And again, to show the varying viewpoints expressed, "An early change of line-definition standards was supported by the B.B.C. and, after initial opposition, by the I.T.A. Opinion among the programme companies was divided: Associated Television and A.B.C. Television were in favour of a change; Granada and Associated Rediffusion were against. The industry, too, was divided: the R.I.C. was against a change, Pye Ltd. were for it. The Association of British Chambers of Commerce supported a change. The Radio and Television Retailers' Association and the Radio Wholesalers' Federation expressed no opinion."

After consideration of the questions involved, the Committee recommended that a change in line standards from 405 to 625 lines be authorised forthwith. In the White Paper published subsequently, the Government agree with this recommendation, and new programmes in u.h.f. will be on 625 lines from the start. At the time of writing, no statement has been issued defining the 625 line standard to be used, but this will probably follow that recommended by the Television Advisory Committee. This standard required that the vestigial vision sideband be 1.25 Mc/s wide and the main vision sideband 5.5 Mc/s wide. The f.m. sound carrier is 6 Mc/s above the vision carrier, and both carriers are intended to occupy an 8 Mc/s channel.

The Change-over

The manner in which the change-over to 625 lines may take place is yet another matter which has been the subject of controversy. Two schemes were put to the Committee. One of these, the "duplication" method, suggests that the existing two programmes continue to be transmitted on 405 lines in Bands I and III, duplicate 625 line transmissions being introduced in Bands IV and V. (The signals would, in fact, be originated on 625 lines, the 405 line signal being obtained by standards conversion.) A third (and possibly a fourth) programme on Bands IV and V could also be started, and about 70% population coverage of all programmes on the 625 line standard in Bands IV and V would be given over a period of five years, the remaining coverage being built up in the following five years or so. In areas covered by the 625 line duplicate transmissions the public would need to buy 625 line receivers only, and these could even be u.h.f. with provision for the later addition of a v.h.f. tuner. In areas not yet covered by the duplicate transmissions, the public could buy 405/625 line receivers. The 405 line service in an area would be closed when satisfactory 625 line u.h.f. transmissions had been provided and an appropriate time allowed for receiver obsolescence. When all 405 line transmissions had closed down, Bands I and III would become available for re-exploitation on 625 lines. The whole process might take ten to fifteen years.

The alternative scheme, the "switchover" method, proposed that, during a seven to ten year period, "shadow" plant consisting of new transmitters and aerials for 625 lines on appropriate new v.h.f. channels be installed at existing B.B.C. and I.T.A. transmitters. During this transition period, the public would then buy 405/625 line receivers. At an appointed date, the 405 line transmissions would cease, and the two programmes would switch over to 625 lines from the "shadow" network. A discussion of pros and cons for these two systems occupies nearly three pages of the Report, and the Committee eventually concluded that the "duplication" method is to be preferred, but it must remain for the opening of a public service in u.h.f. to confirm the usefulness of such a service. The reason for this proviso is that, with the duplication system, *all* British television may have to go, for a period, into u.h.f. In the following White Paper, the Government treats the question of change-over with some caution, stating that test transmissions on u.h.f. will start this year and will help to solve the problem. Also, states the White Paper, "it may well be that this [the change-over] will involve duplicating the existing 405 line programmes on 625 lines in u.h.f."

Other Points

Other points recommended by the Committee, and subsequent Government decisions, cover colour television, pay-television, and sound broadcasting.

The Committee recommended that colour television be started on a modest scale on 625 lines in u.h.f., and this is agreed to by the Government. No colour system is specified.

Pay-television, either by wire or over the air, was decided against by the Committee; but the Government reserves its decision here, pointing out that one objection, the space taken up in the broadcast spectrum by pay-television over the air, does not apply if transmissions are by wire.

The Committee recommended against television for public showing in cinemas or theatres, but the Government feels that there may be a place for this, and its present disposition is to consider applications to provide such a service.

It was recommended by the Committee that a single service of local sound broadcasting be planned, this to be run by the B.B.C. and financed from licence revenue. The Government states, however, that there has been little evidence of any great public demand for local services, and prefers to take cognisance of public reaction before taking a decision.

The Government accepts the Committee's recommendation that

(Continued on page 104)

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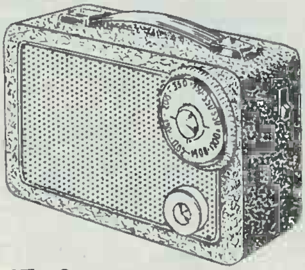

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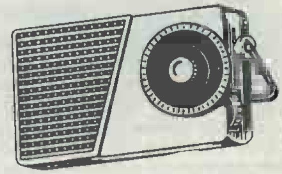

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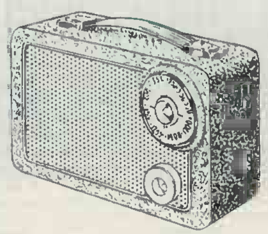

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continued on page 149

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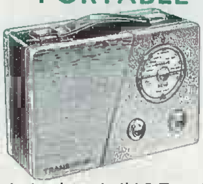

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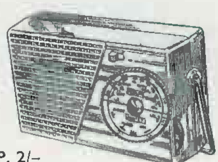

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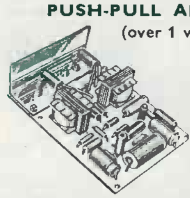

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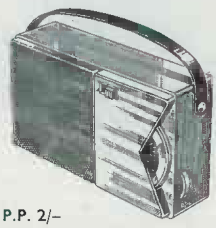

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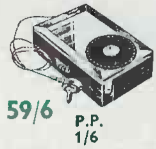

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