THE Radio Constructor

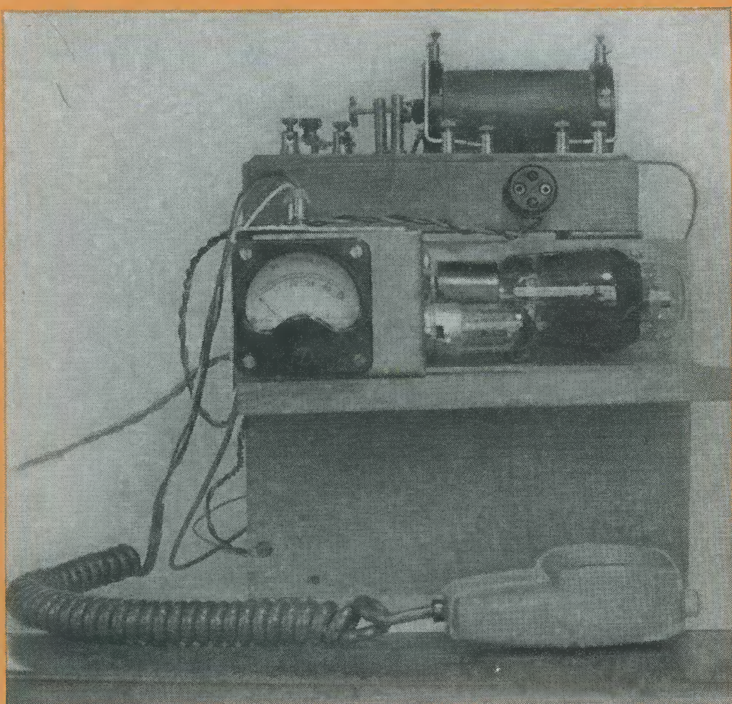
RADIO
TELEVISION
AUDIO
ELECTRONICS

VOLUME 19 NUMBER 7

A DATA PUBLICATION

TWO SHILLINGS & THREEPENCE

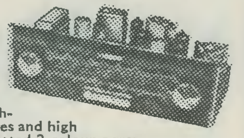
February 1966



Communication by Modulated Arc Beam

Transistor Time Switch ★ Field Effect Transistors ★ Radio Control Battery Charger ★ Morse Code Oscillator

6 VALVE AM/FM TUNER UNIT



Med. and VHF 190m–550m, 86 Mc/s–103 Mc/s, 6 valves and metal rectifier. Self-contained power unit, A.C. 200/250V operation. Magic-eye indicator, 3 push-button controls, on/off, Med., VHF. Diodes and high output Sockets with gain control. Illuminated 2-colour perspex dial 11½" x 4", chassis size 11½" x 4" x 5¾". A recommended Fidelity Unit for use with Mullard "3-3" or "5-10" Amplifiers.

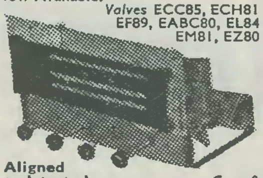
Bargain Price: Complete kit of parts, inc. Power Pack, **£10.19.6**, carriage and insurance, as illustrated. Ditto less Power Pack, **£9.19.6**. Carr. 7/6. Circuit and constr's details, 4/6 Free with kit.

7 VALVE AM/FM RADIOGRAM CHASSIS

New 1965 Model Now Available.

Three Waveband & Switched Gram positions. Med. 200–550m. Long 1,000–2,000m. VHF/FM 88–95 Mc/s. Phillips Continental Tuning insert with permeability tuning on FM & combined AM/FM IF transformers. 460 kc/s and 10.7 Mc/s. Dust core tuning all coils. Latest circuitry including AVC & Neg. Feedback. 3 watt output. Sensitivity and reproduction of a very high standard. Chassis size 13½"x 6½". Height 7½". Edge illuminated glass dial 11½" x 3½". Vert. pointer Horiz. station names. Gold on brown background. A.C. 200/250V operation. Magic-eye tuning. Circuit diag. now available.

Valves ECC85, ECH81 EF89, EABC80, EL84 EM81, EZ80



Aligned and tested ready for use. **£13.19.6** *Carr. & Ins. 7/6.*

Comp. with Tape, O/P socket, ext. spk'r and P/U sockets and indoor F.M. aerial, and 4 knobs—walnut or ivory to choice. 3Ω P.M. Speaker only required. Recommended Quality Speakers 10" Elac, **27/6**. 13½" x 8" E.M.I. Fidelity, **37/6**. 12" R.A. with conc. Tweeter, **42/6**. Carr. 2/6.

Jack Plugs. Standard 2½" Igranic Type, **2/6**. Screened Ditto, **3/3**. Miniature scr. 1½", **2/3**. Sub-min. **1/3**. **Jack Sockets.** Open Igranic Moulded Type, **3/6**. Closed Ditto, **4/–**. Miniature Closed Type, **1/6**. Sub-min. (deaf aid) ditto, **1/6**. Stereo Jack Sockets, **3/6**. Stereo Jack Plugs, **3/6**.
Phono Plugs, 9d. Phono Sockets (open), **9d.** Ditto (closed), **1/–**. Twin Phono Sockets (open), **1/3**.

NEW BRITISH RECORDING TAPE

Famous Mfr. Bulk Purchase — Genuine recommended Tape Bargain. Unconditional Guarantee. Fitted Leader and Stop Foils (except 3").

St'd. (PVC base)	L.P. (PVC base)	D.P. (Milar base)	Triple Play
3" 150ft. ... 3/9	225ft. ... 4/9	300ft. ... 6/6	3" 450ft. ... 12/6
5" 600ft. ... 11/6	900ft. ... 15/–	1,200ft. ... 23/6	4" 900ft. ... 25/–
5¾" 850ft. ... 14/6	1,200ft. ... 17/6	1,800ft. ... 29/6	
7" 1,300ft. ... 17/6	1,800ft. ... 22/6	2,400ft. ... 37/6	

Post and Packing — 3" Reels 6d. Each additional Reel 3d. 4" to 7" Reels 1/–. Each additional Reel 6d. All tape accessories stocked.

EMPTY TAPE REELE (Plastic): 3" 1/3, 5" 2/–, 5¾" 2/–, 7" 2/3.
PLASTIC REEL CONTAINERS (Cassettes): 5" 1/9, 5¾" 2/–, 7" 2/3.

New Boxed VALVES Reduced Bargain Prices

1T4	3/6	EF80	7/6	PCF80	8/–
1R5	6/–	EF86	8/6	PCL83	10/6
1S5	6/–	EL33	12/6	PCL84	10/–
3S4	7/–	EL34	12/6	PCL85	11/6
3V4	7/–	EL84	7/–	PL36	10/6
ECC81	7/–	EY51	9/–	PL81	9/6
ECC82	7/–	EY86	9/–	PL83	8/–
ECC83	7/–	EZ80	7/–	PY33	10/6
ECL80	9/–	EZ81	7/–	PY82	7/–
ECL82	10/–	GZ32	9/6	U25	10/6
ECL86	10/6	PCC84	8/–	UL84	9/–

Electrolytics All Types New Stock

TUBULAR		CAN TYPES	
25/25V	1/9	8+8/450V	4/6
50/12V	1/9	16+16/450V	5/6
50/50V	2/–	32+32/275V	4/6
100/25V	2/–	50+50/350V	6/6
8/450V	2/3	60+250/275V	12/6
4/350V	2/3	100+300/275V	12/6
16+16/450V	5/6		
32+32/450V	6/6	2000+4000/6V	3/6
1000/25V	3/9		

Ersin Multicore Solder 60/40, 4d. per yard. Cartons 2/6, etc.

DE LUXE R/PLAYER KIT

Incorporating 4 Speed Garrard Auto-Slim unit and Mullard latest 3 watt printed circuit amplifier (ECL 86 and EZ 80), volume, bass and treble controls, with 8" x 5" 10,000 line speaker. Superb quality reproduction.

Contemporary styled two-tone cabinet, charcoal grey and off-white with matching blue relief. Size: 17½" x 16" x 8".

COMPLETE KIT £13.19.6 Carr. & ins. 12/6.

Ready wired, 30/– extra.

Illuminated Perspex escutcheon, 7/6 extra. 4 Contemp'y legs 6" 10/6, 9" 11/6, 12" 12/6, ex. Catalogue & construction details 2/6 (free with kit).

STANDARD RECORD PLAYER KIT

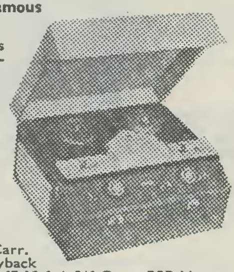
Using BSR UA14 Unit, complete kit **£11.10.0**, carr. 7/6. Ready wired Amplifier, 7" x 4" quality Speaker and O/P trans., **£3.19.6**, carr. 2/6. BSR UA14 Unit, **£6.10.0**, carr. & ins. 5/–. Rexine covered cabinet in two-tone maroon and cream, size 15¾" x 14¾" x 8½" with all accessories plus uncut record player mounting board 14" x 13", 59/6, carr. & ins. 5/–.

Condensers—S/Mica all values 2pF to 1,000pF **6d.** Ditto Ceramic **9d.** each, .005, .01 and .1, etc., **1/–**. Paper Tubular 450V .001 mfd. to .01 mfd and .1/350V **9d.**, .02–.1 mfd **1/–**, .25 mfd **1/6**, 5 mfd **1/9**.

Speakers P.M.—2" Plessey 75 ohms, **15/6**. 2½" Continental 8 ohms, **13/6**. 7" x 4" Plessey 35 ohm, **23/6**.
Ear Plug Phones—Min. Continental type, 3ft. lead, jack plug and socket. High Imp. **8/–**. Low Imp., **7/6**. High sensitivity M/coil 8–10 ohms, **12/6**.

ANOTHER TAPE RECORDER BARGAIN

New re-designed contemporary Cabinet. Famous Mfrs. end of production Surplus Offer



A 24 gns. Tape Recorder offered at the fabulous bargain price of **only 15 gns.** + 10/– Carr. Supplied in 3 Units already wired and tested—only simple inter-Unit connections necessary. A modern Circuit for quality recording from Mike, Gram or Radio, incorporating the latest BSR Twin Track Monardeck Type TD2. Housed in attractive two-tone Cabinet of contemporary design, size 14" x 13½" x 7½" complete with Tape and Mike storage pockets. Valve line up—EF86, ECL82, EM84, EZ80 and Silicon Diode.

Complete Kit comprising items below.
BARGAIN PRICE 15 gns. + 10/– carr.

Cabinet and 7" x 4" Speaker, **£3.5.0** + 5/– Carr. Wired Amplifier complete with Record/Playback Switching, 4 Valves, front Panel, Knobs, etc., **£5.19.6** + 3/6 Carr. BSR Monardeck Type TD2, **£7.7.0** + 4/6 Carr. **Accessories**—Mike, Tape, empty Reel, screened Lead & Plugs, Instructions, etc., **£1.0.0** + 2/– Carr.

Volume Controls—5K–2 Megohms, 3" Spindles Morganite Midget Type. 1¼" diam. Guar. 1 year. LOG or LIN ratios less Sw. **3/–**. DP. Sw. **4/6**. Twin Stereo less Sw. **7/6**. D.P. Sw. **9/6** (100 k. to 2 Meg. only). ½ Meg. VOL Controls D.P. Sw. ¼" flatted spindle. Famous Mfrs. 4 for **10/–** post free.

COAX 80 OHM CABLE
High grade low loss Cellular air spaced Polythene — ¼" diameter. Stranded cond. Famous mfrs. **Now only 6d. per yard.**
Bargain Prices—Special lengths:
20 yds. **9/–**. P. & P. 1/6.
40 yds. **17/6**. P. & P. 2/–.
60 yds. **25/–**. P. & P. 3/–.
Coax Plugs **1/–**. Sockets **1/–**. Couplers **1/3**. Outlet Boxes **4/6**.

Close Tol. S/Micas—10% 5pF–500pF **8d.** 600–5,000pF **1/–**. 1% 2pF–100pF **9d.** 100pF–500pF **11d.** 575pF–5,000pF **1/6**. **Resistors—Full Range** 10 ohms–10 megohms 20% ¼ and ½W **3d.**, ditto 10% **4d.**, ¾W **5d.** (Midget type modern rating) 1W **6d.**, 2W **9d.** **Hi-Stab** 5% ¼–½W 100 ohms 1 megohm **6d.** Other values **9d.** 1% ½W **1/6**. **W/W Resistors** 25 ohms to 10K 5W **1/3**, 10W **1/6**, 15W **2/–**. **Pre-set T/V Pots.** W/W 25 ohms–50K **3/–**. 50K–2 Meg. (Carbon) **3/–**. **Speaker Fret**—Expanded gilt anodised metal ¼" x ⅛" diamond mesh, 4/6 sq. ft., multiples of 6" cut. Max. size, 4ft. x 3ft. **47/6**. Carr. extra. Ditto, finer mesh, 4/6 sq. ft. Multiples 12" only, max size 3ft x 2ft. **27/6**. Plus Carr.

TYGAN FRET (contemp. pat.) 12" x 12" **2/–**, 12" x 18" **3/–**, 12" x 24" **4/–**, 18" x 18" **4/6**, etc.

BONDACOUST Speaker Cabinet Acoustic Wadding, superior grade, 1" thick, 18" wide, any length cut **2/3** per ft, **6/–** per yd.

ENAMELLED COPPER WIRE—¼lb reels, 14g–20g, **3/–**; 22g–28g, **3/6**; 36g–38g, **4/9**; 39–40g, **5/–**, etc.

TINNED COPPER WIRE—14–22g. 4/– ¼ lb.

PVC CONNECTING WIRE—10 colours (for chassis wiring, etc.)—Single or stranded conductor, per yd., **2d.** Sleeving, 1mm. and 2mm., **2d.** yd., etc.

KNOBS—Modern Continental types: Brown or Ivory with Gold Centre, 1" dia., **9d.** each; 1⅛", **1/3** each; Conc. knobs with gold centre 1½" dia., **2/9** per pair. Matching ditto, **2/6** each. LARGE SELECTION AVAILABLE.

TRANSISTOR COMPONENTS

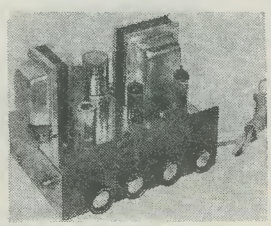
Midget I.F.'s—465 kc/s 9/16" diam., first, second or third	5/6
Osc. coil M. & L.W. 9/16" diam.	5/0
Midget Driver Trans. 9:1	6/0
Ditto O/Put Push-pull 3 ohms	6/0

Elect. Condensers—Midget Type 15V 1mfd–50mfd, ea. **1/9**. 100mfd. **2/–**.
Ferrite Aerial—M. & L. W. with car aerial coupling coil, **9/3**.
Condensers—150V. wkg. .01 mfd. to .04 mfd., **9d.** .05 mfd., .1 mfd., **1/–**. .25 mfd., **1/3**. .5 mfd., **1/6**, etc.
Tuning Condensers. J.B. "00" 208+176pF, **8/6**. Ditto with trimmers, **9/6**. 365pF single, **7/6**. Sub-min. ⅞" DILEMIN 100pF, 300pF, 500pF, **7/–**.
Midget Vol. Control with edge control knob, 5kΩ with switch, **4/9**, ditto less switch, **3/9**.

JASON FM TUNER UNITS
Designer-approved kit of parts:
FMT1, 5 gns. 4 valves, **20/–**.
FMT2, £7.10.0. 5 valves, **35/–**.
JTV MERCURY 10 gns. 3 valves, **22/6**.
JTV2 £13.19.6. 4 valves, **28/6**.
NEW JASON FM HANDBOOK, 2/6. Prompt Alignment Service **7/6**. P. & P. **2/6**.

MULLARD "3—3" & "5—10" HI-FI AMPLIFIERS

3 OHM & 15 OHM OUTPUT



"3–3" Amp. 3-valve, 3 watt, Hi-Fi quality at reasonable cost. Bass Boost and Treble controls, quality sectional output transformer, 40 c/s–25 kc/s ± 1dB. 100mV for 3W, less than 1% distortion. Bronze escutcheon panel.

Complete Kit only 7 gns. Carr. 5/–. **Wired and tested £8.10.0**

MULLARD "5-10" AMPLIFIER—5 valves 10W, 3 and 15 ohms output. Mullard's famous circuit with heavy duty ultra-linear quality output tfr.
Basic amplifier kit price £9.19.6. Carr. 7/6. **Ready built, 11½ gns.**

2-VALVE PRE-AMP. UNIT
Based on Mullard's famous 2-valve (2 x EF86) circuit with full equalisation with volume, bass, treble, and 5-position selector switch. Size 9" x 6" x 2¼".
Ready built, wired and tested, £7.19.6. Carr. 3/6.

Send for detailed bargain lists, 3d. stamp. We manufacture all types Radio Mains Transf. Chokes, Quality O/P Trans., etc. Enquiries invited for Specials, Prototypes for small production runs. Quotation by return.

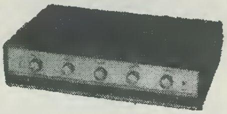
TRS Est. 1946

RADIO COMPONENT SPECIALISTS

70 Brigstock Road, Thornton Heath, Surrey
THO 2188. *Hours; 9 a.m.–6 m., 1 p.m. Wed. Terms C.W.O. or C.O.D. Post and Packing up to ½lb. 1/–, 1 lb. 1/9, 3 lb. 3/–, 5 lb. 3/9, 8 lb. 4/6.*

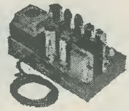
HI-FI AMPLIFIERS ~~~ TUNERS ~~~ RECORD PLAYERS

20+20 STEREO AMP. AA-22U

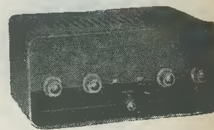


GARRARD PLAYER AT-60

10W POWER AMP. MA-12



3+3W STEREO AMP. S-33H



TRANSISTOR MIXER. Model TM-1. A must for the tape enthusiast. Four channels. Battery operated. Similar styling to Model AA-22U Amplifier. Kit **£11.16.6** Assembled **£16.17.6**

20+20W TRANSISTOR STEREO AMPLIFIER. Model AA-22U. Outstanding performance and appearance. Kit **£39.10.0** (less cabinet). Attractive walnut veneered cabinet £2.5.0 extra.

GARRARD AUTO/RECORD PLAYER. Model AT-60. less cartridge **£13.1.7** With Decca Deram pick-up **£17.16.1** incl. P.T. Many other Garrard models available, ask for Lists.

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

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

3 + 3W STEREO AMPLIFIER. Model S-33. An easy-to-build, low cost unit. 2 inputs per channel. Kit **£13.7.6** Assembled **£18.18.0**

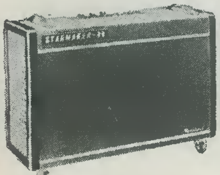
DE LUXE STEREO AMPLIFIER. Model S-33H. De luxe version of the S-33 with two-tone grey perspex panel, and higher sensitivity necessary to accept the Decca Deram pick-up. Kit **£15.17.6** Assembled **£21.7.6**

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

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

Heathkit DAYSTROM ***Make the most of your leisure time...***

FOR THE INSTRUMENTALIST



PA-2

NEW! *STARMAKER-33*

TRANSISTOR PA/GUITAR AMPLIFIER, PA-2. 20 Watt amplifier. Two heavy duty speakers. Four inputs. Two channels. Variable tremolo. Speed and depth controls. Weight 51lb.

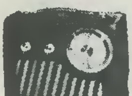
18" high x 29" wide x 10" deep.

Kit **£44.19.0** Assembled **£59.10.0**
Castors or legs available as extras.

TRANSISTOR RECEIVERS

UXR-2

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



UXR-1

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

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

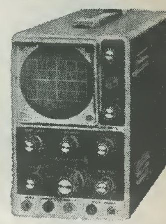
UJR-1

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

WELCOME TO OUR LONDON HEATHKIT CENTRE
In response to the request of many customers, we have opened a showroom and retail stores at:
233 Tottenham Court Road
WHEN YOU ARE IN TOWN, WE HOPE YOU WILL VISIT US THERE

INSTRUMENTS

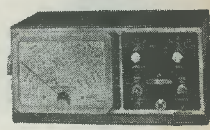
NEW! 3" LOW-PRICED SERVICE OSCILLOSCOPE. Model OS-2. Compact size 5" x 7¼" x 12" deep. Wt. only 9¼lb. "Y" bandwidth 2 c/s–3 Mc/s±3dB. Sensitivity 100mV/cm. T/B 20 c/s–200 kc/s in four ranges, fitted mu-metal CRT Shield. Modern functional styling. Kit **£22.18.0** Assembled **£30.8.0**



OS-2

5" GEN-PURPOSE OSCILLOSCOPE. Model 10-12U. An outstanding model with professional specification and styling. "Y" bandwidth 3 c/s–4.5 Mc/s±3dB. T/B 10 c/s–500 kc/s. Kit **£35.17.6** Assembled **£45.15.0**

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



IM-13U

AUDIO SIGNAL GENERATOR. Model AG-9U. 10 c/s to 100 kc/s, switch selected. Distortion less than 0.1%, 10V sine wave output metered in volts and dB's. Kit **£22.10.0** Assembled **£30.10.0**

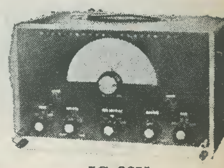
V-7A

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

RF-1U

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

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



IG-82U

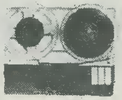
NEW! SINE/SQ GENERATOR. Model IG-82U. Freq. range 20 c/s–1 Mc/s in 5 bands less than 0.5% sine wave dist. less than 0.15μ sec. sq. wave rise time. Kit **£24.10.0** Assembled **£36.10.0**

TRANSISTOR POWER SUPPLY. Model IP-20U. Up to 50V, 1.5A output. Ideal for Laboratory use. Compact size. Kit **£35.18.0** Assembled **£47.18.0**

Prices and specifications subject to change without notice

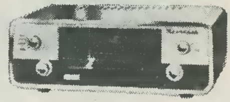
TAPE AMPLIFIERS ~~~ TAPE DECKS ~~~ CONTROL UNITS

FM TUNER FM-4U



MAGNAVOX DECK

TRUVOX DECK



AM/FM TUNER

HI-FI FM TUNER. Model FM-4U. Also available in two units. R.F. tuning unit (£2.15.0 incl. P.T.) with I.F. output of 10.7 Mc/s, and I.F. amplifier unit, with power supply and valves (£13.13.0). Total Kit **£16.8.0**

MAGNAVOX "363" TAPE DECK. The finest buy in its price range. Operating speeds: 1⅞", 3¾" and 7½" p.s. Two tracks, "wow" and "flutter" not greater than 0.15% at 7½" p.s. **£13.10.0**

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

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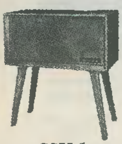

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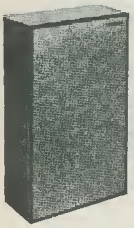

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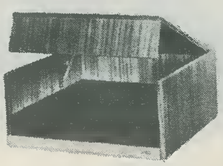

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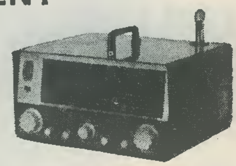

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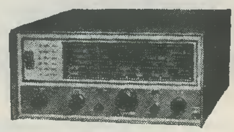

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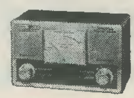

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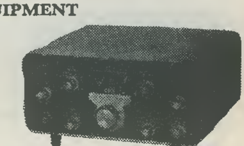

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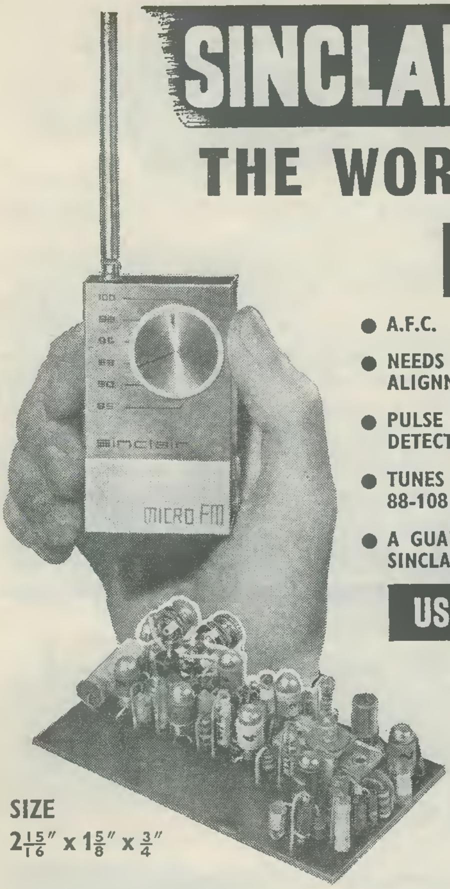
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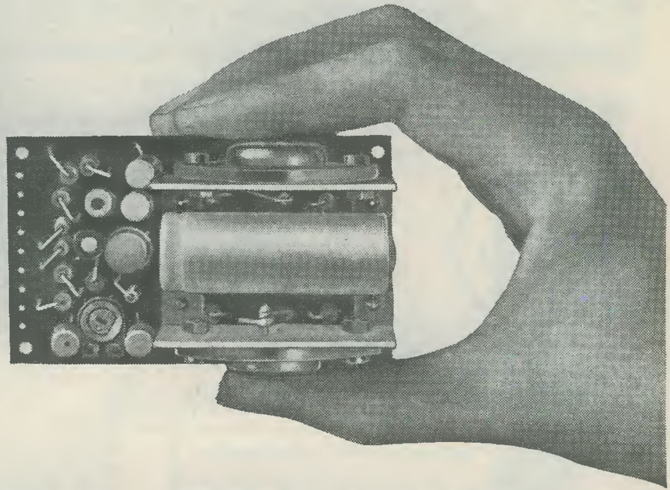

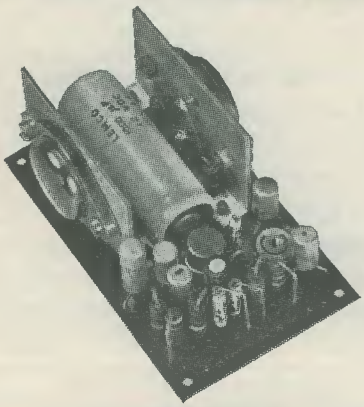

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TRANSISTOR TIME SWITCH

By J. SPENCER, M.A.

THE NEED FOR SOME FORM OF variable time switch arises frequently in the lives of both the experimenter and the photographer. Usually, mains electricity is available so that power consumption is not a serious problem. Also, such a supply lends itself to designs which use thermionic valves as their basis of operation. In the case of the circuit to be described the possible absence of mains supplies had to be assumed, so the unit had to be battery driven. This, in turn, led to a need for a low power consumption in order that dry batteries could be employed to increase the portability of the unit and its associated circuits. Inevitably, therefore, a design based on transistors had to be adopted.

Design

The circuit chosen as a basis for design was the monostable multivibrator, see Fig. 1. In such a circuit one transistor of a pair is normally fully conducting and causes the other transistor to be cut off. This is the stable state, and it persists indefinitely unless a signal is applied to the circuit. Such a signal is a short pulse which may be applied in various ways, and which has the effect of turning on the cut-off transistor. Due to an RC coupling between the two transistors, when this reversal of state of one transistor occurs it automatically reverses the state of the other transistor. The circuit is now in its unstable state, the duration of which is governed by the values used for the RC coupling. When the monostable multivibrator is used as a time-switch it is usual to employ the unstable state duration as the output, and to make it variable by adjustment of R or C, or both.

Although varying R is an obvious choice for adjusting the time period, this resistor carries the base current for TR_2, which puts severe limits on the maximum value that may be used. Consequently, if long durations are wanted, the value of C must be increased. Large values of C are undesirable because of the leakage currents which occur in the electrolytic capacitors that such large values demand. The practical design problem is thus the choice of the "best" compromise between conflicting requirements.

Figure 2 shows the compromise finally selected in the present case.

The base current requirement of TR_2 can be considerably reduced if, instead of one transistor, two are used in a "Darlington pair" arrangement. This allows much larger values of R to be used for the same output current. Thus the value of C necessary for a given delay period can be kept smaller. If inexpensive transistors are employed in the Darlington pair the cost is only slightly increased, if at all.

Unfortunately, the very high current gain of the Darlington pair carries with it the disadvantage of increased temperature sensitivity, especially with the V_{be} and I_{co} characteristics of the pair. If these effects are not to upset the consistency of timing they must be reduced. The use of the largest possible value for the common emitter resistor, R_3, consistent with supply voltage and output current requirements is one correcting feature. Simple temperature compensation is provided, also, by the thermistor, TH_1, in the base circuit of TR_1. The CZ3 thermistor chosen is inexpensive and, together with R_7, gives a resistance of about 10kΩ at 15° C. The 8.2kΩ resistor, R_7, attenuates the temperature coefficient of the CZ3 to a value which gives reasonable temperature stability for the complete circuit. For example, in the prototype with a fixed 10kΩ resistor the unstable state duration changed by approximately −0.8% °C rise in ambient temperature. This reduces to −0.1%/°C with the arrangement shown. The quoted values were obtained for a temperature range of +2.7 to +18.9°C.

Anchor Resistor

Finally, the rather paradoxical addition of a small value resistor between TR_2 base and the positive supply line will be noticed. This helps to reduce leakage current changes in the Darlington pair, but in so doing it reduces the pair to something little better than the single transistor of Fig. 1. Consequently, to anchor the base and at the same time to isolate the resistor from the RC timing coupling, the diode, D_1, is included in series with the anchor resistor. The reverse resistance of the diode is now shunted across the Darlington pair input and so, to maintain long timing periods it is essential to pick a diode with a high reverse resistance. Even if a high value is obtained it will be found that the shunting effect is quite pronounce

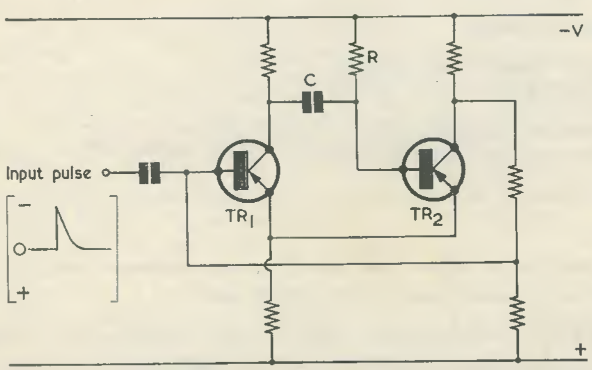


Fig. 1. The monostable multivibrator, adapted for single battery operation. TR_1 is on in the unstable state, and TR_2 is on in the stable state. The circuit may also be triggered by applying a positive pulse to the base of TR_2

Components List

Resistors

(All fixed values 10% ¼ watt)

R_1	100kΩ
R_2	750Ω
R_3	100Ω
R_4	500kΩ potentiometer, linear
R_5	47kΩ
R_6	1.5kΩ
R_7	8.2kΩ
R_8	2.2kΩ

Capacitors

C_1	0.5μF paper
C_2	500μF electrolytic 12V wkg.
C_3	50μF electrolytic 12V wkg.

Semiconductors

TR_1	OC76 (or OC83)
TR_2	OC75
TR_3	OC83
D_1	OA202
D_2	OA81

Switches

S_1	s.p.s.t. press-button
S_2	s.p.d.t.
S_3	s.p.s.t. (Fig. 2) or d.p.s.t. (Fig. 3)

Miscellaneous

Relay type 600, 600Ω coil, contacts as required
TH_1 Thermistor type CZ3
12-volt battery

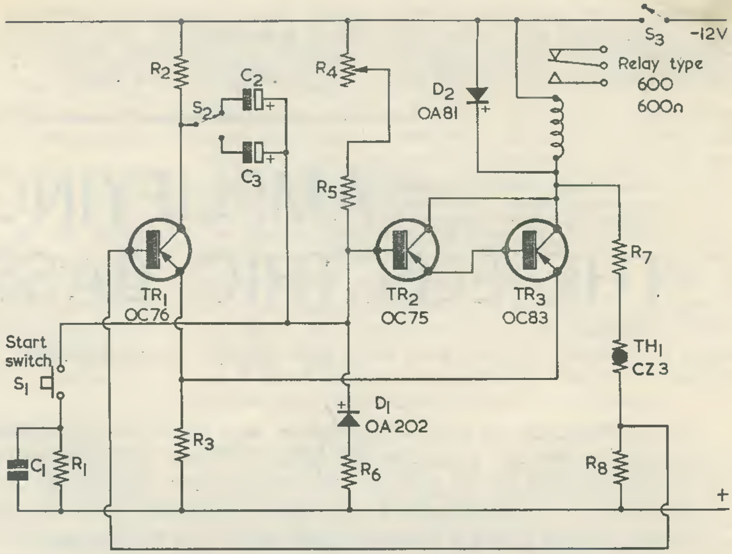


Fig. 2. The circuit of the complete transistor timer. Battery drain is of the order of 16mA. TR_1 may be an OC83 instead of an OC76, if desired

but, of course, temperature effects are reduced considerably. It is probably very much a case of "you pay your money and you take your choice". If changes in ambient conditions are either very small or unlikely, then the shunt resistor plus diode can be dispensed with, and a gain in timing period duration will result. The duration of the unstable state is approximately 0.7 RC. With 547kΩ and 500μF, the calculated duration of the unstable state is 191 seconds. In the prototype, and without the shunt diode and R_6 in circuit, the measured maximum duration was 205 seconds, in fair agreement with the calculation. With the diode and R_6 included, the maximum duration dropped to about 65 seconds.

The 47kΩ resistor, R_5, in series with the timing resistor, R_4, is essential, as it limits the maximum base current that can be passed through TR_2. The relay current, when energised, is 16mA.

The signal which initiates the unstable state is a positive pulse applied to TR_2 base. This turns the Darlington pair off. The 100kΩ and 0.5μF parallel combination, C_1, R_1, ensures that sufficient charge is taken from TR_2 base to cut off the pair whilst still not allowing the circuit to be re-started inadvertently should the start switch still be closed at the end of a timing period.

The values of C (C_2 and C_3 in Fig. 2) are chosen to suit the maximum required duration using the equation given above. Those specified are suitable for a dual range timer covering 0.5 to 6 and 6 to 60 seconds approximately. The measured maximum variability of timing, at a constant setting of R, and with C=500μF, was about ±1.5% of the mean timing period. This result was obtained from a sample of twenty periods. This variability will tend to increase as the value of C is increased.

Construction

Construction is a matter of choice because there is nothing critical in the layout of this type of circuit. In the prototype the complete unit, less batteries, was housed in a tin 3¼in in diameter by 4½in long. The timing capacitors, variable resistor, relay and the range switch were mounted in the tin and the remaining components were attached to a small group board which was fixed to the tin lid. Small connecting block strip was used for the external connections to the battery and for the relay contacts.

Critical Applications

It is important to note that the output signal is obtained when the relay in TR_3 collector circuit is de-energised. To prevent a false signal occurring when the timer is switched off, for example, it is

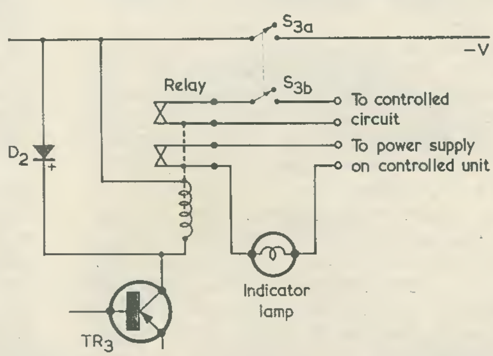


Fig. 3. A switching arrangement for critical applications. $S_{3(a)}$ is the on-off switch for the timer whilst $S_{3(b)}$ is the cut-out for the controlled circuit

advisable to use a 2-pole 2-way supply switch for the unit, this being wired as shown in Fig. 3. This automatically open-circuits the relay contact circuit, whenever the timer is switched off. The indicator lamp is an additional check that may be useful in some cases.

No doubt there are other and probably better ways of "fool-proofing" the timer which will occur to readers.

AMPLIFYING THE ELECTRIC BASS GUITAR

By C. P. BARHAM

Our contributor, an electronic engineer with three years' experience as bass guitarist in a beat group, has devoted a considerable amount of time to the design and construction of amplification equipment both for his own and for other groups. He has also often been called upon to repair commercial amplifiers of various makes. Such first-hand knowledge is amply reflected in this article, which offers a common-sense and very practical approach to the subject of bass guitar electronics

THE ELECTRIC BASS GUITAR IS AN INSTRUMENT which has achieved a great deal of popularity in recent years among both dance band and beat groups musicians. Since its introduction as a more portable substitute for the conventional double-bass it has gained status as an instrument in its own right, requiring different techniques of playing and achieving an individual tonal characteristic.

It should be realised by any persons intending to play this instrument (and therefore intending to purchase or construct the associated amplifiers and loudspeaker systems), that the requirements of the amplifying system are different according to whether the instrument is to be used in the beat group or the dance band. Since a previous article in *The Radio Constructor* has dealt with a system which would be more applicable to the dance band,* this present article deals mainly with the beat group instrumentalist's requirements.

Two Types Of System

To appreciate the difference between the two types of system, it should be understood that, in the beat group, the bass guitar plays a far more prominent part than does the same instrument in the dance band, where it appears to be regarded primarily as a supplement to the percussion. A greater volume of sound is required from the bass guitar in the beat group and its usefulness lies in its being able to provide "body" to the music, both accentuating the beat and combining with the other instruments to provide a simple rhythm, since beat music is, in essence, based upon simple, straightforward rhythm.

For this purpose, an output power of 25 watts must be considered the absolute minimum. Flat response and freedom from harmonic distortion is not only unnecessary, but can be actually detrimental to the sound of the instrument. The amplifier, in fact, should be treated not as a machine for reproducing with high fidelity the sound of the unamplified guitar, but as a means of modifying and enhancing the quality of this sound by the deliberate boosting of certain characteristics at the expense of others. A bass guitar played through a high fidelity amplifier, although giving a smooth, round tone, lacks the particular "edge" or "bite" needed for the beat group.

The Guitar

Before considering the design of the amplifier and loudspeaker system, it may be of interest to discuss briefly the bass guitar itself.

There is a wide variation in price between guitars and, as with most things, one gets what one pays for.

The aspiring guitarist of limited means may, however, construct for himself very cheaply a simple guitar which will give reasonably satisfactory results until he can afford a professionally constructed model of higher quality. The author has himself constructed such a guitar sawn from a sheet of blockboard. The neck was reinforced by a piece of $\frac{3}{8}$in mahogany which, in addition to adding strength, gave a smooth playing surface. The machine heads, bridge, tailpiece and strings were purchased from a musical instrument shop. The pick-up was home-made, but a cheap one may be bought for about £2.

The most important step in the construction of the guitar is to get the relative positions of top

* R. A. Jeffrey, "Some Notes On The Electric Bass Guitar", *The Radio Constructor*, February 1965.

nut, bridge and frets correct. The top nut should be $30\frac{1}{2}$in from the bridge, the first fret $30\frac{1}{2}/17$in from the top nut, the spacing between the first and second frets $\frac{1}{17}$ of the distance from the first fret to the bridge, and so on for 17 fret positions. Fret wire may be bought from the musical instrument dealer.

The Amplifier

Power amplifiers can be obtained in all price ranges. If the novice is intending to purchase one, he should not sacrifice power for quality in this application. He should buy the highest powered amplifier he can get in the range 25–50 watts, at the highest price he can afford. It is false economy to buy low powered equipment with which he will be dissatisfied at a later date.

A low level of harmonic distortion is not of prime importance as distortion far in excess of that produced by the amplifier will be introduced by the loudspeakers. As regards response, if the power is available any loss of response at the lower frequencies can be made up by increasing the volume at the input.

Separate pre-amplifiers with multiple tone controls and filters are unnecessary since adequate adjustment of volume and tone is usually to be found on the controls of the guitar itself. In order to minimise hum and noise level, nevertheless, it is best to work with the guitar volume control at maximum and to control the output volume from the amplifier itself.

Although most commercial guitar amplifiers are provided with several (up to six) input sockets for use with a number of instruments simultaneously, the author feels that this is not a good thing as it is likely to lead to overloading of the amplifier and speakers, and possibly to intermodulation between the various inputs.

Should the enthusiast decide to build rather than buy an amplifier for his guitar, he will find there there are a large number of published designs in the range up to 20 watts and somewhat fewer to choose from at higher power ratings. Most of the Hi-Fi amplifiers rated at 20 watts, can, in fact, be driven up to 25–30 watts, since the 20 watt figure quoted is normally for a low harmonic distortion content. As previously mentioned, multiple tone controls can be dispensed with, so simplifying the pre-amplifier stages. If a published design is not quoted as being specifically for a guitar, the enthusiast should check that the input impedance is suitable. Most guitar pick-ups have an impedance in the region of 1kΩ and give up to 50mV output. This is more or less equivalent to the microphone input of a general purpose amplifier. The other important point to look for is the type of valve used in the output stages of the circuit. A guitar amplifier should have an output stage "damping factor" in the region of 50, which implies that valves such as the EL34, KT88, or 807 with low anode impedance should be used. A high damping factor means that the amplifier is capable of exercising a high degree of control over the movement of the loudspeaker cone. The individual quality of the bass guitar sound derives from the damping of the guitar strings as they are plucked. If the loudspeaker cone is allowed to resonate, this quality is lost. Another factor affecting output stage damping is the type of output transformer used. A transformer of inadequate size will not give a good performance, regardless of the excellence of the amplifier.

A further point which may be mentioned is the question of hum and noise level in the amplifier. An expensive amplifier is necessary in order to keep the hum and noise at a low figure. However, low hum and noise level is not necessary if the equipment is to be used only for playing on stage, but if the amplifier is required for use in a recording studio hum and noise cannot be tolerated.

Speaker Systems

As for the speakers, they should be capable of handling twice the power the amplifier can give or the transients, which are the important factor in bass guitar music, will overload the speaker, producing a "ragged" tone or even wrecking the cone of the speaker. Some manufacturers in fact quote a "bass guitar" power rating for their speakers which may be 40% lower than the normal rating.

If the guitarist cannot afford this, he should budget for the biggest reserve of power he can. If two speakers are used, it is preferable to contain them, properly positioned, in one cabinet, rather than to spend extra money on separate cabinets which, although in theory giving "separation", in practice makes very little difference. As for the design of the speaker cabinet, the enthusiast must choose between a completely enclosed box of extremely rigid construction, or a properly designed and constructed sand-filled bass reflex cabinet. Most commercial manufacturers opt for the former, partly because of the weight and the bulk of the latter, and partly because the expense is not justified in this application, where, as previously stated, linearity of response is not of prime importance. A compromise measure such as a ported box is not to be recommended as it can introduce unwanted resonances.

An open weave speaker mesh should be used as the close-weave type may "buzz" at certain frequencies. A good scheme is to use expanded metal mesh as a speaker grille as this is far more rigid than woven plastic or fabric. It is important, however, to ensure that the expanded metal does not rattle against the cabinet. It should, for best results, be clamped at its edges between two layers of rubber sheet.

As the speaker enclosure is liable to be a heavy piece of equipment, wheels and handles are normally fitted. These need some care in their choice and positioning, or they will rattle whenever full power is used. It is absolutely essential that the amplifiers should be in separate boxes to prevent acoustic feedback, and mechanical damage to valves. Nor is the "piggyback" type of amplifier mounted on top of the speaker enclosure to be recommended.

Even with the amplifier in a separate enclosure, anti-microphonic valveholders are to be recommended. Since the amplifier is likely to be mounted some distance from the speakers, one should make sure that the amplifier is of a type which will not oscillate with long speaker leads attached.

Finally, an important word of warning. Do not on any account, use a.c./d.c. amplifiers where the chassis may become live and which, if used in conjunction with other earthed electrical equipment, may prove lethal. Several recent accidents can be attributed to this cause.

Recent Publications . . .

PICK UPS—THE KEY TO HI-FI. By J. Walton. 110 pages, 5 x 7¼ ins. Published by Sir Isaac Pitman and Sons, Ltd. Price 10s.

This little book is a surprise packet—and a very welcome surprise packet, too—because it squeezes a great deal into a small and modest covering. The author has specialised in the design of gramophone pick ups and he contends that it is the pick up, and not the loudspeaker, which is the weakest link in the high fidelity reproducing chain.

The book commences with a preliminary explanation of terms, then carries on to the information carried by the record and the requirements of the pick up in reproducing that information. Next follow sections on pick up arms and tracking, on clearing practical troubles, on calculations and on references for further reading. At the end of the book are a series of electron and optical microscope photographs of record grooves and some of the frightening things that happen to them after playing with pick ups having a high tip mass.

The hi-fi enthusiast naturally wants to obtain best pick up performance and minimum record wear, and the book under review tells him how to do this both clearly and concisely. Despite its small size it contains a considerable amount of detailed advice and information; and it has patently been written by an author who has had much practical experience in the pick up field.

TRANSISTOR ELECTRONIC ORGANS FOR THE AMATEUR. By Alan Douglas, Sen.M.I.E.E.E. and S. Astley. 82 pages, 5½ x 8½ ins. Published by Sir Isaac Pitman and Sons, Ltd. Price 18s.

Neither Alan Douglas nor S. Astley are newcomers to readers of *The Radio Constructor*, and a complete organ described in one chapter of this book is a development from that described by S. Astley in our issues for August to November, 1962.

Out of the six chapters which make up the book, the first provides some short details on organ terminology, whilst the second gives an introduction to transistor operating principles. The third chapter is devoted to the transistorised organ just mentioned, whilst the fourth carries on to other transistorised organ circuits. These include frequency dividers, oscillators, vibrato circuits, diode shapers and tone filter networks. The light dependent resistor is not forgotten, and this appears in both a vibrato arrangement and a stop control circuit. The fifth chapter is devoted to transistor amplifiers and power supplies whilst the sixth gives notes on semiconductor keying and special effects. An Appendix provides a frequency table for tonal derivatives.

ACOUSTICAL TESTS AND MEASUREMENTS. By Don Davies. 192 pages, 5½ x 8½ ins. Published by W. Foulsham & Co. Ltd. Price 30s.

This book, which appears in the Foulsham-Sams Technical Book series with introductory chapters for English readers, is devoted to the scientific testing methods which can be applied to acoustics. The particular branch of acoustics covered is that which deals with public address and sound reinforcement systems in buildings and stadia.

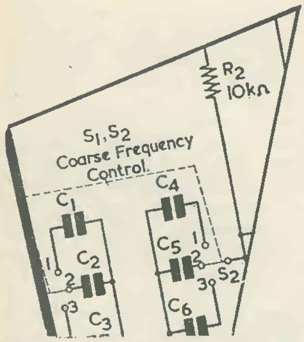
The treatment is comprehensive and deals with such basic quantities as quietness, reverberation, loudness requirements and distortion. The author has had a great deal of experience in auditoria and arenas in the United States and draws extensively from this experience in his text. After describing the test equipment which may be employed, the book carries on to chapters dealing with the measurement of noise, the measurement of reverberation time, and the new technique of pulse testing. Methods of testing a complete sound system come next, these being followed by chapters on the writing of a survey report and specification measurements.

The equipment mentioned in the book is American (although it should be possible to obtain British equivalents) but this does not represent any serious disadvantage. What is of more importance is that the problems discussed apply to any country, and the text abounds with illustrations of successful solutions taken from practical observation on the part of the author.

RADIO MOBILE HANDBOOK. By Charles Caringella, W6NJV. 163 pages, 5½ x 8½in. Published by W. Foulsham & Co. Ltd. Price 24s.

This is another title in the Foulsham-Sams Technical Book series and it offers general advice to the amateur or would-be amateur who wishes to go mobile. The text of the book is of American origin, and deals with mobile operation as it exists in that country. However, there is a great deal that is common to similar operation in the U.K., and fundamental principles are the same for both countries.

The first chapter deals with receivers and converters, the latter being intended for short wave reception with an i.f. output feeding into the aerial terminal of a broadcast band car radio. Chapter 2 covers transmitters, including s.s.b., whilst the third chapter is devoted to modulators. Further chapters cover transceivers and transmitter-receiver, microphones, aerials, power supplies and ignition noise, and there is a folded sheet at the end of the book which gives full circuit diagrams for the Heathkit HR20 mobile receiver, the Heathkit "Pawnee" 2-meter transmitter-receivers, the Heathkit HW-12 s.s.b. transceiver, and the Gonset "Communicator IV" transmitter-receiver. In the text, descriptions of commercially available and home-built equipment appear alongside each other and a useful feature of the book is the provision of full circuit diagrams (in addition to those at the end of the book) for the commercial items.



Fractional Resistance Measurements

SUGGESTED CIRCUIT No. 183

By G. A. FRENCH

It is often desirable, during design and servicing work, to be able to measure low values of resistance. Typical examples are given by the checking of coils or switch contacts whose resistance may be of the order of 0.1Ω or less. Unfortunately, the resistance ranges of conventional multi-testmeters employ the series type of circuit in which an energising battery, the meter movement, and the resistance being measured are all effectively in series, and these do not normally give useful readings below about 0.5Ω. They cannot, therefore, be used for low resistance measurements.

In this article, the writer will show that it is possible to obtain reliable readings of much lower values of resistance than 0.5Ω, and that these readings can be obtained with extremely simple and inexpensive equipment and without having to calibrate against standard resistors. A moving-coil milliammeter is required but its full-scale deflection figure is not important. It is, indeed, possible to employ the scheme to be suggested when the full-scale deflection of the meter is not even accurately known!

It will be assumed, in this article, that the reader understands the simple principles involved in connecting shunt resistors across current-reading meters.

The Basic Principle

Fig. 1 gives a circuit in which a meter is connected in parallel with a shunt resistor. The internal resistance of the meter is R_m and the value of the shunt resistor is R_s. A current I_m flows through the meter, and a current I_s through the shunt resistor. A constant current, designated I_c, flows through the parallel combination of both meter and shunt resistor, and it follows that $I_m+I_s=I_c$. Also, the currents flowing through the meter and the shunt resistor are inversely proportional to their resistances, giving:

$$\frac{I_m}{I_s}=\frac{R_s}{R_m}$$

Since $I_m+I_s=I_c$, we may say that $I_s=I_c-I_m$, and can use the term, I_c-I_m, to replace I_s in the equation just given.

$$\frac{I_m}{I_c-I_m}=\frac{R_s}{R_m}$$

$$\text{therefore } I_m=\frac{R_s(I_s-I_m)}{R_m}$$

$$=\frac{I_cR_s}{R_m}-\frac{I_mR_s}{R_m}$$

$$\text{therefore } I_m+\frac{I_mR_s}{R_m}=\frac{I_cR_s}{R_m}$$

$$\text{therefore } I_m(1+\frac{R_s}{R_m})=\frac{I_cR_s}{R_m}$$

$$\text{therefore } I_m=\frac{I_cR_s}{R_m\,(1+\frac{R_s}{R_m})}$$

$$=\frac{I_cR_s}{R_m+R_s}$$

This simple equation* tells us the current flowing through the meter of Fig. 1, provided that the values of I_c, R_s and R_m are known.

Let us now assume that the meter in Fig. 1 has a scale which is graduated from 0 to 100 and, also, that I_c has a value which causes the meter to read full-scale deflection when I_c passes through it (as would occur if R_s were taken out of circuit). I_m is expressed in terms of I_c multiplied by a resistance ratio, with the consequence that the actual units of current which flow become unimportant, and all we need say is that I_c is 100 "units of current" and is indicated as such by the meter showing "100" when I_c flows through it. I_m is measured in the same "units of current" as is I_c, so that if a certain value of R_s causes the meter to indicate "10" this means that 10 "units of current" are passing through the meter.

Provided we know the value of R_m we are now in a position to find the values of I_m which correspond to different values of R_s. To take an example, let us assume that the internal resistance of the meter is 1Ω and that R_s=0.1Ω. Then:

$$I_m=\frac{100\times 0.1}{1+0.1}$$

$$=\frac{10}{1.1}$$

$$=9.09$$

It will be noted that we have substituted 100 for I_c, because I_c is 100 "units of current". I_m is 9.09 "units of current". Since the meter is graduated from 0 to 100, its needle will point to 9.09 on its scale.

The accompanying Table shows values of I_m calculated for R_s from

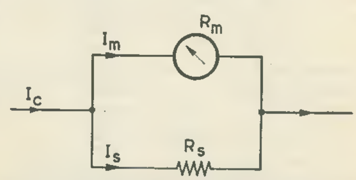


Fig. 1. A current-reading meter in parallel with a shunt resistor. The internal resistance of the meter is R_m, and the value of the shunt resistor is R_s

* The same result is given from $\frac{Im}{Ic}=\frac{Rt}{Rm}$, where Rt is the total resistance given by the parallel combination of Rm and Rs (and equals $\frac{RmRs}{Rm+Rs}$).

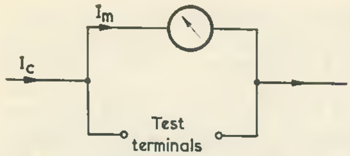


Fig. 2. The circuit of Fig. 1 may be employed for measuring resistance, as shown here. Resistors to be measured are connected to the test terminals, whereupon their value may be evaluated from the Table

0.01 to 10Ω, it being assumed that R_m is equal to 1Ω and that I_c is equal to full-scale deflection in the meter, which is calibrated from 0 to 100. It will be seen that useful readings are given for shunt resistances as low as 0.01Ω, whereupon we now have the basis of a resistance measuring circuit which is capable of measuring very low values of resistance. The resistances to be measured are inserted in the shunt resistance position, as shown in Fig. 2.

The figures in the Table are still applicable if the internal resistance of the meter, R_m, is other than 1Ω. If R_m is 2Ω, all the figures in the R_s column must be multiplied by 2. If R_m is 5Ω, all the figures in the R_s column have to be multiplied by 5. Thus, with a meter having an internal resistance of 5Ω, a reading of 7.40 on its 0–100 scale will correspond to a test resistance of 0.08 x 5=0.4Ω.

TABLE

Values of I_m for R_s from 0.01 to 10Ω, with R_m=1Ω. (If R_m is other than 1Ω, multiply R_s by R_m.)

R_s (Ω)	I_m (*% of f.s.d.*)
0.01	0.99
0.02	1.96
0.03	2.91
0.04	3.85
0.05	4.76
0.06	5.66
0.07	6.54
0.08	7.40
0.09	8.26
0.1	9.09
0.2	16.7
0.3	23.1
0.4	28.6
0.5	33.3
0.6	37.5
0.7	41.2
0.8	44.4
0.9	47.4
1.0	50
2.0	66.7
3.0	75
4.0	80
5.0	83.3
6.0	85.7
7.0	87.5
8.0	88.9
9.0	90
10.0	90.9

Practical Considerations

This last point emphasises the fact that, to be able to measure very low values of resistance in the shunt position, it is necessary for R_m to have a low value as well. It becomes necessary next, therefore, to examine practical meters as are generally available on the home-constructor market to see what values of R_m are offered. A typical example of a practical instrument is the frequently encountered ex-R.A.F. 2½in movement which has a full-scale deflection of 1mA and an internal resistance of 75Ω. 75Ω is much too high a figure for R_m, if we wish to measure really low values of resistance using the circuit of Fig. 2, but it is quite easy to add a shunt to the meter to make it read 10mA full-scale deflection, whereupon the effective resistance presented by the meter (plus shunt) drops to 7.5Ω. Fig. 3 shows the meter with its shunt. So far as the circuit external to the meter is concerned, the meter and its shunt in this present instance are exactly the same as a 0–10mA meter on its own having an internal resistance of 7.5Ω. If we were to add a shunt which made the meter read 100mA full-scale deflection an effective internal resistance of 0.75Ω would be presented to the circuit external to the meter. This low figure for R_m would require that all the figures in the R_s column of the Table be multiplied by 0.75, whereupon a high degree of sensitivity is provided.

It will be seen that, to reduce R_m with a meter of the type commonly available, it will normally be necessary to shunt the meter so that its full-scale deflection figure is increased. Checking at random through his stock of meters, the writer finds that he has a 0–10mA meter with a nominal internal resistance of 6Ω. If this were shunted to read 30mA, the effective R_m becomes 2Ω. Similarly, a 0–100μA meter in the writer's stock has an internal resistance of 460Ω. If this meter were shunted to read, say, 20mA full-scale deflection, the effective R_m presented to the external circuit would be 2.3Ω.

All these figures are representative of actual meter movements commonly available, and they clearly illustrate the fact that a lower effective R_m (and, hence, greater sensitivity in the circuit of Fig. 2) may be obtained by shunting the meter to obtain a higher full-scale deflection. There is, however, a limit to which such shunting may be carried, this limit being set by the difficulty of providing an excessively high constant current to energise the circuit and by the fact that much of the constant current flows through the resistance being measured when this resistance has a low value. Too high a current could damage the resistance being measured, and a practical compromise would consist of making I_c lie between some 10 and 50mA.

It goes without saying that all the meters just referred to are not calibrated directly in terms of 0 to 100. But their scales can, of course, be interpreted in terms of 0 to 100, the I_m figures in the Table then representing the percentage of full-scale deflection.

Some readers may be puzzled at the emphasis on using individual meter movements with, if necessary, shunt resistors to reduce their effective R_m, when it would apparently be much simpler to employ a multi-testmeter switched to a high current range instead. Multi-testmeters are not, however, suited for the present application. This is because such instruments employ universal shunt circuits and high-value swamp resistors in series with the meter movement, with the result that relatively large values of R_m are presented at their terminals. A high-grade expensive testmeter can offer, typically, an R_m of about 5Ω when switched to 100mA full-scale deflection. Other testmeters may give even higher values of effective R_m. These values of R_m are too high for the circuit of Fig. 2 to be really effective.

A Practical Circuit

A practical circuit is shown in Fig. 4. In this diagram the constant current I_c is obtained from a con-

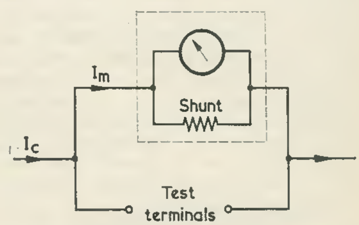


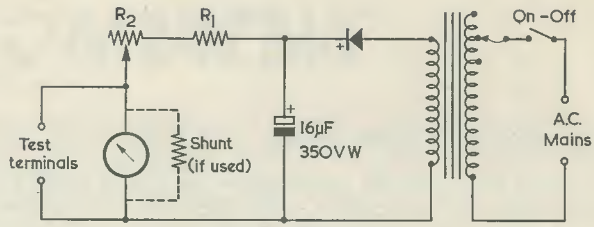
Fig. 3. To obtain high sensitivity it is desirable to reduce R_m and, with practical meters, this may necessitate connecting a shunt across it. The meter and shunt are shown here in a dashed outline to illustrate the fact that, so far as the external circuit is concerned, the R_m given by the meter and its shunt may be considered as the R_m of a meter on its own

ventional half-wave mains power supply giving a rectified voltage of around 250. The current ratings for the mains transformer secondary and rectifier should be higher than the constant current it is intended to employ, and suitable values for the dropping resistors R_1 and R_2 are indicated in the diagram. It should be pointed out here that the constructor has to make his own choice of I_c, bearing in mind the meters he has available, the two limitations on maximum I_c just mentioned, and the sensitivity of resistance readings required. The values shown in Fig. 4 for the fixed resistor, R_1 may need adjustment if the rectified voltage is considerably different from 250 volts.

A constant current is achieved in the circuit of Fig. 4 because the voltage changes across the meter due to the connection of different test resistances are negligibly small compared with the voltage applied to R_1 and R_2. R_2 is a panel-mounted variable resistor which is set up to provide full-scale deflection in the meter when no test resistor is connected. Since R_2 can, if necessary, be frequently adjusted, it is felt that there is little point in incorporating any voltage stabilising circuit to take up possible variations in mains supply potential. If a suitable h.t. power supply is already available, this can be used instead of the mains transformer, rectifier and reservoir capacitor of Fig. 4.

After connecting up the circuit and switching on, R_2 is adjusted to give full-scale deflection in the meter. If R_m is known accurately, it is then possible to obtain resistance measurements by working directly from the Table, multiplying the figures in the R_s column by R_m. If the constructor is uncertain of the exact value of R_m (because, say, he has used a shunt resistor whose exact value is unknown) a resistor of known value which gives about mid-scale deflection should be connected to the test terminals. The value of R_m may then be found by dividing the value of this resistor by the value for R_s obtained from the Table. When the meter is fitted with a shunt to bring its R_m down, it may be helpful to give the shunt a value which causes R_m to be a round figure rather than to aim at a round figure in terms of milliamps for full-scale deflection. Provided that I_c lies within a suitable range of currents, its exact value is of no importance.

The writer checked the results in the Table with a practical set-up, the I_c for which was in the region of 16mA with R_m being equal to 3Ω. Results were in accordance with the figures given in the Table. The writer was fascinated to find that the most convenient way of checking accuracy at low readings was to use short lengths of 36 s.w.g. copper wire as test resistances. This gauge of wire has a nominal resistance of 0.0149Ω per inch!



I_c	R_1	R_2
10-15mA	15kΩ 5w	15kΩ
15-20mA	10kΩ 5w	10kΩ
20-30mA	7·5kΩ 10w	6kΩ
30-40mA	5kΩ 10w	5kΩ
40-50mA	3·9kΩ 15w	3kΩ

Fig. 4. A practical test circuit. The secondary of the mains transformer should offer some 230 to 250 volts. The rectifier may be a silicon, "metal" or contact-cooled component of adequate ratings. Suitable values of R_1 and R_2 for different ranges of I_c are given. R_2 should be a wirewound component capable of passing the current involved

MAGAZINE REVIEW . . .

SPACE. 7½ x 7in. Published by Cockatrice Press Ltd, 99 Mortimer Street, London. W.1.

The various branches of science are so intermingled nowadays that it is very difficult indeed to say where one begins and another ends. Furthermore, electronics is the handmaiden of them all, whether it be in the form of radio communications, accurate data measurements or for control systems, etc. In no sphere is this so true as in that of space research, where absolute reliance must be placed on efficient electronic systems for communications, for control systems, for passing vital data to and from the space craft or satellite—or even for the physical and mental welfare of the astronauts. We make no apology therefore for introducing to our readers the magazine *Space*, knowing that, even though it is not "radio literature" in the strict sense of the term, there can be few of our readers who are not as fascinated with space research activity as they may be with more mundane radio interests.

Quite an unusual publication, *Space* has an unusual format and is a numbered, not a dated, publication. Each series is to consist of consecutively numbered pages, which can later be bound in book form. The magazine is not on general sale, being obtainable on subscription only (£2) for twelve issues. It is very well produced with good large-sized illustrations which adequately convey the impressiveness of many of the photos of rocketry, space craft and associated equipment.

As those who try to keep up with the rapid advances of space technology will know, it is difficult to find suitable literature for this purpose, particularly that suited to the interested lay science reader. This publication very adequately fills this role. We can recommend it without hesitation to all those who want to keep up with science in this field, be it space communications, space chemistry, space medicine, or even space history. It will interest both the lay science reader and professional alike and is a "must" for technical college and science school libraries.

NEWS . . . AND

TV and Radio Show 1966

The Television and Radio Show 1966 is to be held at Earls Court, London, from 22-26 August 1966. The show will be promoted and presented by Industrial and Trades Fair Limited, with the full support and backing of the Radio and Television Retailers' Association. *It will be open to trade visitors only.*

The decision to hold the show follows a country-wide poll of dealers' opinions conducted with the co-operation of the Radio and Television Retailers' Association. Leading companies already taking part include Philips Electrical Ltd., Pye, Rank-Bush Murphy Ltd., Standard Telephones and Cables Ltd. and two sectors of the Thorn Group (Thorn-A.E.I. Radio Valves and Tubes Ltd. and the Marconiphone Division).

Participation in the exhibition will be open to all home and overseas manufacturers of television and radio sets, high fidelity audio equipment, radiograms, record players, amplifiers, discs, tape recorders, musical instruments, transmission and studio equipment and allied products and services.

Full-scale international advertising, promotional, publicity and press relations campaigns, including a special nation-wide dealer publicity campaign, will be arranged by the organisers' Public Relations Division, ensuring that all potential trade buyers and visitors are kept fully informed concerning the show.

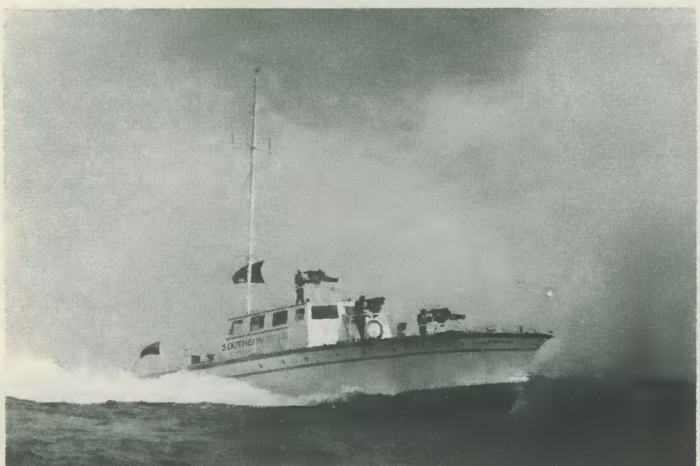
Paint-on Plastics Conduct Electricity

Plastics which conduct electricity have been invented in the United States, adding an entirely new dimension to the use of these versatile materials.

They can be applied in liquid form, almost like paint, to give an electrically-conducting coating to the surface of insulating materials, including ordinary plastics. They should be suitable for printed circuits.

Plastics at present in use are virtually incapable of conducting electricity and are therefore widely used as insulators.

Research work on the new plastics has been conducted by scientists of the U.S. General Electric Company. Additional development work is necessary before these plastics are available commercially.



Forecast

Predictions are always in the air at this time of the year, there being one on the periphery of our hobby which will interest many of our readers.

Mr. Sarnoff, former chairman of the Radio Corporation of America, at a dinner in New York spoke of the technical advances which have already enabled the human voice, pictures, telegraph and data transmissions to pass simultaneously through the same relays in the form of identical electronic pulses. He went on to say—"Not only television and telephone, but books, magazines and newspapers will be converted into identical energy for transmission over any distance. At the receiving end these electronic signals will be converted into any form we choose, either visual display or recorded sounds or printed pages."

Thinking Point

Professor Colin Cherry, Professor of Telecommunication at the Imperial College of Science and Technology, in the third Cantor lecture at the Royal Society of Arts, recently drew attention to the probability that much ill mannered driving on our roads is due to lack of communication. A motorist can flash lights or honk, but "in no sense can he, for example, apologise", and he may drive in an anti-social manner for the same reasons that a man "sent to Coventry" or in prison, may act anti-socially.

Professor Cherry suggested that radio communication between car drivers might do much to remedy the situation.

The "Southerner"

The many readers who are interested in boats will see with interest the fine looking powerboat illustrated "alongside".

Such readers, particularly, will notice the television cameras at the ready. The picture is of the powerboat *Southerner* speeding through the Solent at 34 knots on another outside broadcast assignment for Southern Independent Television. *Southerner* is the only O.B. boat of its kind in this country, possibly the world. Three EMI 4½-in image orthicon television cameras are mounted on deck, one on a specially strengthened section of the cabin deck, the others at port and starboard on the forward deck. The camera mountings have guard rails and safety harnesses for the cameramen.

• • • COMMENT

Underwater Transmission

What may well be the first amateur radio transmission from under the water was reported in a recent issue of *Mobile News*, the journal of the Amateur Radio Mobile Society. Transmissions were made by Gerry Jackson, G3HQU, and were picked up by three local amateurs, G3IKV, G3EFC and G3KKJ, as well as by a monitor van at the waterside, in which the entire broadcast was taped.

The transmission took place at Ormsgill Reservoir, Lancashire, and G3HQU was accompanied by two other divers, one of whom checked the leads through the heavy weed in the reservoir whilst the other acted as general safety cover and observer. Previous trials had shown the necessity for waterproofing the crystal microphone, and it had been found that the best way to feed the leads into the Siebe full face mask worn by G3HQU whilst submerged was under the jacket, over the head and into the top of the mask.

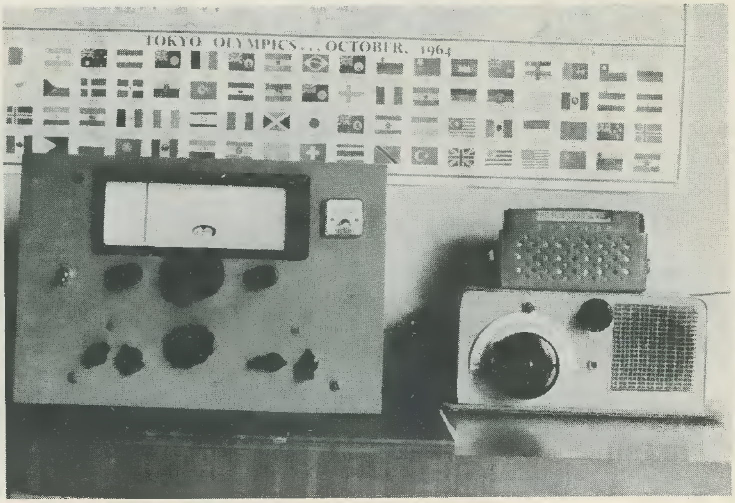
Surface equipment, held in a dinghy above the diver, included a 10-watt transmitter operating on 1.925 Mc/s, a 12-volt battery, a transistor power unit and a whip aerial with capacitor disc and an additional bottom loading coil.

The *Mobile News* report is taken from *Triton*, the journal of the British Sub-Aqua Club. Further technical information, written by G3HQU, should be appearing in later issues of *Mobile News*. Future experiments are aimed towards employing fully submersible "personal" transmitters, which can be coupled by a single lead to a small float aerial.

Quotes

From Professor Cherry's lecture referred to earlier in these notes:—"A glance at any railway station bookstand tell me that today there is far more mental poison in print than on the television screen. Sharp comments and complaints about corrupting influences of television programmes are common, yet rarely are books criticised. Can I conclude that these complainers don't read?".

As we go to press we read in the *Daily Mail* that "Russian technicians have developed a colour television system in an attempt to break the West's hold over the future of international broadcasting."



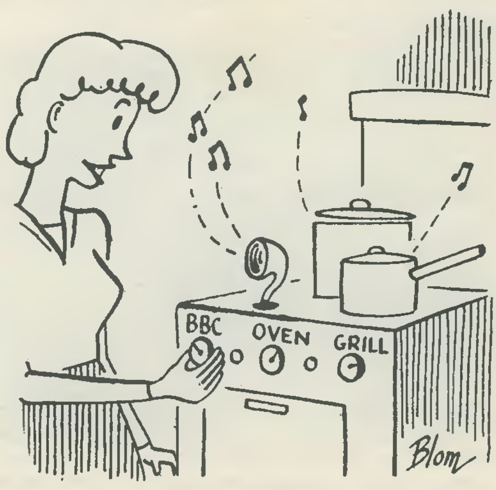
Comment from VK

Our daily postbag, like that of most radio magazines, contains letters from all over the world. It is always of particular interest to us when a reader from abroad sends us a photograph of equipment built up from one of our designs.

The photograph above is from D. Tovey of Melbourne, Australia who although he emigrated from this country some 10 years ago, has continued to read *The Radio Constructor* regularly ever since.

The main receiver is based on the General Coverage Double Superhet Receiver by Frank. A. Baldwin which we published in the November 1963 issue. The secondary set is the 6-Stage 3-Transistor Short Wave Reflex Receiver by Sir Douglas Hall, K.C.M.G., described in our August 1964 issue. Our reader says that the latter receiver pulls in BBC programmes at speaker strength using a 10in vertical aerial. In view of the location and the simplicity of design, he considers the set "a marvellous little job".

No Comment !



Mechanical Adjustment of Moving-Coil Meters

By G. W. McDONALD, G2OX

There are, at present, large numbers of ex-Service moving-coil meters in the hands of home-constructors or which are offered by retailers. The performance of many of these instruments can be improved by small mechanical repairs or adjustments, and these form the subject of this article. It should, of course, be pointed out that, unless the reader has the ability and has acquired sufficient experience, repairs and adjustments on more expensive meters should be passed to a competent instrument mechanic

MOST AMATEUR RADIO CONSTRUCTORS HAVE AT some time or another found it necessary to use a meter to make electrical measurements, but few have sufficient knowledge of the meter "innards" to make the necessary mechanical adjustments to the movement should its operation be erratic, or if it fails to read or reads wrongly.

The type of meter used most commonly by the amateur is the ex-Service moving-coil type. These instruments are cheap and easily obtainable in a wide assortment of scale readings. They are very reliable but are not always up to the peak of their efficiency, mechanically. This is due in many cases to prolonged storage under bad conditions, although the supplier cannot be blamed for this as they are bought in bulk direct from storage. At current prices—almost a quarter that of the new article—these meters are good value for money in spite of minor faults. Many are ex-equipment and may have been repaired at some time.

The main point of this article is to show that, with some knowledge of how a meter works and of its mechanical construction, a great deal can be done to improve a faulty instrument. One need not be a skilled instrument mechanic to repair simple faults on moving coil meters. A steady hand, good eyesight and patience are the main requirements for success.

The writer must stress, however, that any meter of value, such as a good multi-range instrument, should not be the subject of first experiments in the repair of meters. Treat a good instrument as you would a good watch, and send it to the expert for repair.

Moving-Coil Action

A very brief outline of the action of a moving-coil meter is as follows. Current to be measured is passed via two balance springs to a mechanically light coil which is suspended within the field of a strong permanent magnet. The current passing through the coil causes it to move within the field of the magnet. The instrument movement is so designed that the amount of deflection is proportional to the current passing through the coil.

A pointer is attached to the coil, this indicating on a calibrated scale a measure of the current flowing in the coil. Any moving-coil meter is dependent upon the current which flows in the circuit to which it is connected, and this fact holds good whether it has its scale marked in Ohms, Volts, Amps, or even Gallons per Minute!

Each movement requires a specified current to make it read full scale deflection, or f.s.d.

Tools Required

The tools required to tackle repair of small meters are simple and few in number. A useful kit would contain the following tools: watchmaker's eyeglass, set of instrument screwdrivers, pair of small pointed brass tweezers, pair of small long-nosed pliers, pair of small flat-nosed pliers, small pin-chuck vice, fine sewing needle and three small shallow glass jars. These tools will enable all minor adjustments to be made, but if more ambitious stripping of the movement is contemplated a very small instrument type of soldering iron will be necessary. The Adcola miniature soldering iron with $\frac{3}{16}$in bit is ideal for meter repair work.

The following sundry items will also be necessary, pieces of pointed matchstick, small quantity of shellac, quantity of cleaning fluid (carbon-tetrachloride) and small quantity of methylated spirit.

It is essential to have a perfectly clean work table before commencing the repair or inspection of a meter movement. Do not use the workbench in your workshop, as there is a great risk of iron filings and odd particles of metal being picked up by the meter magnet system. The writer usually uses a small card table set up near a window where plenty of good natural light is available, and where the risk of picking up stray ferrous metal does not exist. Cover the working part of the table with a sheet of white paper so that any small screws accidentally dropped may be easily seen, and not lost for ever down some crack.

Inspection of the Movement

We shall now carry on to the inspection of a typical movement.

Two useful tests can be carried out without removing the movement from its case. First, using a small screwdriver, check if the set zero adjuster is working. Secondly, rock the movement by moving the meter in your hand and check that the pointer moves across part of the scale and then goes back to its zero mark. Repeat this test with a metal "short" such as a screwdriver blade placed across the meter terminals. The pointer should still move across the scale but at a much slower rate, indicating that the circuit through the meter coil is complete. This test is only valid, incidentally, if there is no low resistance shunt across the meter movement inside the case, and is therefore not a reliable test to use when, for instance, buying a meter over a shop counter.

The next step is to remove the movement from its case. This is done by removing three small countersunk screws situated on the back edge of the case. One screw head may be hidden under a sealing compound, which has to be picked out with the point of a screwdriver.

During screw removal care must be taken to ensure that the movement does not fall out of the case and drop on the work table. If the movement is a tight fit in the case, force should not be used to remove it. It may be found that a sealing compound has been applied to the back edge on assembly whereupon, if the case cannot be pulled free from the movement, some methylated spirit or cleaning fluid must be sparingly applied to the sealed joint. After due time it will then be found that the case can be easily removed.

Never use a turning motion when removing a meter case. This will damage the set zero adjusting fork and may even damage a balance spring. Pull the case carefully clear of the meter movement without turning. Also, trying to force the case away from the meter by levering; with a screwdriver will only result in a broken case.

Having separated the case from the movement, examine the former to see if any loose pieces of metal are lying inside it. Such debris may be a clue to the fault in the movement. Loose screws, parts of a broken spring, and even parts of a pivot have been found in meters examined by the writer. The glass should next be examined to see if it is firmly fixed in the case. A loose glass is one of the more common causes of a pointer sticking at some point in its travel. It can be re-fixed with a cellulose-based cement or a contact adhesive such as Durofix or Evo-Stik. It should be noted in passing that it is bad practice to tap the glass of a meter if the pointer sticks. This treatment will break the adhesive and the glass will certainly move inwards and foul the pointer, and may even cause damage to it. Next time a meter sticks in service, tap the panel, not the meter.

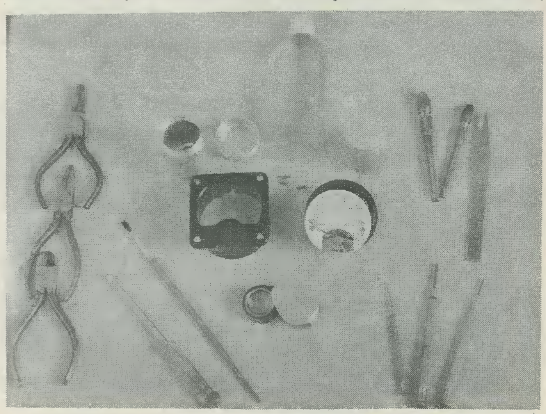
The set zero adjuster operates by way of a small pin fixed eccentrically to the adjuster screw. This pin may be missing; if so, replace it in the hole by a piece of stiff copper wire which is no longer than is necessary to just locate into the fork on the movement. The wire can be a tight push fit into the adjuster screw because the strain on it is very little. After cleaning the glass and the case, this part can be laid aside ready for reassembly later.

Checking the Pointer

The next process is to check that the pointer is free to move across the scale without sticking at any part of its travel between zero and f.s.d. This test needs some care and is best carried out by gently blowing across the pointer whilst observing the movement. Another method of safely moving the pointer across the scale is to push it with the hair of a very flexible camel hair paint brush, one of the paint box type or artist's brushes being suitable.

If the pointer is sticking, the cause must be found. The first possibility is that the pointer may be fouling the scaleplate. Should this be so, the pointer can be eased off the scale by gently applying the tweezers under it so as to lift it just clear of the scale. If this procedure is overdone, however, the pointer may then foul the glass when the case is fitted. The pointer should be adjusted to just clear the scale with the movement held both horizontally and vertically. Testing in both planes can show up excessive play in the pivots, causing the coil assembly to move towards the scale when the movement is used lying on its back. This represents, of course, a fault in the movement but at the present stage of the game it may be better to accept it than to risk adjusting the pivots. The question of pivot adjustment is dealt with later in this article.

If the pointer is bent, it may be straightened by working it gently between the tweezers. Unless great care is used, this treatment may cause it to break,



Some of the tools which are required for repairs and adjustments. The instrument shown, a typical ex-W.D. milliameter, has already been removed from its case but even then all is not lost as it can be joined up to the broken stub by using shellac as an adhesive. This is a tricky but far from difficult if patience is used in the process. The pointer on a meter which has been badly overloaded in service may be so twisted that it cannot be straightened. A new one can be made from a bristle taken from a domestic broom. The bristle is stiffened with shellac and attached to the stub of the damaged pointer with the same material. It is often, in fact, easier to do this than to try straightening out a badly twisted pointer. Practical mechanics must be prepared to improvise at all times and this improvisation works quite well. Pointers are normally made of aluminium foil or tubing of a special light gauge and are almost impossible to obtain in small quantities such as are required by the amateur repairer.

The next item on the agenda is a careful examination of the phosphor-bronze balance springs. These springs carry the current to the moving coil as well as acting as the opposing force to the coil movement. They are set up to that the pointer reads zero with no current flowing through the coil. The watchmaker's eyeglass is necessary to examine the springs. The most usual trouble likely to be met is given by adjacent turns touching each other. A gentle touch with a fine sewing needle usually clears this fault but a distorted spring may require careful adjustment with the tweezers. The springs are very robust and not too difficult to straighten out but the operation needs care and a very steady hand. It is usually obvious what treatment is called for. It is often found that a spring has come adrift from its top anchor point, and if this is the case it must be re-soldered in position. This is done by holding the spring between the tweezers and pulling it toward the anchor point, whereupon a gentle touch with a very hot fine pointed soldering iron will make the necessary joint. For the reader who does not possess an instrument soldering iron, one can easily be made, for occasional requirements, by wrapping a piece of copper wire of about 12 s.w.g. round the bit of any soldering iron. Too much heat will de-temper the spring along part of its length, thus making it useless as a spring, so a hot iron and a momentary touch must be employed for the job.

The Pivots and the Bearings

A word would not be out of place at this point on the pivots and their bearings. It will be obvious that pivots and bearings cannot be replaced without completely stripping the movement, but provision is made for adjusting the pivots in their bearings. This requires care in setting the adjusting screw, as it is only too easy to over-do the adjustment and bend the pivot. Such adjustments should only be attempted when the play is so bad that the meter pointer fouls the scale plate when it is used in the horizontal position. The writer has found that a meter will work well with a fair amount of play in the pivots and it is usually the back pivot which requires adjustment. Since this involves further stripping of the movement, it is up to the reader to judge whether the job is worth doing. It happens occasionally that a pivot has broken partly loose from its mounting point on the coil. This partial looseness can be rectified by using shellac as an adhesive, gently pressing the pivot against the coil until the shellac has set.

Should it be necessary to gain access to the back spring or pivot, all that is usually needed is the straightforward job of removing the terminal plate at the back. The method of tackling the job differs from movement to movement but should offer no particular difficulties.

Balancing the movement

After repair to a movement it may be found that the pointer zero, if set with the meter positioned vertically, shifts when the meter is set horizontally. This indicates that the movement is out of balance. If the meter is to be used in one plane only, such as on a vertical panel, the out-of-balance condition is not of great importance. Nevertheless, some details will now be given on the subject of re-balancing a movement.

It will be noticed on examining the pointer that there are short stubs at the base of the pointer. These stubs consist of extension of the pointer beyond the pivot and two short bars at right angles centred on the pivot. Balancing is done by adding or subtracting or subtracting weight from these stubs or bars, until the pointer remains at zero with the movement held in any plane. For the benefit of the reader who wishes to try re-balancing a movement, suitable "weights" can be made from small blobs of solder. The easiest way to get these blobs is to melt some solder on the top of an iron and tap the iron on the bench, thereby causing many particles of solder the size of pin heads, and smaller, to be formed. These can be used as balance weights and are attached to the balance arms with shellac. It is obvious that the least possible amount of weight must be used, otherwise the movement will be made too heavy.

Reassembly

After having proceeded this far, the question of reassembly should prove a simpler matter. If the adjustments have been of a minor nature the original calibration will not have altered very much.

The writer hopes that the details covered here will enable users of ex-Service meters to make good use of them. It may be, also, that this article will encourage some readers to take an increased interest in instrument repairs, a fascinating subject for anyone with patience, good eyesight and, above all, a steady hand.

CHANGE OF ADDRESS

The International Short Wave League has advised us that the address of their Headquarters is now—60 White Street, Derby.

FIELD EFFECT TRANSISTORS

By J. B. DANCE, M.Sc.

The latest important semiconductor device to emerge from development at a price suitable for the pocket of the home experimenter is the field effect transistor. In this article our contributor discusses the exceptionally high input impedance of the F.E.T., together with its operation in typical amplifier circuits

THE FIELD EFFECT TRANSISTOR (or F.E.T.) is a semiconductor device which has properties much more like those of a thermionic valve than of a normal transistor. One of the most important advantages of field effect transistors is their high input impedance which, in one type, can be as great as a million megohms [1, 2] but is more commonly some hundreds or thousands of megohms. The device can provide a high power gain (approaching that of a thermionic valve) and have low noise figures.

Field effect transistors are, like thermionic valves, voltage operated devices, whilst ordinary transistors are current operated. For this reason the parameters of field effect transistors include mutual conductance (g_m) and amplification factor (μ), but not the current gains (α and β) of a normal transistor.

If field effect transistors have all these unique properties, why are they not more commonly used? One of the answers to this question is that they are fairly new devices, but as far as the amateur experimenter is concerned their main disadvantage has been (at least until recently) their comparatively high price. Many field effect transistors cost in the region of £20 to £40, so one is not likely to obtain a few for experimental work and then discard them. However, some types are now available which at the time of writing, are little more than £1 each.* If one wishes to utilise their high input impedance, one does not usually require more than one field effect transistor per amplifier (in the input stage) and this does bring the cost of the cheaper types within the range which an amateur can afford.

Basic Structure

In its simplest form the field effect transistor is a device with three electrodes which are known as the gate, the source and the drain, the region of the semiconductor material between the source and the drain being known as the "channel". The basic type of structure which can be employed is shown in Fig. 1. The device shown has an n type channel and a p type gate, but similar devices with interchanged polarities can also be obtained.

The gate is the input or control electrode, the drain is normally the output electrode, whilst the source is usually tne common electrode which is at earth potential as regards the signal frequency. The source and the drain are connected to ohmic electrodes so that the current flowing between them is proportional to the applied voltage.† The semiconductor material is almost always silicon.

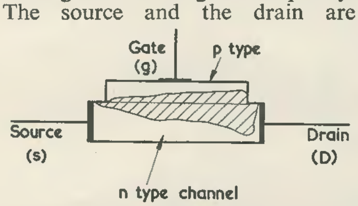


Fig. 1. A field effect transistor with an n type channel. The depletion region is shown shaded

Principles of Operation

The main operating current in a field effect transistor flows between the source and the drain. This current is carried by majority carriers (which are electrons in the case of an n type channel); this may be contrasted with the normal type of transistor in which the current passes through the base region by means of minority carriers.

The junction between the p and n type semiconductor materials is normally reverse biased and therefore the impedance of the gate circuit is very high. A typical value of the gate current is 10^{-9} amp, this being the leakage current of the reverse biased junction. At 100°C the input current is more likely to be in the region of 10^{-7} amp. The capacitance of the reverse biased diode is often of the order of 20pF, and limits the high frequency performance of field effect transistor circuits.

When the applied reverse bias is increased, the depth of the depletion layer between the two materials is increased so that the effective channel width decreases. This results in a greater channel resistance and a smaller channel current for a certain applied potential. Thus the field effect transistor behaves as a voltage controlled variable resistor. It the channel is connected in series with a suitable load resistor and source of direct current, amplification can be obtained.

The reverse bias which must be applied to the channel-to-gate diode to cause the depletion region to extend completely across the channel is known as the "pinch-off" voltage, V_p. This voltage will prevent current from flowing in the channel. Typical values of pinch-off voltage are 4 to 10 volts, but "Low Pinch-Off Unifets" are manufactured by Siliconix Inc. with values of V_p of about 1.7 volts. The Ferranti ZFT12 has a V_p of only 1.5 volts. Field effect transistors with pinch-off

* F.E.T.'s type C.86 may, for instance, be obtained at relatively low cost from Messrs. Semitron Ltd., Cricklade, Wiltshire. The C.86 is suitable for circuits where the normal close control on the characteristics is unnecessary.

† "Ohmic electrodes" may be defined in the following manner. The current which passes between ohmic electrodes is directly proportional to the applied voltage, i.e. Ohm's Law is obeyed.

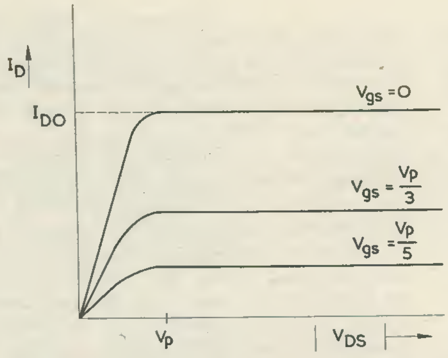


Fig. 2. Typical field effect transistor characteristics

voltages of up to 25 volts are available from Semitron Ltd.

The name "field effect transistor" is derived from the change in the channel resistance which results from a change in the transverse electric field in the junction region.

Characteristics

The characteristics of a typical field effect transistor are shown in Fig. 2. At much higher drain potentials the drain current rises rapidly and the transistor will be destroyed. If the gate and source potentials are kept equal, the curve $V_{GS}=O$ is obtained as an increasing voltage of the polarity shown in the accompanying Table is applied to the drain. The maximum value of the drain current, I_{DO}, is reached at a drain-source voltage approximately equal to the pinch-off voltage (ignoring the polarities). I_{DO} is typically a few milliamps.

There is an appreciable voltage drop along the channel when the maximum value of the drain current is reached and this results in the depletion layer being much wider at the drain end of the channel than at the source end.[3] The channel constriction thus formed limits the current to I_{DO} as the drain voltage is increased within the working range. The constriction cannot reduce the channel current, since it depends for its existence on the flow of I_{DO} at zero gate-to-source potential.

TABLE

	p type channel	n type channel
Drain electrode	—	+
Gate electrode	+	—

Table showing the polarities of the voltages which must be applied to the drain and gate electrodes in the case of p type and n type channel devices. The source electrode is considered to be at zero potential.

The characteristics of Fig. 2, showing the gate to source voltage as a parameter, resemble a family of pentode valve curves. The reverse biasing of the gate-to-channel junction diode results in saturation occurring at lower drain currents. The drain current is basically related to the gate to source voltage by an equation of the form:

$$\frac{I_D}{I_{DO}}=\left[1-\frac{V_{GS}}{V_P}\right]^2$$

This square law relationship leads to a parabolic type of mutual characteristic such as that shown in Fig. 3.

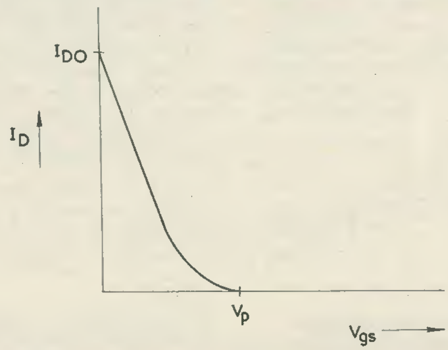


Fig. 3. Mutual characteristic of a field effect transistor

Parameters

Field effect transistor parameters are similar to those of thermionic valves.

(*a*) *Drain Incremental Resistance*, r_D

This is defined as a small change in the drain voltage divided by the resulting small change in the drain current at constant gate voltage. Typical values of this parameter are 300kΩ to 300MΩ.[4]

(*b*) *Mutual Conductance*, g_m

This is the reciprocal of a small change in the gate voltage divided by the resulting change in the drain current at constant drain voltage. Typical values of the mutual conductance are 0.05 to 3mA/volt.

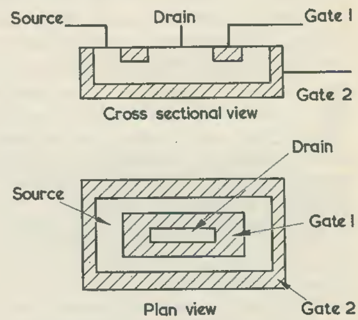


Fig. 4. The structure of a typical field effect transistor

(*c*) *Amplification Factor*, μ

If the gate voltage is increased by a small amount and it is found that the drain voltage must be changed to bring the drain current back to its former value, the ratio of drain voltage change to gate voltage change is μ.

For simplicity the parameters are defined in such a way as to make them positive. It may be shown that $\mu=g_m r_D$ (which can be compared with the $\mu=g_m r_a$ equation for valve parameters).

Structure of a Practical F.E.T.

The diagram of Fig. 1 is somewhat simplified. The structure of a typical field effect transistor is shown in Fig. 4.[5] The two gate electrodes are usually connected together, but the input capacitance can be reduced by earthing the outer gate and using the inner gate only as the input electrode. This will, however, result in reduced gain, since the mutual conductance will be lower.

Symbol

The normal symbol for a field effect transistor is shown in Fig. 5.

Some Applications:

(i) High Impedance Amplifiers

One possible circuit for a high impedance amplifier using a field effect transistor is shown in Fig. 6.[5] The resistor R_S provides the gate bias and may be compared with the cathode bias resistor of a valve amplifying stage; as in a valve stage it also serves the purpose of stabilising the operating point by providing negative feedback at zero frequency.

The amplification, A, given by this circuit is

$$A=\frac{g_m R_L}{1+\frac{R_L}{r_D}}$$

R_L/r_D is usually much less than unity, so $A \simeq g_m R_L$.

Another method of biasing a field effect transistor is shown in Fig. 7.[5] The diode is smaller and cheaper than a resistor in parallel with a capacitor.‡

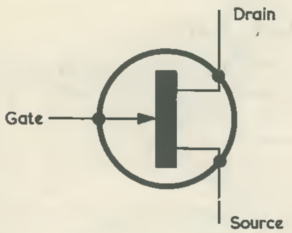


Fig. 5. Symbol for a field effect transistor

A high gain amplifier of high input impedance is shown in Fig. 8.[4] The input impedance is determined by R_2 which should not normally exceed 50MΩ. The load is a p.n.p. silicon transistor. The arrangement has the advantage that a lower value of power supply voltage can be employed than when a resistive load is used. The gain of the circuit, A, is given by the equation

$$A=\frac{g_m \alpha R_L}{1+\frac{R_L(1+\alpha)}{r_D}} \text{ if } r_b \ll r_a$$

where α and r_b are the normal parameters of the transistor which is used as the load.

If $R_L \ll r_c$, $A \simeq g_m \alpha R_L$ (r_c is the normal transistor T-network parameter).

Source Follower Circuits

One of the limitations of the field effect transistor is the comparatively high input capacitance, typically 20pF. The effective input capacitance may be reduced by the use of a source follower circuit which is analogous to the valve cathode follower and the transistor emitter follower circuits. The name of the source follower is derived from the fact that the source potential "follows" the gate potential; that is, any change in gate voltage results in a similar change of the source voltage.

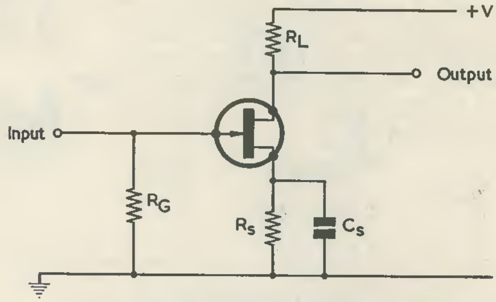


Fig. 6. A high impedance amplifier

A simple source follower circuit is shown in Fig. 9.[5] It should be noted that the output is taken from the source instead of the drain (compare this with the cathode follower and emitter follower circuits). The gain of the stage, A, is given by

$$A=\frac{g_m R_s}{1+g_m R_s}$$

where R_s is the source resistor which provides the negative feedback (10kΩ in the circuit of Fig. 9). As in the cathode follower and emitter follower, the voltage amplification is always slightly less than unity, typically about 0.9. The reason for this can be seen from the above equation.

The gate source capacitance, C_{GS}, is effectively reduced to C'_{GS} according to the following equation $C'_{GS}=C_{GS}\ (1—A)$. Thus as A approaches unity, C'_{GS} tends to zero. The effective input resistance of a source follower can be quite high. For example, if R_G is 10MΩ in the circuit of Fig. 9, the effective input resistance is 150MΩ and the input capacitance is 6pF. The use of a source follower circuit also has the advantage that the general stability of the circuit is greater than that of circuits where the output is taken from the drain, this being due to the 100% negative feedback which occurs in source follower circuits.

High Input Impedance 2-Stage Amplifier

In the circuit of Fig. 10, a ZFT12 field effect transistor with a load in the drain circuit is used as the first stage of an amplifier which is coupled to a conventional transistor amplifier.[5] Almost the whole of the output signal is fed back to the source electrode of the first stage in order to produce a high effective input impedance and low input capacitance. The feedback acts in a similar way to that in a source follower circuit, but is even more effective owing to a high circuit loop gain.

The gain of the whole amplifier is almost exactly unity, although the gain of the first stage is well below unity. The effective input capacitance is 4.5pF, whilst the effective input resistance varies from about 65MΩ to 500MΩ as the input resistor, R_G, is increased in value from 1MΩ to 10MΩ.

(ii) Chopper Circuits

If an amplifier is to be designed so

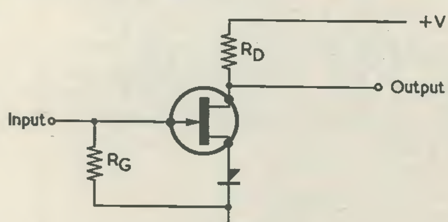


Fig. 7. Biasing with a diode

‡ It would seem that the diode in Fig. 7 is a silicon type which "turns on" at about half a volt.—EDITOR.

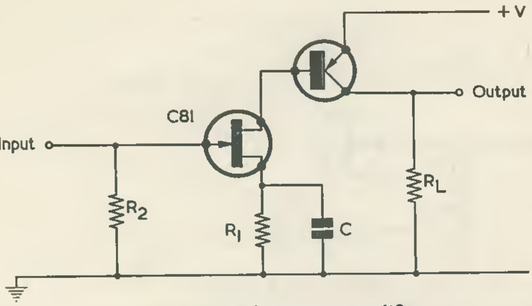


Fig. 8. A high gain amplifier

that it can operate at zero frequency, one meets the difficulty of the drifting of steady potentials. In order to avoid this trouble, the input to the amplifier is commonly "chopped", that is, the voltage to be measured is continuously switched to the input of the amplifier. The frequency to be amplified is then no longer zero and a normal capacitance coupled amplifier can be used; the effect of drifting is then small.

Contacts on a mechanical vibrator have been used in the past as chopper devices, but semiconductor circuits are now normally used, since they are very much more reliable and can operate at higher frequencies. Normal transistors are by no means ideal chopper devices, especially if the input voltage is small. A transistor is switched off (that is, passes little current) when the base is open-circuited and a bias current must be supplied to the base to bring it into its normal working condition. The offset voltage of a conducting transistor is by no means negligible and varies with the temperature and with the age of the transistor. This offset voltage limits the applications of transistors for the measurement of small input voltages.

Field effect transistors are generally much more suitable for use in chopper circuits. They are fully conducting when the gate electrode is open circuited and the offset voltage is zero.

(iii) Variable Resistors

Field effect transistors may be operated at a low drain voltage as voltage controlled variable resistors. The applied voltage should be less than about one third of the pinch-off voltage or the current passing through the channel will not be approximately proportional to the applied drain to source voltage. Such variable resistance devices are often used in circuits for the automatic balancing of Wheatstone bridge type networks.

Other Uses

Field effect transistors have a wide range of other applications and new uses will certainly be found for them, especially if they become cheaper. In analogue computers they can be used in multipliers and in non-linear function generators. They also have applications in ramp generators, filters, oscillators, etc. The square law mutual characteristic of the field effect transistor enables it to be used in applications such as r.m.s. voltmeters, modulation and demodulation circuits, etc. One type of field effect transistor has been used in i.f. amplifiers and mixers[1].

Photosensitive field effect transistors ("Photofets") are available from Messrs. Siliconix Inc.

Acknowledgements

The writer is indebted to Messrs. Ferranti Ltd., of Gem Mill, Chadderton, Oldham, Lancs., Messrs. Mullard Ltd., of Torrington Place, London, W.C.1, Messrs. Semitron Ltd., of Cricklade, Wiltshire, and Messrs. Walmore Electronics Ltd. (British agents of Siliconix Inc.) of

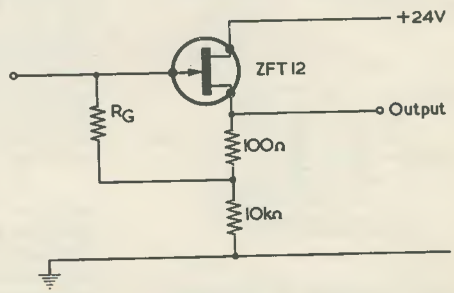


Fig. 9. A source follower

11–15 Betterton Street, Drury Lane, London, W.C.2, for the information they have kindly sent him about their field effect transistors.

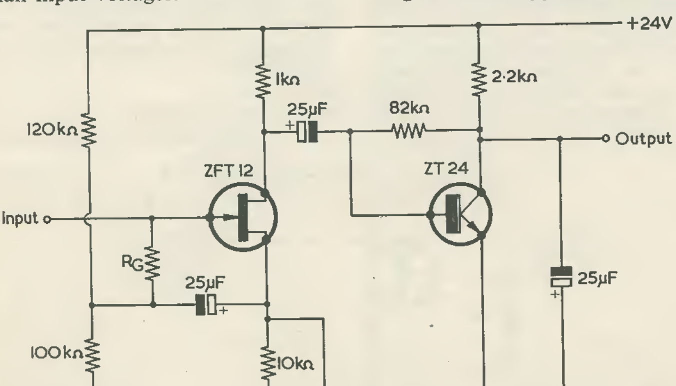


Fig. 10. A high input impedance amplifier

References

1. *Mullard 95BFY Development Type Metal-Oxide-Semiconductor Transistor*. Mullard publication TP602.

2. J. B. Dance. "New Semiconductor Device with a Million Megohm Input Impedance," *The Radio Constructor*, Vol. 18, No. 6, p. 421 (January 1965).

3. M. O. Deighton. "The Properties and Characteristics of Diffusion and Field Effect Transistors". Lecture given at the Post-Graduate Education Centre, Harwell.

4. Semitron publication on Field Effect Transistors.

5. "Field Effect Transistors and Applications." Ferranti Application Note No. 22 (May 1964).

Those readers who require further information on the subject are recommended to consult the book *Field Effect Transistor Applications* by W. Gosling (Heywood Press Ltd.).

Simple Automatic Switch for Record Players and Radiograms

By F. E. Addis

Check your gram deck to see if it has an auto-switch. If so, this can be used, when required, to switch off the amplifier as well

Many automatic and some single record-players have an arrangement for turning off the motor, but not the amplifier, when the record or records have been played. Various modifications employing micro-switches and relays have been devised in order that the amplifier may also be turned off automatically along with the motor.

In some of the more recent autochangers the motor is switched off after playing by a switch located under the turntable. (In some of the older models the mechanism merely disengages the turntable drive whilst leaving the motor running.)

Some single player decks (e.g. Collaro) employ a micro-switch activated by the pick-up arm, this being so arranged that when the arm swings towards the centre of the record the micro-switch breaks the supply to the motor.

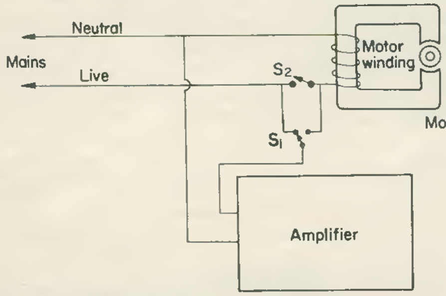


Fig. 1. Modifying the gram motor switch circuit. S_2 is the existing motor switch, S_1 and the appropriate wiring being added. S_1 may be mounted on the panel of the record-player or radiogram

For any record playing deck, single or automatic, which employs an actual switch, the following modification enables the amplifier to be turned off automatically with the motor, or to be left switched on whilst the motor cuts out in the usual way.

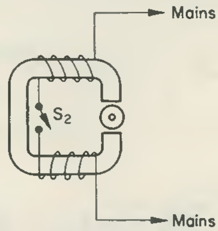


Fig. 2. With some gram decks, the motor switch appears between the motor windings

The Modification

The modification circuit is simple. (See Fig. 1.) When the additional control toggle switch, S_1, is in position A, the amplifier draws its supply direct from the mains and the motor will turn itself off as usual when the record or records have been played. When S_1 is in position B, the amplifier draws its supply via the motor control switch, S_2. Thus, when the record or records have been played, both the motor and the amplifier become switched off.

To turn the amplifier on again S_1 has merely to be turned back to position A. Alternatively, starting the turntable (in the case of autochangers) will cause both the motor and the amplifier to be switched on again, to be switched off once more when the record or records have been played.

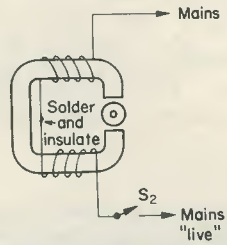


Fig. 3. Before the modification can be effected, the switch of Fig. 2 has to be taken out of circuit and the inside ends of the motor windings joined together as shown. The motor switch is then re-introduced into the live side of the mains supply to the motor

Locating the Switch

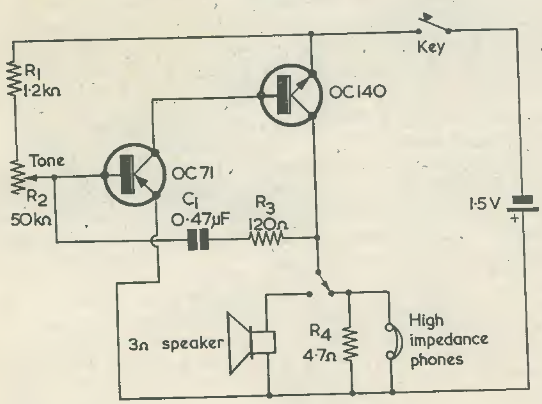
With auto-changer models, first locate the switch then remove the turntable as directed by the manufacturer in order that the two bolts holding the switch to the underside of the deck may be reached. After this the switch may then be removed and the appropriate connections made to it. It is advisable to make a sketch of the switch before removal in order that it may be replaced correctly.*

* The manner in which the additional connections are made to the motor switch will depend upon the individual design of the deck. The wiring to the switch should be carefully traced out before proceeding further. Take care to ensure that additional connections are adequately insulated from the chassis of the deck, and that changer mechanisms are not in any way misaligned.—Editor.

On single player models the switch can be located by either removing the pick-up arm or, in some models, by checking immediately beneath the support post and balancing mechanism for the arm. With some models, the motor switch is connected between the two windings of the motor as shown in Fig. 2. Before carrying out the modification the motor switch circuit has, in this instance, to be altered to that shown in Fig. 3.

Simple Morse Code Oscillator

By A. FOORD



Most of the oscillators suggested for Morse code practice use a transformer in a blocking oscillator circuit. This particular circuit uses a p.n.p. and an n.p.n. transistor in a relaxation oscillator, and avoids "difficult to obtain" components.

As may be seen, the circuit is extremely simple and the only power supply required is a 1.5 volt cell. The oscillator will drive a loudspeaker directly, or headphones shunted by a low value resistor. No on-off switch is required, as the Morse key disconnects the supply when it is raised.

MORSE CODE

A	.-
B	-...
C	-.-.
D	-..
E	.
F	..-.
G	--.
H	....
I	..
J	.---
K	-.-
L	.-..
M	--
N	-.
O	---
P	.--.
Q	--.-
R	.-.
S	...
T	-
U	..-
V	...-
W	.--
X	-..-
Y	-.--
Z	--..
1	.----
2	..---
3	...--
4	....-
5	.....
6	-....
7	--...
8	---..
9	----.
0	-----
Apostrophe	.----.
Brackets	-.--.-
Break sign	-...-
Comma	--..--
End of message	.-.-.
End of work	...-.-
Error	....
Fractional bar	-..-.
Full stop	.-.-.-
Hyphen	-....-
Inverted commas	.-..-.
Invitation to transmit	-.-
Note of interrogation	..--..
Preliminary call	-.-.-
Separation (used between whole number and fraction)	.-..-
Underline	..--.-
Understood	...-.
Wait	.-...

SPACING

A dot equals 1 unit — A dash equals 3 units

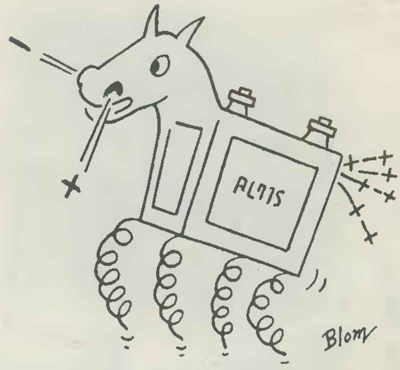
Space between symbols forming a letter equals 1 unit

Space between two letters equals 3 units

Space between two words equals 5 units

BATTERY CHARGER FOR THE RADIO CONTROL ENTHUSIAST

By Arthur C. Gee, M.R.C.S., L.R.C.P., D.P.H.



The batteries and accumulators used for model radio control purposes can be divided roughly into two groups: those employed for powering electric motors and transmitters, etc., and the much smaller rechargeable types used in radio control receivers and for operating servos, relays and similar devices on the model itself.

Apart from their obvious difference in size, these two groups differ very widely in their charging rates. The first group needs up to an amp or so whereas, in the second group, the charging current is a matter of a fraction of an amp, or milliamps, only.

Two Charging Rates

The charger described here has facilities for charging at both these rates and offers metering and control arrangements for both the amp rate and the milliamp rate. In order to keep the instrument as simple as possible two separate meters are used, as shown in Fig. 1, one having a full-scale deflection of 1.5 amps, and the other a full-scale deflection of 150mA. Two separate variable resistors are also employed. One of these controls the high charge rate and the other the low, and the two levels of charge rate are brought out to separate positive terminals, the negative output terminal being common to both. In this way, switching arrangements are kept to a minimum, and mistakes in applying the wrong charging rate are less likely to happen.

The circuit also allows charging to take place simultaneously at both the high and low rates, provided that the total current does not exceed the 1.25 amp secondary rating of the mains transformer.

Components List

Resistors
- R_1 20Ω ½ watt 20%
- R_2 200Ω variable, 5 watts
- R_3–R_7 See text

Transformer
- T_1 Charger transformer. Secondary, 0–9–15V, 1.25A. (R.S.C. (Manchester) Ltd., 54 Wellington Street, Leeds 1)

Rectifier
- MR_1 Battery charger bridge rectifier, 12V, 2A. Cat. No. MR21. (Home Radio (Mitcham) Ltd.)

Meters
- M_1 0–150mA
- M_2 0–1.5A

Switch
- S_1 Multi-contact wafer switch (see text).

Miscellaneous
- Case, terminals, knobs, wire, etc.

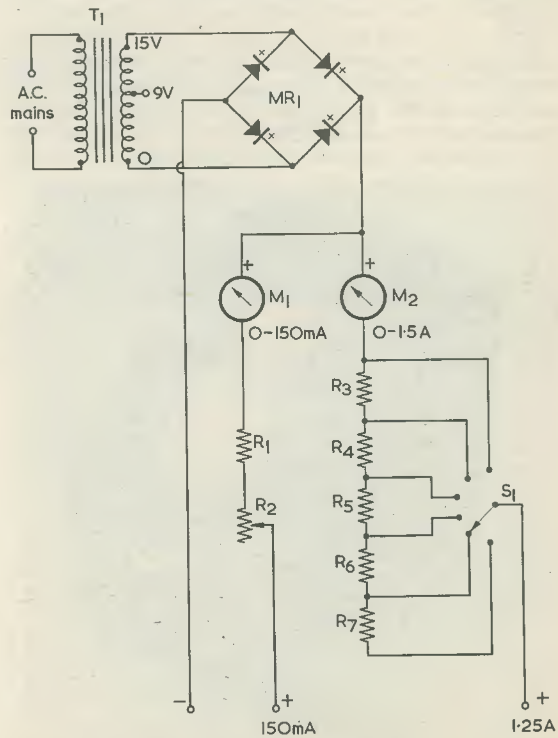
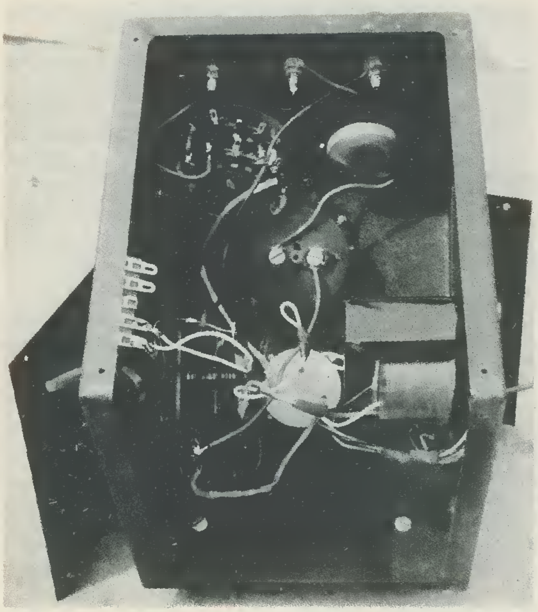
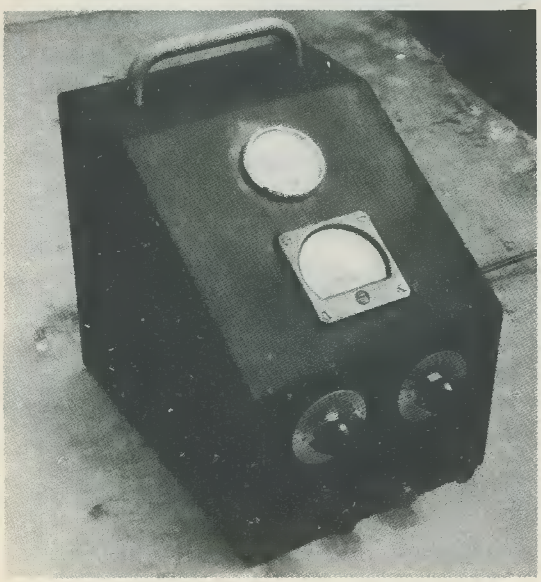


Fig. 1. The circuit of the battery charger



Internal layout of components in the author's unit

The d.c. charging current is provided by the metal bridge rectifier, MR_1. As shown in the circuit diagram, the rectified current is then fed through the meters and the variable resistors to the output terminals. The variable resistor in the low current circuit, R_2, takes the form of a 5 watt wirewound 200Ω potentiometer, the 20Ω $\frac{1}{2}$ watt resistor, R_1, acting as a current limiter. The variable resistor in the high current circuit is shown as R_3 to R_7, the resistance required being switched into circuit by S_1. In practice, R_3 to R_7 are made up from a single length of resistance wire. The total resistance of this wire should be about 10Ω, and it should be of sufficient thickness to carry 1.25 amps without heating. The writer found some suitable wire on an old filament rheostat from the junk box. The number of contacts on the switch is not important, provided there are sufficient to give a reasonable number of steps in controlling the current. In the writer's case, six were available. The 10Ω length of wire was cut into five equal lengths, each piece being then coiled up and soldered from contact to contact as indicated in Fig. 2.



The external appearance of the complete charger

As was mentioned earlier, two meters are required; these being a 150mA meter for the low current range and a 1.5 amp meter for the high current range. The 150mA meter can be obtained easily as

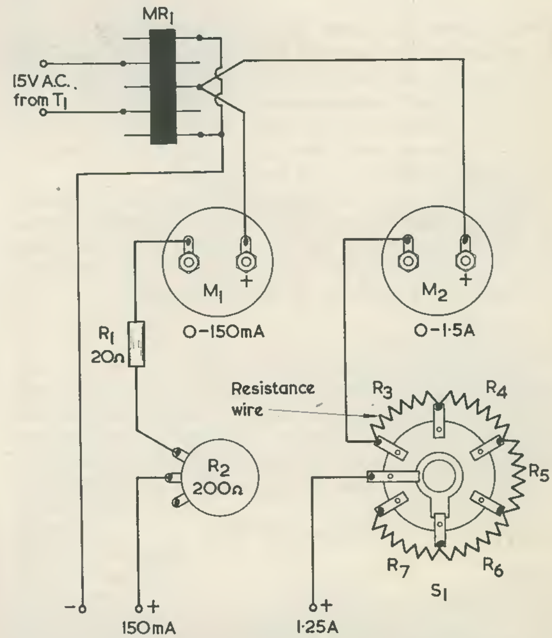


Fig. 2. How the components are connected together. Back views are given for the two meters, R_2 and S_1. The 9 volt secondary tapping of transformer T_1 is not used

a surplus item, and the 1.5 amp meter is available from many suppliers of motor cycle accessories as well as from radio component suppliers specialising in meters.

The charger transformer employed has the usual primary for 200 to 250 volts a.c. mains, together with a secondary offering 9 and 15 volts at 1.25 amps. The 9 volt secondary tapping is not used in this circuit.

The metal rectifier is of the bridge type. That used by the writer was obtained from Home Radio (Mitcham) Ltd., under Cat. No. MR21., and suited the purpose nicely. This rectifier is intended specifically for battery charger applications and is rated at 12 volts 2 amps. It runs quite cold when used in the present design.

Construction and Use

Construction is perfectly straightforward, and the wiring is illustrated in Fig. 2. The layout used by the writer is shown in the accompanying photograph, an existing metal cabinet with a sloping metal front making an ideal case for the unit.

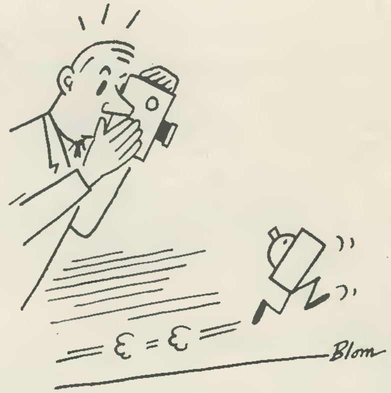
It may be worth emphasising that connections to the bridge rectifier are made in the following manner. The rectifier has five plates, the two outer ones being connected together and the common connection taken to the negative output terminal. The middle plate is the positive one, and two leads from this go to the positive terminals of the meters. The two leads from the 15 volt secondary of the transformer then connect to the remaining two plates of the rectifier.

One important point which should be borne in mind when the unit is in use is that maximum resistance must always be inserted, by R_2 or S_1 as applicable, when a battery is connected to the charger. Only after all connections have been made and the mains supply applied should resistance be reduced until the desired charging current is obtained.

Photo-Sensitive Switch

By P. J. LeRICHE

One method of obtaining a swift-acting light controlled switching circuit which operates at a specific illumination level could consist of coupling a phototransistor to a Schmitt trigger. But our contributor takes this idea one stage further by having the phototransistor enter the Schmitt trigger circuit itself!



MOST LIGHT OPERATED RELAY CIRCUITS SUFFER from the disadvantage that slow changes in light intensity result in slow changes in relay energising current, and do not give a "snap" action when the illumination falls below a certain level. The circuit described in this article overcomes this disadvantage by the use of a Schmitt trigger, giving very rapid relay operation at a pre-determined light intensity however slow the change in light intensity may be. As such, the circuit can be of considerable use for automatic switching of car parking lamps and similar applications.

The Schmitt Trigger

The circuit of a typical Schmitt trigger is given in Fig. 1.

In this circuit, operation occurs in the following manner. When there is no input, TR_1 is cut-off as it has no bias, and in consequence its collector is at a high negative potential. This allows TR_2 to conduct heavily, giving a substantial voltage drop across R_e, which also assists in keeping TR_1 cut-off. If a gradually increasing negative voltage is applied to the input terminal nothing happens at first, because the emitter of TR_1 is still more negative than its base, and so it remains cut-off. As the input voltage passes the voltage at the upper end of R_e, TR_1 commences to conduct as its base now becomes negative of its emitter. The falling voltage on TR_1 collector which then results is passed to the base of TR_2, reducing the current passing through this transistor and the voltage drop across R_e. The fall in voltage across R_e allows TR_1 to conduct more heavily, thus reducing still more the current in TR_2.

The net effect is that the circuit switches over very rapidly, leaving TR_1 conducting and TR_2 cut-off. If the negative input voltage is now gradually reduced, the state of affairs remains unchanged until the collector voltage of TR_1 rises sufficiently to allow TR_2 to conduct. The circuit now rapidly

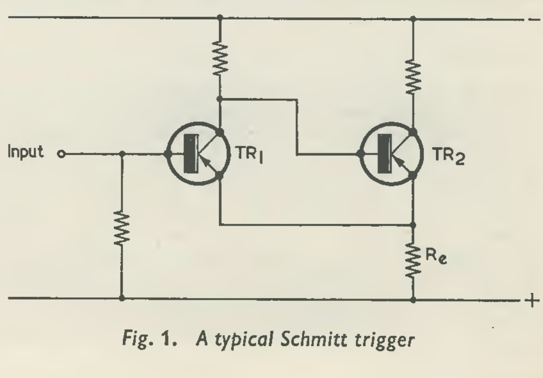


Fig. 1. A typical Schmitt trigger

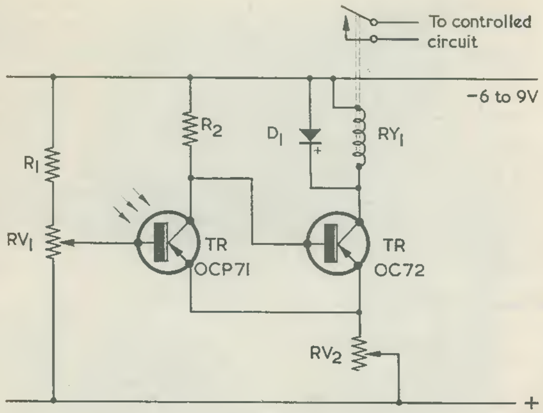


Fig. 2. The circuit of the photo-sensitive switch

switches back to the original state by the reverse process to that just described, leaving TR_1 cut-off and TR_2 conducting. It will be found that, by suitably reducing the coupling between the transistors, the switch-on and switch-off voltages can be made to very nearly coincide, thus reducing backlash (the difference between these two voltages) almost to zero.

The Photo-Sensitive Switch

The circuit of the photo-sensitive switch is shown in Fig. 2, and it will readily be seen that it consists basically of a Schmitt trigger. The switching action is now promoted by changes in the current passed by phototransistor TR_1, the latter being dependent on the illumination falling upon it. The light intensity at which the circuit switches is determined by the setting of potentiometer RV_1, the relay energising when light intensity falls below the predetermined level.

Coupling between the transistors can be altered by either a potentiometer between the collector of TR_1 and the base of TR_2 or, as in Fig. 2, by the variable emitter resistor RV_2. The variable emitter resistor was adopted here as the other method reduces the current swing in TR_2, thus necessitating a more sensitive relay.

The relay used in the prototype was a Post Office type with a coil resistance of 2kΩ, this closing at about 2mA when carefully adjusted. It had a single pair of make contacts and snapped on very reliably. The diode D_1 across the coil can be almost any type, and it serves to short-circuit the back e.m.f. that appears across the coil as TR_1 switches off.*

A disadvantage with phototransistor circuits is that they are sensitive to heat as well as to light. This fact can be utilised if TR_1 is replaced by an OC71, whereupon the circuit could become a heat-sensitive switch with TR_1 mounted at the point where the varying temperatures occur. If, on the other hand, sensitivity to temperature changes is not wanted, as in the light operated application, this sensitivity may be minimised by placing TR_1 and TR_2 in close proximity. Similar changes in leakage current will then occur as ambient temperature varies.

* An earlier experimental version of the circuit used a relay with a 200Ω coil, an energising current of 10–15mA flowing when the OCP71 was non-illuminated. In this circuit R_2 was 2.2kΩ and a 6.8kΩ resistor was inserted between the OCP71 collector and the base of TR_2. A 6-volt supply was used. It should be pointed out that the present circuit, with its more sensitive relay, offers better results.

Components List

Resistors

R_1	56kΩ 10% ¼ watt	
R_2	10kΩ 10% ¼ watt	
RV_1	10kΩ potentiometer	
RV_2	30Ω potentiometer	

Transistors

TR_1	OCP71
TR_2	OC72

Diode

D_1	OA71 or similar (see text)

Relay

RY_1	P.O. relay with 2,000Ω coil, 2mA energising

Setting Up

To obtain best results from this circuit a little care is needed over the adjustment of RV_1 and RV_2. Connect a milliammeter with an f.s.d. of around 5mA in series with the relay coil, or a voltmeter of 5 or 10 volts f.s.d. across it, and set RV_2 to about the middle of its track. Now slowly turn RV_1 back and forth over a range that produces wide variations of meter reading. If RV_2 is set at too high a value, sharp switching will be observed but there will be a significant gap between the switch-on and switch-off positions. If RV_2 is set at too low a value, no switching at all will occur, and it will be found possible, by careful adjustment of RV_1, to get the meter needle to stop anywhere between two extreme positions. The optimum setting of RV_2 is that where there is minimum backlash but reliable switching still occurs. RV_1 may now be set to make the unit switch on at any desired level of illumination. The adjustment of RV_1 and RV_2 is rather critical, so reliable noise-free components should be used, and these should not be fitted with large dials which are easily jogged. Slow motion drives would be an asset, particularly for RV_1.

If the particular application for which the switch is to be used can accommodate a significant amount of backlash, then the setting of RV_2 is by no means so critical. Similarly, RV_1 will not require such careful adjustment if the illumination at which switching takes place is non-critical.

Should the unit be used for car parking lights, TR_1 has to be positioned with a little care to ensure that it is not affected by lamp posts and the headlights of other cars.

Consumption is quite low, being 1mA when illuminated and 3mA when non-illuminated with a 6-volt power supply.

The Large and the Small

By J. B. DANCE, M.Sc.

Any radio engineer worth his salt knows that the prefix kilo means one thousand times and that micro means one millionth, but how many people know what a femtoamp is?

The International Committee for Measures and Weights has now added two new prefixes to its list of decimal multipliers, namely femto to signify 10^{-15} and Atto for 10^{-18}. The full list of these multipliers now recommended by the Committee is given below:

T	Tera ..	1,000,000,000,000	10^{12}
G	Giga ..	1,000,000,000	10^{9}
M	Mega ..	1,000,000	10^{6}
k	Kilo ..	1,000	10^{3}
h	Hekto ..	100	10^{2}
D	Deka ..	10	10^{1}
d	Deci ..	0.1	10^{-1}
c	Centi ..	0.01	10^{-2}
m	Milli ..	0.001	10^{-3}
μ	Micro ..	0.000,001	10^{-6}
n	Nano ..	0.000,000,001	10^{-9}
p	Pico ..	0.000,000,000,001	10^{-12}
f	Femto ..	0.000,000,000,000,001	10^{-15}
a	Atto ..	0.000,000,000,000,000,001	10^{-18}

It might be thought that these prefixes would be adequate to describe all quantities used in electronics. However, if one wishes to state the mass of an electron (9.1083×10^{-27} grams), one can refer to it as 9.1083 millimicroattograms, a combination of the prefixes being necessary.

It should be noted that the American billion is one thousand million (10^{9}), whereas the British billion is one million million (10^{12}). Similarly the American trillion is 10^{12} and the British trillion 10^{18}.

NEXT MONTH IN THE Radio Constructor

Plug-in Speech Clipper

This article describes a simple speech clipper for the amateur transmitter, and is primarily intended for use with a modulator employing two 6L6's, although it could be used equally well with different valves and in alternative positions. (6H6,6J5).

Dual-Purpose Power Supply

Ideal for experimental work with both valve and transistor circuits, this power pack offers 250 volts h.t. at 100mA, together with a low voltage which is variable in small steps from 3 to 30 volts. (BY100—2 off, BY114—4 off).

Integrated Circuits

Integrated circuits are proving to be of considerable importance in computers and logic engineering. A basic integrated circuit can be formed on a tiny single chip of semiconductor material, and this article provides a fascinating insight into the processes which are involved.

Dual-Conversion Superhet for 2 Metres

This is a compact self-contained receiver design featuring a comprehensive circuit and a very high level of performance. Complete constructional details are given, including coil winding data. (E88CC, ECC85, EF 91,ECC81, ECH81, EF183, EBC91, EL95, QS150/15, OA79, BY100—2 off).

Cover Feature

By H. S. KING

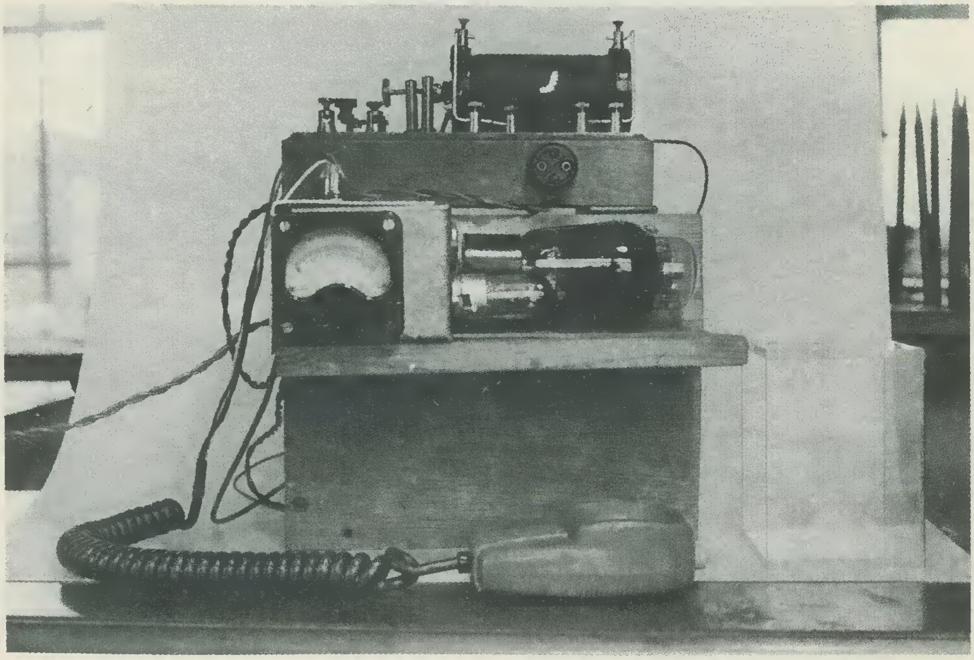
COMMUNICATION BY MODULATED ARC BEAM

We have previously published articles on modulated light systems, these all employing transmitting lamps whose filament current was modulated by the audio signal to be transmitted. A disadvantage with all these systems has been given by the thermal inertia of the filament, which limits the maximum frequency the system can handle. Our contributor has overcome this problem by using an arc lamp as light source, whereupon a maximum frequency of 10 kc/s is capable of being transmitted. Also, the arc lamp provides an intense light source of very small area, enabling transmissions to be received over long distances. Tests with the prototype resulted in clear reception of the modulated beam at a distance of nearly a quarter of a mile in daylight

HAVING EXPERIMENTED WITH VARIOUS PUBLISHED and unpublished methods of modulating a light beam it was concluded that the incandescent filament is not the best light source to modulate.

Both mains and battery bulbs suffer from the obvious disadvantages of narrow bandwidth due to thermal inertia, and low beam concentration due to the large size of the source.

A pea bulb may be connected directly to the speaker transformer secondary of a 10 watt amplifier or a mains bulb into the anode circuit of a power amplifier and speech which is just about intelligible may be received on a photocell a few feet away using a simple lens system. Greater distances may be obtained using a more complex lens system but the better the transmitting lens the smaller the area of the filament which is actually employed.



The Sylvania arc lamp fitted to an ex-W.D. torpedo directing telescope. The telescope is used merely to provide a convenient mounting, together with sighting facilities. The arc lamp is to the right on the bracket, with the single lens which concentrates its beam at the left. Connection to the lamp is via the twin flex leading from its base

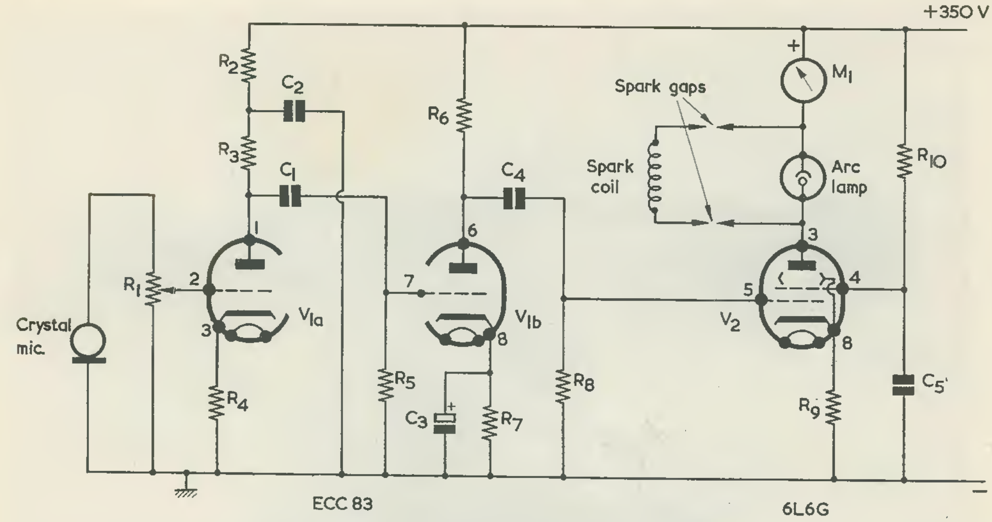


Fig. 1. The circuit of the light beam transmitter

Components List (Fig. 1)

Resistors
(All fixed values ¼ watt 10% unless otherwise stated)

- R_1 1MΩ potentiometer, log track
- R_2 47kΩ
- R_3 220kΩ
- R_4 1kΩ
- R_5 100kΩ
- R_6 100kΩ
- R_7 1kΩ
- R_8 100kΩ
- R_9 390Ω 2 watts*
- R_{10} 4.7kΩ 5 watts*

Capacitors

- C_1 0.01μF paper 350V wkg.
- C_2 0.25μF paper 350V wkg.
- C_3 25μF electrolytic 6V wkg
- C_4 0.1μF paper 350V wkg.
- C_5 0.1μF paper 350V wkg.

Valves

- V_1 ECC83
- V_2 6L6G

Arc Lamp
Enclosed Concentrated-Arc Lamp Type A2 (Sylvania)

Meter
Moving-coil, 100mA f.s.d.

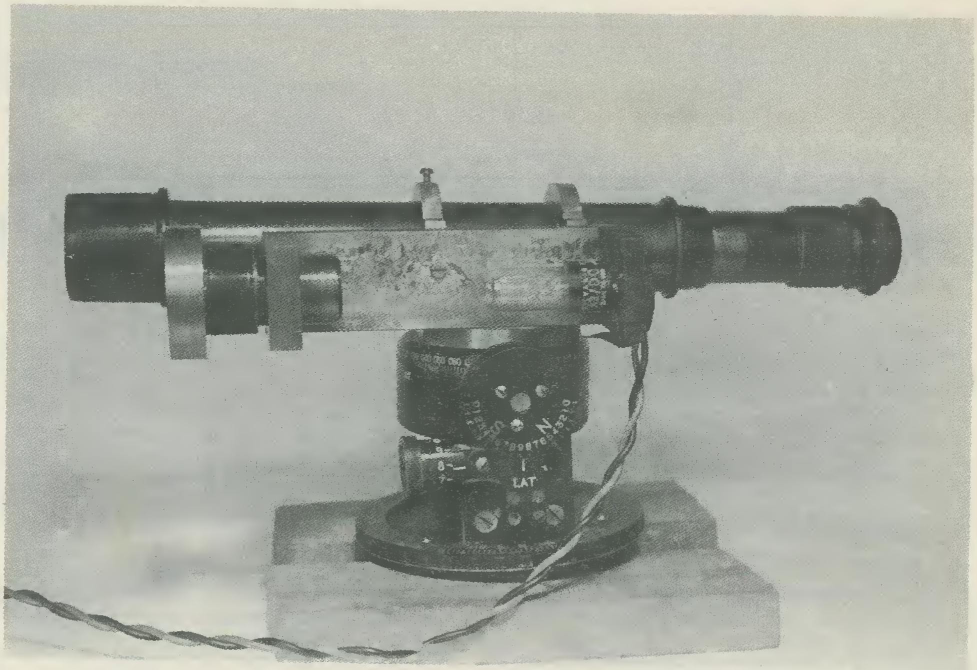
Miscellaneous
Crystal microphone
Spark coil, with spark gaps (see text)
Power supply offering 350V h.t. at 60mA and 6.3V at 1.2A
Lens and mounting for arc lamp

* May require adjustment to provide correct arc current.

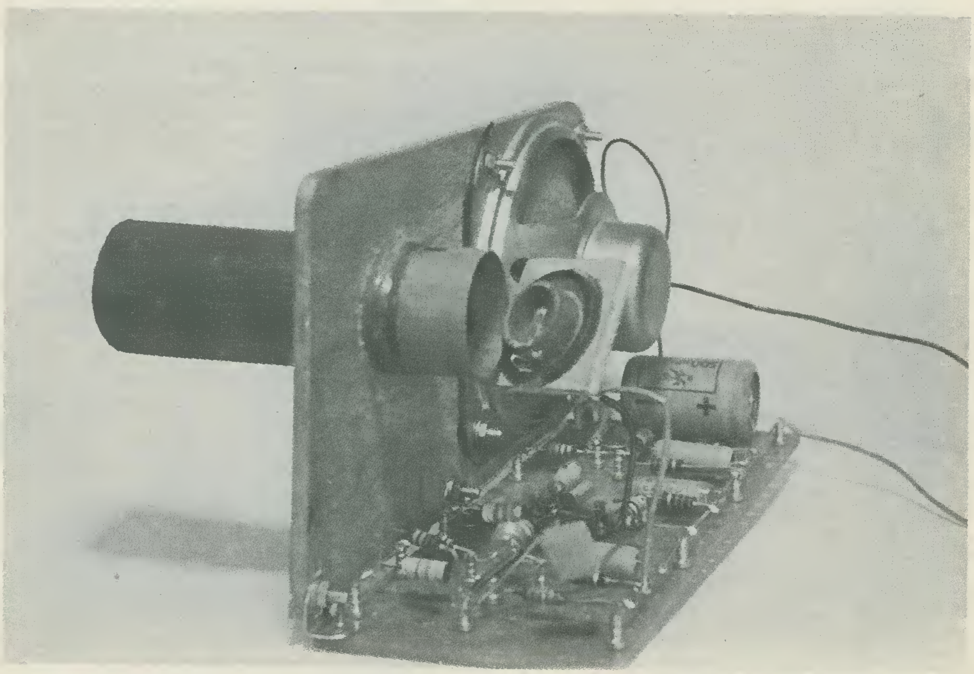
If the light source can be concentrated into the smallest possible area a greater proportion of the light produced can then be put into the beam. This principle has been the main aim in the design of film projectors. One of the most concentrated light sources is the arc lamp but it was decided not to attempt the modulation of the open arc. However when attention was drawn to an enclosed arc which could be maintained in the anode circuit of a modest power valve it was decided that this method had attractions for the amateur.

Arc Lamp Transmitter

The Sylvania Concentrated-Arc Lamp type A2 was therefore made the subject for experiment in the light beam transmitter. A disadvantage is the price, which is rather high for the amateur, but this is possibly due to the small demand. The range of Sylvania lamps includes many at considerably higher prices but the A2 seems the most suitable for amateur experiments. The A2 lamp is quite small physically, as may be seen from the appropriate illustration, and it requires a maintaining voltage of 38 volts when 55mA is passed. This may be obtained in the anode circuit of a 6L6 but arrangements must be made to strike the arc as described later. The lamp electrodes consist of a small disc, the anode, with a central hole through which projects a fine wire which is the cathode. The arc strikes between the wire and the anode and has a tendency to wander round the hole in the disc, thus disturbing the beam direction slightly. However, the light source is extremely small and, by using a simple 1-inch convex lens with a focal length of 2 inches, the light can be seen shining very brightly even in daylight at a distance of a quarter of a mile. In the photograph the lamp is shown mounted upon an old astro compass adapted to take an ex-naval torpedo directing telescope. This telescope, although short of a lens and thus giving a magnification of



The transmitter amplifier. The 6L6G valve is mounted horizontally behind the ECC83. Above the 6L6G is a 2-way socket to which the arc lamp connects. The spark coil for striking the arc is at the top. The spark coil output connects to the two outside terminals of the four terminals immediately in front of it. Spark gaps are then formed, as shown in Fig. 4



The receiver. The black tube projecting to the left shields the OCP71 from ambient light and also provides a mounting for the receiver lens. The OCP71 is fitted in the inside end of the tube, this being shown removed

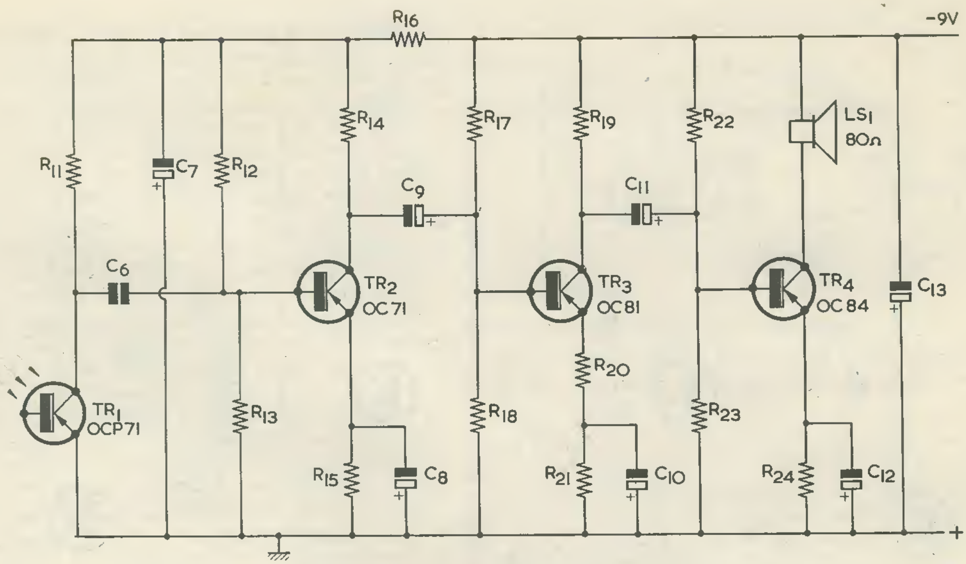


Fig. 2. A simple receiver, as used for initial tests

Components List (Fig. 2)

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

R_{11}	12kΩ
R_{12}	47kΩ
R_{13}	22kΩ
R_{14}	3.9kΩ
R_{15}	2.2kΩ
R_{16}	1kΩ
R_{17}	47kΩ
R_{18}	22kΩ
R_{19}	3.9kΩ
R_{20}	150Ω
R_{21}	2.2kΩ
R_{22}	15kΩ
R_{23}	2.7kΩ
R_{24}	1kΩ

Capacitors

C_6	0.1μF paper
C_7	25μF electrolytic 12V wkg.
C_8	32μF electrolytic 6V wkg.
C_9	25μF electrolytic 6V wkg.
C_{10}	25μF electrolytic 6V wkg.
C_{11}	25μF electrolytic 6V wkg.
C_{12}	32μF electrolytic 6V wkg.
C_{13}	500μF electrolytic 12V wkg.

Transistors

TR_1	OCP71
TR_2	OC71
TR_3	OC81
TR_4	OC84

Loudspeaker
LS_1 Moving-coil 80Ω impedance

Miscellaneous
9-volt battery
Lens and mounting for OCP71

unity, does possess cross-wires which make alignment of the beam on to the receiver fairly easy. At a distance of one eighth of a mile the beam spreads to about three feet diameter.

The transmitter is quite straightforward and capable of many variations. The circuit, shown in Fig. 1, was built up from first principles as an exercise for school pupils and has no refinements. The h.t. voltage, screen and cathode resistors of the 6L6 should be adjusted to give an anode current of 50 to 55mA. The valve can be triode-connected if desired. A crystal microphone has been used successfully. Alternatively, of course, a signal from a radio or other source can be applied, and this makes adjustment easier at the receiver end.

Striking the Arc

At least 1,000 volts are required to strike the arc and several methods may be employed to achieve this. A pulse transformer and rapid switch-off choke circuits were under consideration when the arc was in the early stages of experiment. But to get things going the induction spark coil shown above the 6L6 in the photograph of the transmitter amplifier was used. To make the circuit safe and enclosed the spark coil is used with a Perspex cover (not shown).

The spark coil secondary is taken to spark gaps between the two pairs of terminals. (See Fig. 4.) The other terminals of the spark gaps connect directly across the arc lamp via the 2-pin socket shown centrally below the spark coil. Hence no d.c. from the power supply flows through the coil.

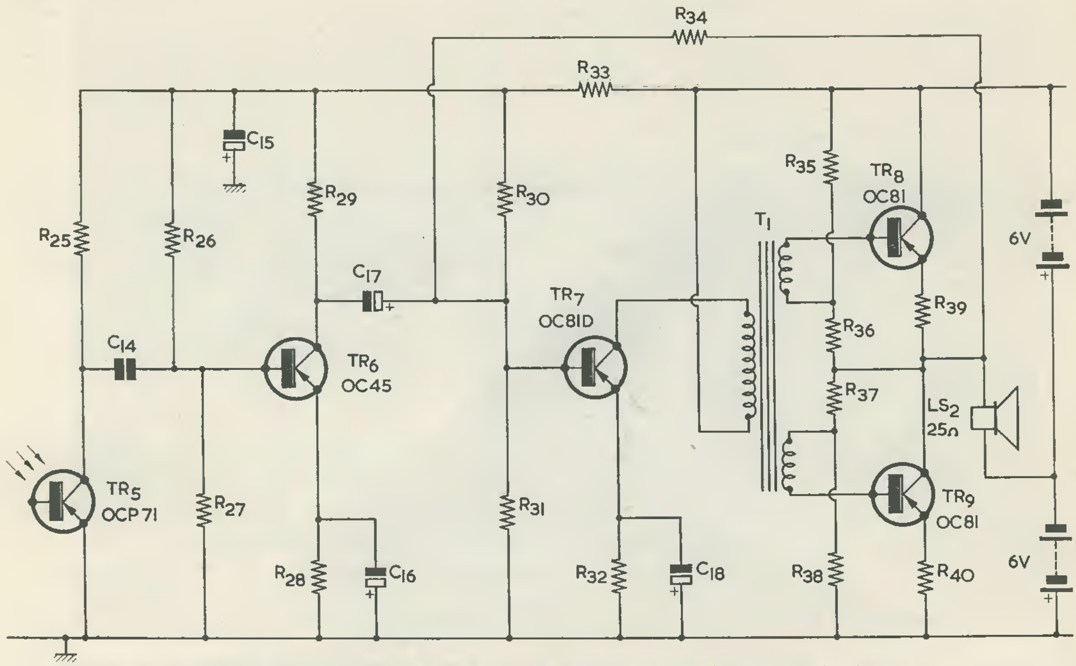


Fig. 3. The standard receiver. This offers a better quality of reproduction

Components List (Fig. 3)

Resistors
(All ¼ watt 10% unless otherwise stated)

R_{25} 12kΩ
R_{26} 91kΩ
R_{27} 47kΩ
R_{28} 4.7kΩ
R_{29} 5.6kΩ
R_{30} 27kΩ
R_{31} 10kΩ
R_{32} 1.8kΩ
R_{33} 4.7kΩ
R_{34} 750kΩ
R_{35} 3.3kΩ 5%
R_{36} 91Ω 5%
R_{37} 3.3kΩ 5%
R_{38} 91Ω 5%
R_{39} 2.7Ω 5%
R_{40} 2.7Ω 5%

Capacitors

C_{14} 0.1μF paper
C_{15} 100μF electrolytic 12V wkg.
C_{16} 100μF electrolytic 6V wkg.
C_{17} 10μF electrolytic 6V wkg.
C_{18} 25μF electrolytic 6V wkg.

Transistors

TR_5 OCP71
TR_6 OC45 (or similar)
TR_7 OC81D
$TR_{8,9}$ OC81 (matched pair)

Transformer

T_1 Driver transformer type T/T5 (Radiospares)

Loudspeaker

LS_2 Moving-coil 25Ω impedance

Miscellaneous

2 6-volt batteries
Lens and mounting for OCP71

The correct polarity for the spark is found by trial and error and the requisite pulse is provided by quickly flashing a low tension supply to the coil primary. In fact if the 6.3 volt heater supply is used momentarily in the primary the polarity of the spark is bound to be correct long enough to strike the arc. Once struck the arc should be maintained at not more than 55mA. Less than this can be used by adjusting the 6L6 current but the arc will lose intensity thereby. The meter is useful as a warning in case the arc has not struck or goes out because unless steps are taken very soon the screen resistor of the 6L6 will become hot and the valve may be damaged.

The Receiver

Several photocell types have been tried in the receiver but the only one more sensitive than the three OCP71's which were tested was an early OC71 with paint removed.

The original receiver circuit, shown in Fig. 2, was again designed for simple instruction and is not recommended for other purposes. Using an 18-way tagboard with two rows of tags, the components were soldered into the same positions as shown in the diagram. Although the circuit of Fig. 2 works well enough and is useful for demonstrations, it has the undesirable feature of allowing d.c. to flow through the speaker. Also, better negative feedback could be arranged. In view of these points the standard receiver, which is based on the Mullard OC81 design (see Fig. 3) has been used, and quite good quality signals have been received. Over short ranges of the order of hundreds of feet the frequency response has proved satisfactory up to 7 kc/s and there is still some signal at 10 kc/s. No doubt improvements could be made with attention to circuit details but in this case the main aim was distance.

The author did not find a gain control necessary in either receiver as the transmitter gain control gave sufficient control over modulation for his requirements. At close range, however, the receiver lens is removed so that the transmitter beam falls directly on to the OCP71. A gain control could be incorporated in the receiver if particularly desired.

Using a single lens system at the receiver similar to that at the transmitter, signals were received quite clearly at nearly a quarter of a mile in daylight. As the receiving OCP71 is well shielded in its tube from ambient light, the system is not likely to work a lot better at night. The OCP71 is fitted in the end cap of the tube. On top of the tube is a small hole so that the light beam can be adjusted to fall on the sensitive part of the cell at close ranges. At longer distances the beam has spread sufficiently for this to be unnecessary.

Some difficulty was experienced in aligning the beam to start with and early experiments were conducted after dark. But the difficulty of locating the receiver from the transmitter eventually led to daylight experiments being held, when the setting up was found to be much easier as the beam is quite visible in daylight. It is best to focus up in a long room on to a white card to get familiar with the sighting device and then transfer out of doors.

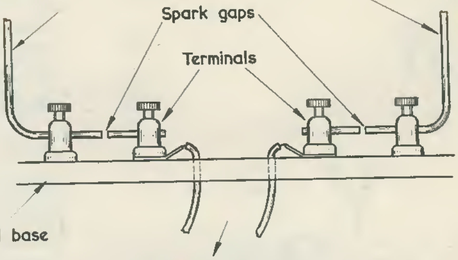


Fig. 4. Detail showing how a spark gap is inserted in each connection from the spark coil to the arc lamp

All the receiving equipment, part of the transmitting end and all the operating has been carried out by school pupils and the apparatus formed part of the exhibition held in Cambridge in September 1965, in connection with the British Association for the Advancement of Science annual meeting.

Editor's Note

The Sylvania Enclosed Concentrated-Arc Lamp, type A2. is a 2-watt lamp having a cylindrical round-topped glass envelope with a diameter of $\frac{9}{16}$ in. Overall length, including pins, is $2\frac{1}{16}$ in. The average life is specified as 150 hours.

The lamp is available from the Sylvania Division of Thorn-A.E.I. Radio Valves and Tubes Ltd., 155 Charing Cross Rd., London, W.C.2.

Previous articles on modulated light systems appearing in *The Radio Constructor* were: "Modulated-Light Broadcast Transmitter" by Douglas Letts (March 1965 issue); "Modulated-Light Transmitter and Receiver" by M. J. Banthorpe (September 1964 issue); "Speech-on-Light System for Communication" by C. Morgan (January 1964 issue); "Light-Beam Transmitter-Receiver" by J. Emmett (April 1963 issue); and "Light Modulation" by G5UJ (February 1960 issue).

SILVER MEDAL AWARD FOR MULLARD FILM

The Mullard film, "Thin-film Microcircuits", was awarded a silver medal (1st prize) in its category at the 10th International Festival of Scientific-Teaching Films, organised by the University of Padua in conjunction with the 1965 Venice Film Festival. Over 150 films from 18 countries were entered and of these 52 were selected for showing to the international jury.

Britain did particularly well this year. Seven of the ten films entered were chosen for screening and three gained awards.

"Thin-film Microcircuits" is a 16 mm sound and colour film which deals with the manufacture of this new type of electronic component from design stage to the finished product. The film also described typical applications including space vehicles, miniature computers and industrial electronic equipment.

Another Mullard film, "Electromagnetic Waves-Part 2", won a bronze medal (2nd prize) at Padua last year.

"V.F.O. TOP BAND PHONE TRANSMITTER"

In the Components List for "V.F.O. Top Band Phone Transmitter", published in our October 1965 issue, C_3 is specified as "1,00 pF". This should read "1,000 pF".

In Your Workshop

"The computer field of electronics is expanding so fast these days that any electronically-minded young man who takes an interest in the subject is almost certain to be doing himself a good turn for the future."

Thus speaks Smithy the Serviceman as, for the benefit of his able assistant Dick, he lifts the veil from some of the basic principles in the fascinating world of computer logic circuitry

"I," announced Dick, "am worried."

Smithy brushed the last of his lunch from the front of his jacket and regarded his assistant enquiringly.

"What about?"

"I'm worried," continued Dick, "by recent developments in electronics."

Smithy reached over and picked his battered mug of tea from his bench.

"What part," he prompted, "of electronics?"

"Computers."

Smithy's eyebrows rose.

"Computers?"

"That's right," confirmed Dick.

Smithy raised his mug to his lips and took a large draught of the post-prandial brew.

"Why," he queried, patently refreshed by the life-giving fluid, "should you be worried about computers?"

"Because," said Dick aggrievedly, "it's impossible to get away from them these days. You can hardly pick up a magazine or a newspaper without seeing *some* reference to computers. What worries me is that I haven't the faintest clue whatsoever about how they work!"

Logic Circuits

"I don't think," grinned Smithy, "that you're on your own there."

"It's what goes on *inside* a computer that puzzles me," said Dick, frowning. "I've been trying to pick up some gen by reading about them, but all I've found are references to things called OR gates, AND gates, NOR gates and NAND gates. When I bump into *that* sort of patter I'm demoralised before I begin. There's no such *word* as NAND!"

"There is now," chuckled Smithy. "And I must confess that I'm rather pleased to see you showing an interest in this particular branch of electronics despite the fact that you haven't, as yet, even seen inside a computer. The computer field of electronics is expanding so fast these days that any electronically-minded young man who takes an interest in the subject is almost certain to be doing himself a good turn for the future. Added to that is the fact that anybody connected with electronics should always do his best to keep up a nodding acquaintance with all the new techniques which appear."

"The trouble with computer electronics," wailed Dick, "is that it's so *weird*! For example, those gates I mentioned are employed in stuff called logic circuitry. That's bad enough, but what is worse is that everything is tied in with something horrible called Boolean algebra. Boolean algebra, so far as I'm concerned, is just another name for Double Dutch!"

"You're trying to run," commented Smithy, "before you can walk. So let's get down to first principles. All the big computers you read about these days are digital computers, and the word 'digital' merely means that they deal directly with figures as occurs when, for instance, they're used to print out the pay roll for a large company. Because they have to take logical steps in making their calculations, digital computers include circuits which carry out logical processes. And these logic circuits employ gates like the ones you've just referred to."

"All that's understandable enough," said Dick. "What I can't get to grips with is the way in which these logic circuits work."

"Not to worry," said Smithy soothingly. "If you're prepared to concentrate and use a little imagination, you'll find that the basic principles of logic gate circuits are fairly easy, and that even Boolean algebra isn't all that hard, either. What you have to remember, though, is that the concepts involved are so completely removed from the sort of things we bump into in ordinary radio and TV that you just *can't* start reading about them without first getting clued up on their basic principles. Which, incidentally, requires an elementary knowledge of logic."

"There you are, then," said Dick triumphantly. "I'm stymied before I begin!"

"No, you aren't," responded Smithy. "Fortunately the only logic you require for basic logic gate circuits is nothing more complicated than straightforward common sense with a few rules tacked on. If you come over here, I'm prepared to devote the remainder of our lunch break to explaining what I mean."

Even Smithy was surprised at the alacrity with which Dick picked up his stool and crossed over to his bench.

"Are you," asked Dick, eagerly, as he settled down alongside the Serviceman, "going to give me the complete gen on these gate circuits?"

"I wouldn't," replied Smithy, "even *attempt* to do that in a single session. But what I will do is give you an introduction to logic gates, together with a few ideas on what they do."

Smithy pulled his notepad towards him and sketched out a circuit. (Fig. 1.)

"Now here," he continued, "is a very simple circuit employing nothing more than a battery, two switches in series and a lamp. I've labelled the two switches A and B, and you'll notice that they are normally open. What do I have to do to get the lamp to light?"

"That's easy," replied Dick, promptly, "you close both the switches."

"What would happen," asked Smithy, "if I only closed one of the switches? Or if I closed none of them?"

"It's obvious," replied Dick. "The lamp wouldn't light."

"Fair enough," said Smithy. "Can you, therefore, define the condition of the switches which causes the lamp to light?"

"The lamp lights," pronounced Dick, "when both switch A and switch B are closed."

"Good," said Smithy. "Well, that's got our first illustration of logic circuitry sorted out. What you've just described are the requirements for an AND logic circuit!"

"I've done *what*?"

"Described the requirements for an AND logic circuit," repeated Smithy. "You said that the lamp can only light when both switch A *and* switch B are closed. For any other condition of switches A and B, the lamp stays out."

"Well, I'm dashed," said Dick incredulously. "That's a logic circuit?"

"It's a very simple illustration of one," said Smithy, "and it gives an excellent introduction to what comes next. Let's now make up a little table giving all the possible switch combinations and the consequent condition of the lamp."

Smithy drew up a table on his pad. (Fig. 2.)

"Here we are," he announced. "Now, we read this table in the normal manner from left to right. As we read along the top line we see that both switches are open. The entry on the top line in the third column then tells us that the lamp is off, or that it doesn't light. Which is, of course, obvious enough. In the second line we have switch A open and switch B closed, and we see from the third column that the lamp still doesn't light. On the third line, switch A is closed and switch B is open and, once again, the lamp does not light. It is only on the bottom line, where switch A *and* switch B are closed, that the table says that the lamp is alight. Any difficulties up to date?"

"Nothing," said Dick, his brow furrowed, "that I can put my finger on."

"Good," said Smithy. "Now this table is known as a 'truth table'."

"Come again?"

"A 'truth table'."

There was silence for a moment.

"Did you," asked Dick cautiously, "say a 'truth table'?"

"I did."

"Didn't I tell you," complained Dick, "how weird computer electronics is? Why on earth is it called a 'truth table'?"

"Because of the connection with logic," replied Smithy patiently. "Now for the next few steps you've got to concentrate a little, as we're going to cover a new bit of territory."

True and False

Smithy tapped his pen against the circuit with the two switches in series.

"It can be said," he remarked, "that this little circuit is an electrical equivalent of an exercise in logic in which there are two statements leading up to a third statement. If both the first two statements are true then the third statement is also true, but if either, or both, of the first two statements is false, then the third statement is false as well."

"Blimey," breathed Dick, "weird isn't in it!"

"Let us," continued Smithy, ignoring his assistant's comment, "make the first statement 'Switch A is closed', and let us make the second statement 'switch B is closed'. And, finally, let us make the third statement 'the lamp is alight'."

"The *lamp* may be alight," grumbled Dick, "*I'm* completely in the dark."

"The next thing," Smithy carried on doggedly, as he applied himself once more to his notepad (Fig. 3), "is to redraw that table of ours in terms of these three statements. In the top line of the previous table switch A is open. So the statement 'switch A is closed' is obviously false, and we put the word 'false' in the appropriate place in our new table. In the top line of the previous table switch B was open also, so the statement 'switch B is closed' is false too, and we enter the word 'false' again. We do the same in the third column because the statement 'the lamp is alight' is obviously false as well. When we turn to the second line of the previous table we start off again with switch A open. So, once more, we enter 'false' in the table. But when we come to the column for switch B we find that the statement is true because switch B *is*, this time, closed. So we enter 'true' in the table. The lamp still isn't alight, though, so we put 'false' in the third column. We carry on in the same way along the third line, and then we come to the bottom line. In this line all the statements are true, because both switches are closed and the lamp is alight. In consequence, we enter the word 'true' in all three columns."

Dick gazed at Smithy's second

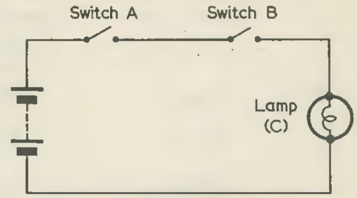


Fig. 1. A simple switch circuit which represents the logical AND

SWITCH A	SWITCH B	LAMP (C)
OPEN	OPEN	OFF
OPEN	CLOSED	OFF
CLOSED	OPEN	OFF
CLOSED	CLOSED	ON

Fig. 2. A truth table showing the functions of the switches of Fig. 1 and the consequent state of the lamp

SWITCH A IS CLOSED	SWITCH B IS CLOSED	THE LAMP IS ALIGHT (C)
FALSE	FALSE	FALSE
FALSE	TRUE	FALSE
TRUE	FALSE	FALSE
TRUE	TRUE	TRUE

Fig. 3. The reason for the term "truth table" becomes apparent when the words "true" and "false" are used to define the conditions shown in the table of Fig. 2

table and scratched his head.

"It's just the same," he said eventually, "as your first table except that you've put 'false' and 'true' instead of 'open' or 'closed', or instead of 'off' or 'on'."

"It *is* the same," confirmed Smithy, "and it helps to get the idea of 'true' and 'false' into your noddle. 'False' corresponds to either switch in its normal position or the lamp not alight, and 'true' corresponds to either switch in the actuated position or the lamp lit up. The terms 'true' and 'false' are commonly encountered in logic circuitry, and it is because of them that we refer to these tables as 'truth tables'."

"Well," conceded Dick, "that explains *one* thing, at any rate."

"We next," continued Smithy, "move away from the 'true' and 'false' business."

"Thank goodness for that!"

"I do wish," snorted Smithy testily, "that you wouldn't keep on with these interruptions of yours. You ask me to give you the gen on logic circuits and then you keep butting in with gash comments all the time!"

"Sorry, Smithy," said Dick contritely, "but all this isn't easy, you know."

"It isn't difficult, either," replied Smithy irritably. "All that it is is *unfamiliar*. Anyway, I'm going to keep on with truth tables and I'm next going to bring in binary figures."

It was as though a ray of spring sunshine had broken through the wretchedness of a foggy February day.

"Binary figures," repeated Dick, his whole face lighting up. "Why, I know all about them! Instead of having 0 to 9 as in our ordinary decimal system, you've just got 0 and 1. And I know why the binary system is used in digital computers, too."

"For this relief," remarked Smithy devoutly, "much thanks. Now tell me why the binary system is used in digital computers."

"Because," replied Dick happily, "digital computers have to use things like transistors for calculations and these are used in circuits whether they're either cut-off or fully conductive. If they're cut-off they can correspond to 0 and if they're fully conductive they can correspond to 1. Or vice versa."

"Dear me," said Smithy, impressed. "You *are* with it. How do you count in binary numbers?"

"The figures 0 and 1," replied Dick promptly, "are the same in both decimal and binary systems. There's no figure 2 in the binary system, so this is represented as 10. Figure 3 becomes 11, figure 4 becomes 100, figure 5 becomes 101 and figure 6 becomes 110. And so on."

"Exactly," confirmed Smithy. "In the decimal system the next number after 9 is 10 because there's no digit higher than 9. In binary, there's no digit higher than 1, so the next number is 10. With binary, the rules are the same as for the decimal system, but you can't go higher than 1. Anyway, all this is more than enough about the binary system for our present purpose, so let's go back to the truth table."

SWITCH A	SWITCH B	LAMP (C)
0	0	0
0	1	0
1	0	0
1	1	1

0 = FALSE
1 = TRUE

Fig. 4. Employing the binary numbers 0 and 1 in place of "false" and "true"

Binary Table

Smithy remembered his mug of tea, picked it up and drank deeply.

"Ah, that's better," he said, smacking his lips, "just the job! Now, you said just now that a transistor could either be cut-off or fully conductive, and that it could then represent 0 or 1 respectively. The same applies to any other device which can take up one of two states. The two switches in series in our diagram are two-state devices because they can either be open or closed. We've made the assumption that, when open, they correspond to 'false' and that, when closed, they correspond to 'true'. We can use the two binary digits 0 and 1 instead of 'false' and 'true', whereupon we could make another assumption and say that an open switch corresponds to 0 and a closed switch corresponds to 1. Similarly, the extinguished lamp corresponds to 0 and the illuminated lamp to 1. Let's see what our table looks like now."

Smithy drew a third table. (Fig. 4.)

"Here we are," he said, "we now have a truth table using the binary digits 0 and 1. Now, I've assumed that the digit 0 corresponds to 'false' in the previous table and that the digit 1 corresponds to 'true'; and this is, in fact, a convention that's used in computer logic circuits. In the present circuit with the two switches in series, 0 corresponds to any device which is not actuated, whilst 1 corresponds to any device which *is* actuated. When a switch is closed, it is actuated, and so it represents condition 1. When the lamp is lit it is actuated, and this corresponds to condition 1 also."

"Why," asked Dick, "didn't you go straight away into explaining the conditions as 0 and 1, which seems fairly reasonable to me, instead of going through all this 'true' and 'false' business?"

"I thought you'd ask that," grinned Smithy. "And the answer is that, if you're going to do any serious delving into computer logic circuits you'll bump into the 'true' and 'false' concept almost from the word go. In practice, you'll find that you get used to it surprisingly soon."

"I'll take your word for it," commented Dick guardedly. "What's the next move?"

"We're going to quickly dip our toes," replied Smithy, "into Boolean algebra!"

"Ye gods," groaned Dick. "Roll on colour TV. Let's get on to something simple like dynamic tube convergence."

"Stop dripping," commanded Smithy. "In the last two tables I drew up we said that when switch A is true or is in condition 1, and when switch B is true or is in condition 1, so also is the lamp. If we refer to the lighting of the lamp as C, we can then say that C is true when A and B are true. O.K.?"

"Fair enough," said Dick grudgingly, "that seems reasonable."

"In Boolean algebra," said Smithy, "this set of conditions is represented by the equation $C=A \times B$. The multiplication sign doesn't mean the same as in ordinary algebra, and it simply stands for the word 'and'. Very often a full-stop is nsed instead of the multiplication sign because it means the same thing, whereupon the set of conditions becomes represented by C=A.B. Or, again, even the full stop may be dropped, giving you C=AB. All these mean the same thing in Boolean algebra and they state that C is true when A *and* B are true."

OR Circuit

Smithy paused and waited expectantly.

"Go on," said Dick.

"That's all for the present about Boolean algebra," replied Smithy. "I *said* we were only going to dip our toes in!"

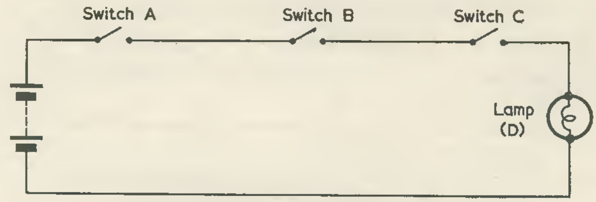
"Let's think a minute," said Dick reflectively. "In this Boolean algebra, you represent 'and' by showing the two letters as though they were multiplied together."

"That's right," confirmed Smithy. "For the record, an expression like $A \times B$, or A.B, is known as the 'logical product'."

A thought suddenly occurred to Dick. He seized Smithy's notepad and sketched a second circuit. (Fig. 5.)

"Have a look at this," he exclaimed. "What I've done here is to put *three* normally-open switches in series. Could this represent an AND circuit, too?"

"Definitely," replied Smithy. "The lamp will only light if switch A *and* switch B *and* switch C are actuated. If we call the lighting of the lamp condition D and stick to our previous terms we can say that D is true only when A, B and C are true. This can be represented in Boolean algebra as $D=A \times B \times C$, D=A.B.C or D=ABC."



D=A.B.C

Fig. 5. Illustrating the logical AND with three switches

"Well, blow me," gasped Dick. "Do you know, Smithy, now that I've got over the initial strangeness, all this is beginning to make sense."

"It does with time," said Smithy. "Like most practical blokes working in electronics, you've been immersed for a long time in ordinary electronic circuits where the only things you have to consider are easily imagined quantities like amps, ohms and volts. Don't forget that even amps, ohms and volts can be a little indigestible when you first have to deal with them."

"I suppose they can be," said Dick reflectively. "I can't even remember when I first encountered them."

"Of course you can't," replied Smithy. "You've got so used to thinking in terms of amps, ohms and volts that you can't recall the time when they were a hidden mystery to you. *All* new things are difficult at first."

"I suppose you're right," said Dick. "Anyway, what's next with these AND circuits?"

"Oh, I've finished with them for the moment," stated Smithy. "What I'm next going to do is start on a bit of OR logic."

Smithy recovered his notepad and drew out a further circuit. (Fig. 6.)

"This circuit," he continued, "shows two normally open switches in parallel connected between the battery and the bulb. Let's draw up the truth table for this little set-up and we'll use the figure 0 to represent a device that isn't actuated and the figure 1 to represent one that is."

Again, Smithy's pen went into action. (Fig. 7.)

"The result we get," continued Smithy, "is very obvious. So obvious, indeed, that we don't really need the truth table at all. Nevertheless, it's good practice to go through the truth table routine so that we can get familiar with its use. The top line of the table is a row of 0's, and represents both switches open and the lamp not lit. In the second line, the 1 in the B column tells us that switch B is closed, and the 1 in the C column tells us that the lamp is lit. In the third line down, switch A is closed and the lamp is lit and, in the fourth line both switches are closed and the lamp is lit again."

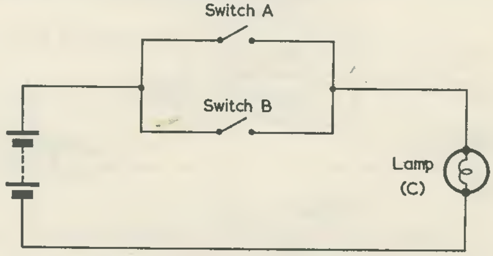
"What does the circuit represent?"

"It represents a logical OR," replied Smithy. "The lamp is lit either when switch A is closed, *or* when switch B is closed *or* when both switches are closed. If we use the true and false approach, we can say that the circuit represents the case where C is true when A *or* B *or* both are true. In Boolean algebra this is shown as C=A+B."

"A *plus* B?"

"That's right," confirmed Smithy. "This is another instance of a sign which doesn't mean the same thing as in conventional algebra. What the plus signs means is *or*, in the sense that C is true when A *or* B *or* both are true."

"That," commented Dick, "is the second time you've said 'A or B or both'."



C=A+B

Fig. 6. A circuit representing the logical OR

SWITCH A	SWITCH B	LAMP (C)
0	0	0
0	1	1
1	0	1
1	1	1

Fig. 7. Truth table for the circuit of Fig. 6. This may be compared with the truth table of Fig. 4, which is for an AND circuit

"That's because I want to emphasise the relationship," explained Smithy. "This particular OR is described as the 'inclusive OR' because it applies to A or B or both. There's also an 'exclusive OR' and this covers the case where C is true when A or B is true but not when both are true. Thus, with the exclusive OR you get C being true only when *one* of the two, A or B, is true. The exclusive OR requires a rather more complex circuit to demonstrate it than does the inclusive OR and I've only mentioned it so that you can be aware of its existence. All the ordinary OR circuits you find in computer logic are for the inclusive OR unless otherwise stated. As I've just told you, you use a plus sign to indicate the OR relationship, and the expression A+B is known, in consequence, as a 'logical sum'."

"Can you," asked Dick, "have three switches, like I had with the AND circuit?"

"You can have as many as you like," replied Smithy, picking up his pen. "Let's add another one to the two-switch circuit and refer to the lighting of the lamp as D. (Fig. 8.) Then, D is true when A *or* B *or* C *or* any two *or* all three are true. The Boolean algebra presentation is D=A+B+C."

Logic Gates

"I certainly seem," commented Dick, "to be learning something today. It's beginning to get interesting, too."

"If you keep on," replied Smithy cheerfully, "this logic business becomes completely engrossing. Let's carry on, next, to one or two practical gate circuits."

Smithy tore the now completely covered top sheet from his pad, and applied his pen to the new surface. (Fig. 9.)

"Here," he said after a few moments, "is a diode AND gate. I've given it three inputs and I'm going to assume representative voltages to make the explanation easier. The inputs can be at one of two states, these being either at zero volts or at +10 volts, and we'll say that the zero volts state corresponds to the 0 condition in the binary system, and that the +10 volts state corresponds to the 1 condition. And, to make things even simpler, I've also drawn a thermionic diode alongside a semiconductor diode just to remind you which way the current goes through the latter!"

"That," remarked Dick appreciatively, "is very civil of you."

"I'm like that," replied Smithy grandiosely. "To return to the gate circuit, when all inputs are at zero volts, all the diodes are conducting in the forward direction. In consequence we can look upon them as being short-circuits, and zero voltage appears at the output. What happens to the output if we take one of the inputs up to +10 volts?"

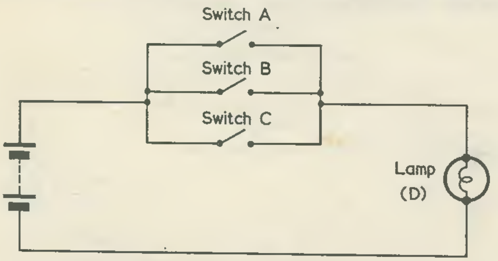


Fig. 8. A representative OR circuit employing three switches

Dick concentrated on Smithy's circuit.

"Why," he remarked after a moment. "Nothing!"

"That's right," confirmed Smithy, "but why?"

"Because the other two diodes will still conduct," said Dick, "and will hold the output down at zero level. The diode whose input went up to +10 volts will merely become reverse biased."

"That," responded Smithy warmly, "is my boy. What happens if two of the inputs go up to +10 volts?"

"The same again," replied Dick promptly. "There'll still be one conducting diode left which will hold the output down at zero volts. The other two diodes will just become reverse biased."

"Excellent," said Smithy. "Finally, what happens when all *three* inputs go up to +10 volts?"

"In that case," said Dick decisively, "the output will go up to +10 volts as well."

"Fine," said Smithy. "In other words we only get an output of 1, which corresponds to +10 volts, when all the inputs are similarly at 1. We've got ourselves, therefore, an AND gate, since the output only appears when A *and* B *and* C are present. If the output is D then, according to Boolean algebra, D=A.B.C. Incidentally, we could have two inputs, or more than three inputs if we wanted to, provided that each input coupled into a diode. Let's take a shufti now at an OR gate!"

Again, Smithy set to work on his note-pad. (Fig. 10.)

"Here it is," he announced, "a nice simple OR gate. We'll keep our inputs the same as in the previous case with zero volts corresponding to the binary 0 condition, and +10 volts corresponding to the binary 1 condition. You'll notice that the load resistor couples this time to a negative voltage, which could be something like −10 volts."

"This circuit," remarked Dick, "is a piece of duffy! All the diodes are conducting even when the inputs are at zero volts. If one input goes up to +10 volts then its diode carries the output up to +10 volts also, with the rest of the diodes becoming reverse biased. The output goes up to +10 volts as well if two of the inputs do or if all three of the inputs do."

"You're really catching on," said Smithy approvingly.

"I'm on home ground here," replied Dick confidently. "I've never been beaten by a diode yet!"

"Good show," said Smithy. "I must add that, like the AND gate, this OR gate could have two inputs, or more than three inputs, provided that each input had its own diode. And the Boolean algebra expression for the gate is D=A+B+C where D is the output. Now let's bring in a transistor!"

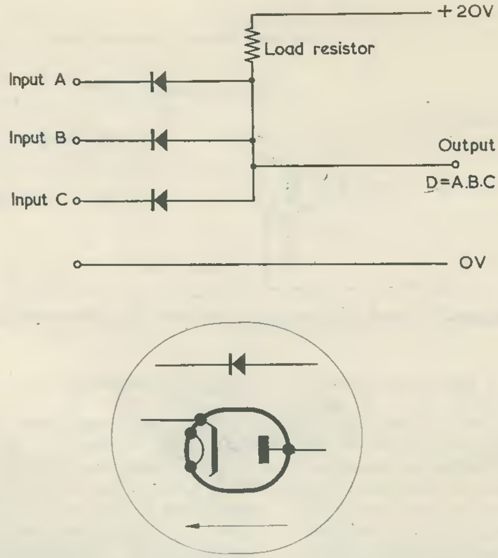


Fig. 9. A diode AND gate with output D (=A.B.C.). The inputs may be either at zero volts (=0) or at +10 volts (=1). In the inset, the thermionic diode is shown alongside the semiconductor diode as a reminder of the direction of forward current flow in the latter. In both devices conventional current (from positive to negative) flows in the direction of the arrow

Inverter

Smithy's pen rattled busily over his much-used notepad. (Fig. 11.)

"This," he remarked, "is a common-or-garden transistor connected as a grounded emitter amplifier. I've chosen an n.p.n. transistor, which means that collector current increases as the base goes more positive. Let's start with zero voltage applied to the input. The base will then have the same potential as the emitter and so the transistor will not pass any current. In consequence, the output will be at the positive supply voltage. If now we change the input from zero to +10 volts we will cause the transistor to become fully conductive. Incidentally, the resistor in series with the base is inserted merely to ensure that excessive base current doesn't flow. What happens to the output?"

"Why," said Dick, a little startled at Smithy's sudden question, "it goes negative, of course. It will go very nearly to zero potential."

"Exactly," agreed Smithy. "If we made the transistor supply voltage 10 volts, an input of +10 volts will result in what is virtually zero voltage output, whilst a zero voltage input will result in +10 volts output. In other words the transistor acts as an inverter, because it inverts the polarity of the input. Stand by for another symbol in Boolean algebra!"

"I am," replied Dick, "maintaining a state of full readiness."

"Excellent," said Smithy. "We'll start off by representing the input to the transistor by the letter A, this letter being true when the +10 volts input is present. The output from the transistor is the dead opposite of A and so we call it 'not-A'. And we distinguish it as not-A by drawing a bar above the letter, like this: $\overline{A}$."

Smithy scribbled the character on his pad.

"So," he went on, "if input A is reversed it becomes A with a bar over the top and we call it 'not-A'. Let's see what happens if we couple up our previous AND gate to the transistor."

Smithy thought for a moment then sketched out a circuit. (Fig. 12.)

"This should do the trick," he remarked. "We've got the same three diodes in an AND gate as before, and you'll remember that their output went up to +10 volts only when all three inputs went up to +10 volts. This time we've got the output hitched to the base of our p.n.p. transistor via a resistor to limit base current to a safe value. I've also added a resistor from the base going to a negative bias line, but this is only to keep the transistor base slightly negative of the emitter when the output of the diode gate is nominally zero. This bias circuit keeps the transistor fully cut-off under this condition, despite any small voltages which may, in practice, be dropped across the diodes. When the output from the diode gate is zero, therefore, the transistor is cut-off and its output is at positive supply voltage. When inputs A *and* B *and* C go up to +10 volts so does the output from the diodes and this causes the transistor to become fully conductive. The transistor output falls, therefore, to zero volts. We already know that the output from the diode AND circuit is given by D=A.B.C. The output from the transistor is, however, the dead opposite of this and we can, in consequence, call it 'not-A.B.C.'. Since it is 'not-A.B.C.' we write it as A.B.C. with a bar along the top of all three letters. Thus: $\overline{A.B.C.}$"

Smithy wrote the symbol on his pad as Dicked looked on.

"To finalise," Smithy went on, "if we call the transistor output E, then E=$\overline{A.B.C.}$"

"Is this circuit," asked Dick, "an important one?"

"It is," confirmed Smithy. "It's a NAND gate, the word NAND deriving from not-AND. If you're dealing in binary terms, the output is 0 only when input A *and* input B *and* input C are 1. Do you feel like a bit of really heavy brain-bashing?"

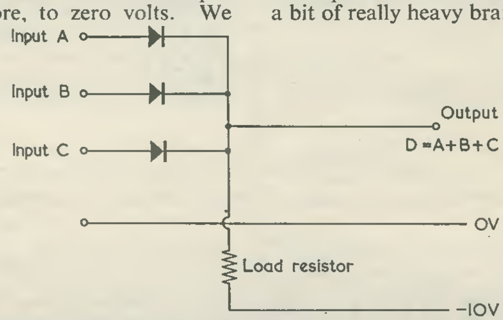


Fig. 10. A diode OR gate with output D (=A+B+C). As with Fig. 9, the input may be either at zero volts (=0) or at +10 volts (=1)

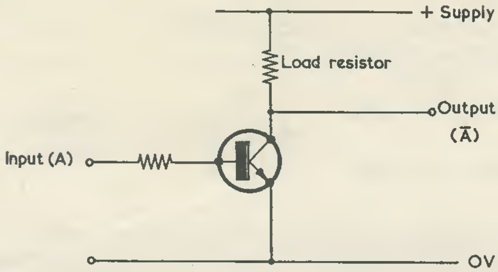


Fig. 11. A transistor inverter. This reverses the polarity of the input signal

"I think I could stand a bit more," replied Dick, "but take it easy now!"

"When," said Smithy, "all the inputs to the NAND circuit are at +10 volts, the output is at zero. If, however, any input goes down to zero volts the transistor cuts off and its output goes to full supply potential. The same applies if any two inputs go down to zero volts or if all three do. What does that remind you of?"

"Just a minute," said Dick thoughtfully, "that sounds familiar. Why, it's the same as with the OR gate! The OR gate you drew just now gives an output D if A or B or C or any two or all three go up to +10 volts."

"That's the idea," said Smithy, pleased. "With the NAND gate, though, we get an output if any one input or any two inputs or all three go down to zero volts. Going down to zero volts is the dead opposite of going up to +10 volts and so we find we get a true output from the gate for $\overline{A}$ or $\overline{B}$ or $\overline{C}$ or for any two or for all three. In other words, the true transistor output, E, is equal to $\overline{A}+\overline{B}+\overline{C}$. Also, since both are equal to E in the same circuit, we can say that $\overline{A.B.C.}=\overline{A}+\overline{B}+\overline{C}$."

"This," protested Dick, "is getting rather heavy going."

"Okey doke," said Smithy equably. "But what I've just mentioned is something you can think about at a later time. The final thing I'm going to do is couple our previous OR gate to the transistor."

Again Smithy scribbled out the appropriate circuit. (Fig. 13.)

"I don't think," he said, "we need go into the full detail again, because we covered it pretty fully with the NAND gate. We know that the output for the diode gate is D= A+B+C. The transistor then inverts this so that its output, E, is $\overline{A+B+C}$. The bar meaning 'not' goes over the whole of the A+B+C expression. This circuit is known as a NOR gate. If you feel like undertaking the mental exercise, you can look at this circuit the other way round, too. This time, a true output from the transistor is given only when $\overline{A}$ and $\overline{B}$ and $\overline{C}$ are applied to the inputs. This gives us $E=\overline{A}.\overline{B}.\overline{C}$, from which we can say that $\overline{A+B+C}=\overline{A}.\overline{B}.\overline{C}$. However, I'll say no more about that, except to leave it with you as something to think about in the future. I should add, for the record, that the alternative results given by the gates are examples of what are known as De Morgan's Rules. These are usually given with two terms only and state that $\overline{A.B}=\overline{A}+\overline{B}$ and that $\overline{A+B}=\overline{A}.\overline{B}$."

"De Morgan," repeated Dick, curiously. "Who was he?"

"He was a mathematician," replied Smithy, "who lived in the nineteenth century, about the same time as did George Boole. It was Boole who invented the Boolean algebra. De Morgan's Rules were an addition to Boole's work."

"Are you telling me," asked Dick incredulously, "that all this algebra was conceived in the nineteenth century?"

"I am."

"But," protested Dick, "there wasn't anything even approaching electronics in those days. No radio, no valves, no transistors, no anything!"

"I know," said Smithy. "The algebra was based entirely on formal logic. Marvellous, isn't it?"

Modern Times

"I should say," agreed Dick warmly. "Anyway, now that I've learned all about logic circuits, when are we going to get our first computer in for servicing?"

"Not for quite a little while yet," chuckled Smithy. "I must remind you that we've only just skimmed the surface of logic circuits and that, even then, we've been picking out the easier bits. Still, what I've told you should get you over the initial hump if you ever start digging up further information on the subject. A point I must mention is that modern NOR and NAND gates don't always have the diodes before the transistor. Each input can go direct to the transistor base via a resistor. If the voltages and valves are right, this arrangement can give you the same NAND or NOR action as with the gates I showed you using diodes. Incidentally, the fact that the NAND and NOR gates use a transistor has resulted in them being more popular with computer manufacturers than the AND and OR gates."

"Why's that?"

"Because," explained Smithy, "you can use the transistor to give amplification, which doesn't occur with the diode AND and OR gates. If you have a string of AND and OR gates you have to pop in an amplifier every now and again to make good the losses. But transistor NAND or NOR gates have their

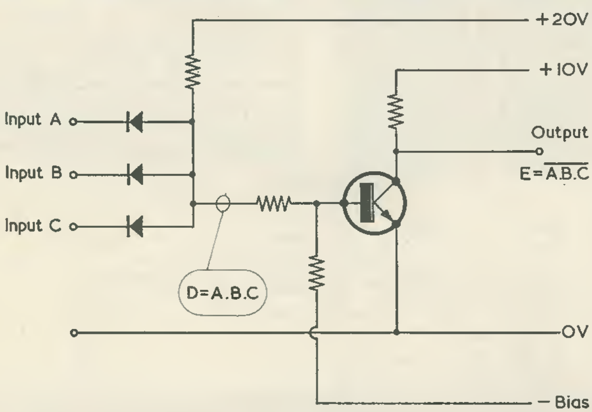


Fig. 12. Adding the AND gate of Fig. 9 to a transistor inverter to form a NAND gate. The output is E (=$\overline{A.B.C}$). The positive supply voltage figures shown are intended to be representative only

own built-in amplifier and further amplifiers aren't needed."

"Are there any other points on these gates?"

Smithy looked at his watch, picked up his outrageous tin mug, and drained it with an air of finality.

"Not at this stage," he replied, "except, perhaps, to say that the gate circuits I've described during this little session of ours are only examples of what can be done. A considerable amount of permutations on the circuits can be given by ringing the changes on supply potentials, input signal potentials, by changing from n.p.n. to p.n.p. transistors, and so on. And now, my lad, it's well past the end of lunch break, so let's have a stab at a few nice simple radios and TVs!"

But Dick's face was heavily contorted in a grimace which indicated that, as happened on occasion, he was being visited by his Muse. Recognising the symptoms, Smithy sighed and waited for the inevitable.

After some moments, his assistant's face cleared.

"Listen to this, Smithy," said Dick exultantly. "How about this to cap off everything we've been talking about today?

"Said the logic research supervisor,
'Our new gate is a real tantaliser,
It's not an OR or an AND,
Nor a NOR or a NAND,
It's none of these things, it's a NEITHER!'"

And even Smithy, as he switched on the mains supply to his bench, had to privately admit that there were occasional advantages in having someone like Dick around the place.

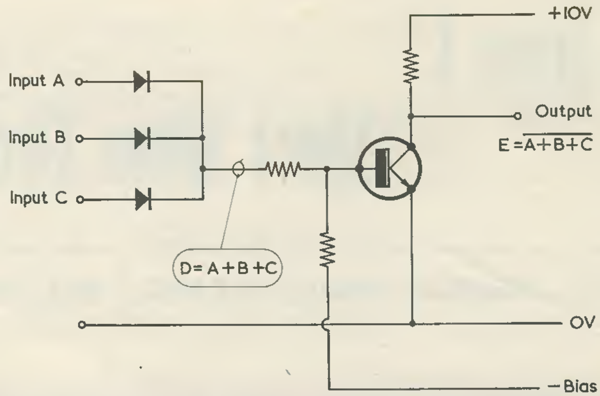


Fig. 13. A NOR gate, given by a transistor inverter following the OR gate of Fig. 10. The output is E ($=\overline{A+B+C}$). The load resistor of Fig. 10 is replaced by the series base current limiting resistor and the further resistor connecting to the negative bias supply

PYE RADIOTELEPHONES FOR SHERPA HOSPITAL

The world's most remote hospital, 13,000ft up the slopes of Everest, is to have two powerful radiotelephones to provide a "lifeline" with civilization.

Sir Edmund Hillary will lead a New Zealand expedition into Nepal next year to begin construction of a six-bed hospital for 4,000 Sherpas in the Khumbu area of the Himalayas. The expedition will carry with it two compact single-sideband transmitter-receivers, manufactured by Pye of Cambridge, which will give hospital staff a vital link with Kathmandu, 160 miles away. The sets, which are Pye SSB 125's, have been presented to Sir Edmund by Mr. G. A. Wooller, managing-director of Pye (New Zealand), Limited.

"By foot it would take at least eight days to reach Kathmandu with a message, and a further eight days to return," says Sir Edmund. "These radios, with their strong signal, will be an invaluable asset."

Another vital link for the hospital, which will be built at Khunde, near the Tibetan Border, is an airstrip which Sir Edmund and his party built last year, a day's walk down the valley from the village. The radiotelephones will make it possible for the hospital staff to give pilots advance information on weather conditions in the valley.

"This is particularly important," says Sir Edmund, "because the weather conditions there can change very quickly, and pilots are reluctant to leave Kathmandu for the valley unless they are sure that the weather is favourable."

Radio interference will be no problem, despite the remote location of the proposed hospital. Mr. Peter Mulgrews, who is treasurer of the Sherpa Hospital Appeal Committee and manager of Pye's Telecommunications Division (New Zealand), says the sets are powerful enough to receive a clear signal virtually from anywhere in the world, and the design is such that interference is virtually eliminated.

The 4,000 Sherpas of the Khumbu (Everest) area of the Himalayas asked Sir Edmund to help them establish a hospital. Sir Edmund says the Sherpas are cheerful, hardworking people, but live in conditions of great hardship.

In recent years expeditions led by Sir Edmund have worked with the Sherpas to establish seven elementary schools, and to build two water pipelines, two bridges and an airfield.

"But the greatest Sherpa need", says Sir Edmund, "is medical treatment. They have no hospitals, drugs, doctors or nurses, only 60 per cent of their children survive their first 10 years, and an appalling percentage of mothers die in childbirth."

Sir Edmund's hospital expedition plans to begin construction at Khunde in September next year, and a New Zealand doctor and an assistant are ready to staff it.

"3 from 1" Short Wave Circuit

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

Another ingenious circuit from our popular contributor. In this short wave receiver covering 3.5 to 20.6 Mc/s one triode-pentode functions as aperiodic r.f. amplifier and triode detector with reaction, after which the pentode section doubles as a reflexed triode output valve.

For over 30 years a simple circuit consisting of an untuned radio frequency stage followed by a triode detector with a final stage of triode audio frequency amplification has been deservedly popular for the reception of short wave signals on headphones. Despite its simplicity the circuit has the advantage of quiet background, and for this reason will sometimes pull in stations which would be missed on an elaborate communications superheterodyne.

One Valve—Three Stages

The circuit to be described is just such a three stage receiver except that it obtains its three stages through the agency of a single valve—a 3A8GT. This represents a considerable saving in construction costs, especially as the valve is obtainable for a few shillings.[1] All the components necessary for the receiver, including materials for a set of three plug-in coils can be bought for comfortably under £2.

The use of a 3A8GT valve will be found to result in splendidly short wiring. But constructors can, if they wish, use two more generally available valves instead, these being a 1N5GT for the pentode and a 1H5GT for the triode. This alternative has been tried by the author and gives satisfactory results provided the grid capacitor and leak (C_4 and R_4) are taken direct to the grid cap of the 1H5GT with only the minimum of wire necessary for the solder connection at the cap.

It will be seen from Fig. 1 that the aerial is taken to the slider of a potentiometer and thence to the grid of the pentode section of the valve. One of the many advantages of the buffer stage thus provided is that it is possible to vary the input from the aerial without upsetting either the tuning or the reaction setting. It will be found that VR_1 can be employed as a useful selectivity control, especially when a long aerial is in use. Jamming stations can be sorted out by backing down VR_1 and advancing VR_2 to the edge of oscillation.

L_2 is in the anode circuit of the pentode and couples to L_1, which is tuned to the signal by VC_1 through the agency of an 8:1 slow motion drive. The rectified signal is passed by way of R_2, C_1 and R_1 back to the pentode section and further amplified. Because of L_2 the pentode becomes a triode at audio frequencies, with its anode and screen-grid connected together. In consequence a fairly low output impedance results which matches quite well to a pair of 4,000Ω phones.

Because of C_2 and provided L_2 is in correct phase relationship with L_1, L_2 serves for reaction as well as forming the primary of a coupling transformer. Reaction is controlled by VR_2 which varies the d.c. voltage available for the anode of the triode, and hence its tendency to oscillate. This arrangement has the advantage of ensuring that the a.f. load for the triode is as high as is consistent with the provision of satisfactory reaction, a factor which is important with the high output impedance involved, this being about 200kΩ. Good low frequency amplification results. For smooth control, VR_2 has a log track and is connected so that reaction increases in an anti-clockwise direction.

It is recommended that good quality potentiometers be used for VR_1 and VR_2. In the author's experience some potentiometers become noisy after a few hours' use if the smallest current is passed through them or, sometimes alas, even when no current is involved at all.

Although VC_1 has a capacitance of only 60pF it will be found that, with the small stray capacitances in the circuit, the frequency coverage of each coil will be nearly 2:1. This is as good as with 150pF tuning capacitance in some circuits.

It will be seen that C_2 not only enters the reaction circuit but that it also provides a little negative feedback at the higher audio frequencies. This cancels a tendency for instability at these frequencies resulting from the reflex action. If C_2 is disconnected, not only will there be no reaction but there will probably be an audio frequency howl.

As is the author's usual practice, the exact layout is left to the constructor. But a suggestion as to the positioning of the valveholder in relationship to the plug-in coil holder is given in Fig. 2. In this diagram the reader is looking at the underneath of the valveholder, but at the top of the coil holder. The arrangement shown is convenient when mounted to the front panel, as it allows the coil to protrude where it can easily be changed, while the valve projects away from the coil, behind the panel. The two holders are secured together by a long bolt, a sleeve about ¾in long being fitted to space them apart. This leaves room for components underneath the valveholder, whilst bringing the coil holder flush with the panel. Clearly, it will be necessary to rearrange things if two separate valves are used.

Making the Coils

Some commercial coils will prove satisfactory with the circuit, but others will not suit. It was found that Globe-King coils, Nos. 2 and 3, worked well and gave a coverage of from 17.6 to 5.2 Mc/s, with a small overlap between them.[2] But the

[1] Among dealers who, at the time of writing, stock the 3A8GT are Alpha Radio Supply Co., 103 Leeds Terrace, Wintoun Street, Leeds; and Z and I Aero Services Ltd., 44A Westbourne Grove, London, W.2.

[2] "Globe-King" products are manufactured by Johnsons (Radio), St. Martins Gate, Worcester.—Editor.

author has designed his own plug-in coils which are easy to make, cheap and very efficient. The materials required to make three coils to provide a coverage from 20 to 3.5 Mc/s consist of a piece of Paxolin, 6in by 5in by ⅛in, three 4-pin plugs of the type which fit a B103 battery,[3] a small quantity of 24 s.w.g. and 32 s.w.g. enamelled wire, three ½in 6BA countersunk bolts with nuts, and some strong adhesive.

The Table gives details of the three coils and the coverage which may be expected. It is a coincidence that L_1 has exactly the same number of turns for coil No. 2, as for No. 3. The inductances are very different, as one is space-wound and the other close-wound. And the odd ¾ turn in each case is due to the spacing of the pins.

It is suggested that coil No. 2 be made first and the receiver tried out with it. Three pieces of Paxolin should be cut as in Figs. 3 (*a*), (*b*) and (*e*). A fretsaw with a fairly tough blade is the tool to use. The edges of the pieces shown in Figs. 3 (*a*) and (*b*) have 25 shallow cuts in order to keep the turns of the main coil in position. These cuts are $\frac{1}{10}$in apart and the way to make them is to put the two pieces together with outlines corresponding exactly, and grip them in a vice together with a ruler held about ¼in below the edge, so as not to be cut. A small hacksaw will make the cuts quickly and accurately. The 26th cut—the one nearest the feet—is deeper since it has to take 7 turns of wire for L_2. The holes marked 1 to 4 are to take the ends of the windings and should be drilled, as shown, using a $\frac{1}{16}$in drill.

When the piece shown in Fig. 3 (*e*) has been cut out it should have a ⅛in hole drilled in its exact centre. The underneath of this hole should be countersunk. The 4 pin plug will probably already have a hole through its centre (if not, this must be drilled) and the side of the hole between the pins should be lightly countersunk. The plug is then bolted to the base piece with a 6BA bolt and nut. A $\frac{1}{16}$in drill is passed through each of the four pins in turn so that the holes marked 1 to 4 in Fig. 3 (*e*) are made. These holes will allow the ends of the windings to be passed through the pins and soldered.

Next, the pieces shown in Figs. 3 (*a*) and 3 (*b*) are slotted together in such a way that the holes take up the positions shown in Fig. 3 (*e*); and the four feet are passed through

[3] The coil base is the same as the B4 valveholder used extensively in this country before the war.—EDITOR.

Coil Number	L_1 turns	L_1 type	L_2 turns	L_2 type	Coverage (Mc/s)	Coverage (Metres)
1	9¾*	Spaced 1/10in	6*	Spaced 1/10in	20.6 —11.6	14.5 —25.8
2	24¾*	Spaced 1/10in	7	Pilewound	12.1 —6.5	25 —46
3	24¾	Closewound	9	Pilewound	6.7 —3.5	44.7 —85.6

*24 s.w.g. enamelled wire. All other windings 32 s.w.g. enamelled wire.

Components List

Resistors
(All fixed resistors ¼ watt 10%)
- R_1 100kΩ
- R_2 10kΩ
- R_3 1MΩ
- R_4 5.6MΩ
- VR_1 5kΩ potentiometer, linear track, with switch
- VR_2 2MΩ potentiometer, log track

Capacitors
- C_1 0.01μF, paper
- C_2 100pF, silver-mica or ceramic
- C_3 100pF, silver-mica or ceramic
- C_4 200pF, silver-mica or ceramic
- C_5 2,000pF, ceramic
- VC_1 60pF, Cat. No. 582 (Home Radio)

Inductors
- $L_{1,2}$ See text

Valve
- V_1 3A8GT (see text)

Switch
- S_1 (a), (b) d.p.s.t. (combined with VR_1)

Phones
- 4,000Ω headphones

Miscellaneous
- 1 International Octal valveholder
- 1 B4 valveholder (for coil)
- Slow-motion drive, 8:1, Cat No. 2155 (Jackson Bros.)

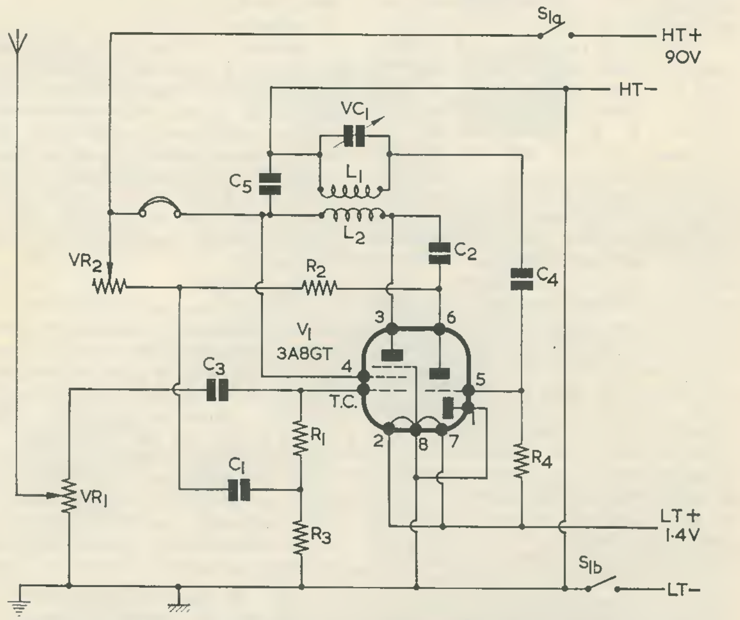


Fig. 1. The circuit of the receiver. The pentode section reflexes as, first, a pentode aerial buffer amplifier and, second, a triode a.f. output valve

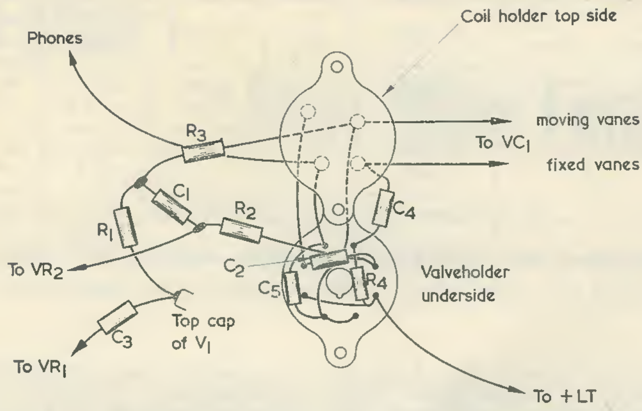


Fig. 2. Detail of the wiring around the coil base and valveholder

the four slots which have been cut in the base of Fig. 3 (*e*). Cement is used to secure the four feet in the four slots, and the coil former is then ready for use.

Enamelled 32 s.w.g. wire is passed through hole 4 in the upright part of the former and then passed through pin 4 and soldered. Seven turns are wound in the deep slot in a clockwise direction, looking at the pins, and the end is passed through hole 3 and pin 3 and soldered. Enamelled 24 s.w.g. wire is then passed through hole 2 and pin 2 and soldered. 24¾ turns are wound in the slots provided, the end being taken through hole 1 and pin 1 and soldered. The coil is then complete and should appear as in Fig. 3 (*f*).

Coil No. 1 is made in a similar manner except that it can be shorter and L_2 is space-wound like L_1, and not in a single slot as occurred with coil No. 2. L_2 has 6 turns and L_1 9¾ turns. As with coil No. 2, both windings are put on in a clockwise direction looking at the ends of the pins. Fig. 3 (*c*) and 3 (*d*) show how the upright parts of the former are cut and drilled. The base is as in Fig. 3 (*e*).

For coil No. 3 the shorter uprights are used, as shown in Figs 3 (*c*) and 3 (*d*), but only one set of deep slots is cut, these being near the feet, and of the same type as occurred in Figs 3 (*a*) and (*b*). No other cuts are needed as there is no spaced winding. Also, holes 3 and 4 should be cut as in Fig. 3 (*b*) to take the ends of L2. Instead of drilling holes 1 and 2 to take the ends of L_1 it is simpler to cut two lengths of stiff wire about 2in long, pass them through pins 1 and 2 respectively and solder them in place before any winding is done. Next, L_2 is wound in place. Then, 32 s.w.g. wire is soldered to the stiff wire passing through pin 2 at a point about ¼in above L_2, and 26¾ turns are close wound, the end of the winding being soldered to the stiff wire passing through pin 1.

The size of L_2 in relationship to L_1 is fairly critical. If L_2 is too large, it may be found that it is impossible to prevent oscillation with VR_2 at zero, when VC_1 is fully open. If L_2 is too small it may be found that oscillation cannot be obtained when VC_1 is fully closed. But if the coils are carefully made there should be no trouble, as allowance has been made for some variation. It is unlikely, therefore, that constructors will need to add to, or take away from, the number of turns of wire used for L_2.

Conclusion

Because of the radio frequency stage, the circuit will be found very independent of the aerial used, and there will be no hand capacitance effects whatsoever, provided the hands are not placed too close to the coil. Current consumption is 100mA from a 1.4 volt battery, and about 2mA from a 90 volt battery. Small batteries will, therefore, give good service.

Editor's Note

Although no errors should occur if the coil-winding instructions given above are followed carefully, the possibility remains that an incorrect connection or a short-circuit between the two windings may exist. This could cause the full h.t. supply to appear across the headphones, whereupon it is suggested that the resistance across the h.t. supply lines be checked with each new coil after construction, and before the h.t. battery is applied.

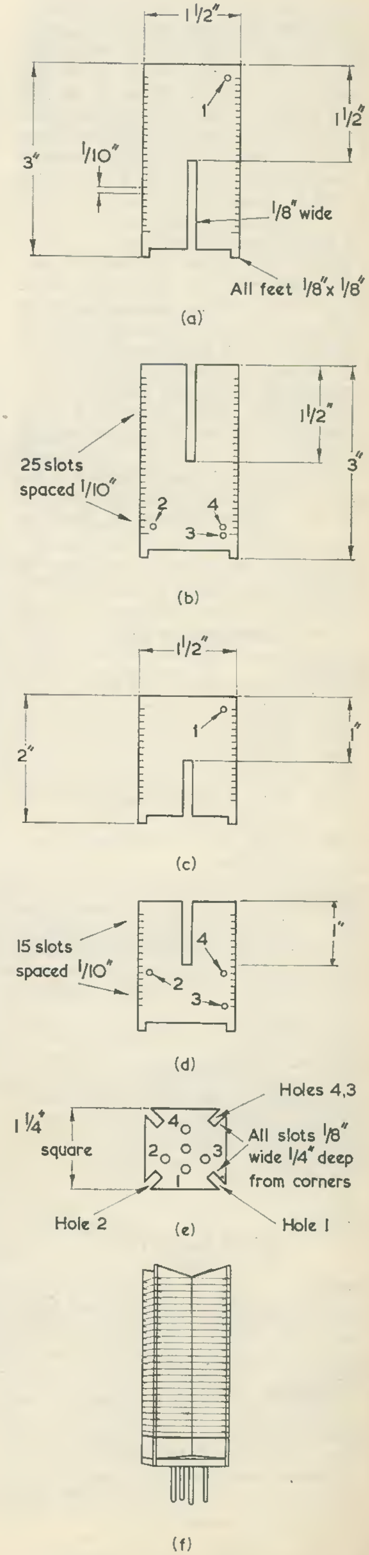
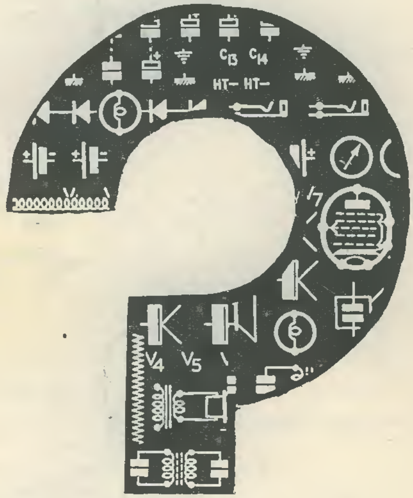


Fig. 3. Constructing the coil formers for the three ranges. In (e) the pins project towards the reader

understanding



radio

Practical Voltage Amplifiers

By W. G. Morley

IN LAST MONTH'S ISSUE, WE SAW THAT WE COULD determine the performance of an audio frequency voltage amplifier triode under working conditions by drawing a loadline across its I_aV_a curves. The "slope" of the loadline corresponded to the resistance of the anode load and we noted, further, that a complete picture of the valve's operation was given by adding a second loadline having a slope equal to the resistance of the anode load and the following grid resistor in parallel. This second loadline was the dynamic loadline.

We shall next turn our attention to some generally available triodes and examine their capabilities in practical circuits.

Triode Combinations

When we come to examine practical triodes intended for use as a.f. voltage amplifiers and for similar functions we encounter the somewhat surprising fact that such triodes are not, these days, normally manufactured as single units. We find, for instance, that some valves consist of a triode voltage amplifier in combination with one or more dioes, all of these being contained within a single envelope. These particular valves are known as single-diode-triodes or double-diode-triodes, as applicable. Again, a triode may be contained in a single envelope with a second triode of similar characteristics, giving a combination which is described as a double-triode. Another common valve is the triode-pentode, in which a voltage amplifying triode is combined with a pentode. The function of the latter is, typically, that of providing sufficient power to drive a loudspeaker.[1]

The scarcity of single voltage amplifier triodes is due to developments and improvements in valve design. At present, it is possible to manufacture voltage amplifier triodes which occupy relatively little space, whereupon it becomes economically desirable to combine these with other valves in single envelopes. No conventional domestic radio equipment employs a single triode on its own without any other valves, and the present-day designer chooses from the currently available range of double-triodes, diode-triodes and triode-pentodes, etc., to find a combination which best meets his particular requirements. If the equipment being designed is, for instance, a radio receiver which requires only one triode voltage amplifier amongst its complement of valves, the designer may choose a suitable type combined with one or more diodes (which can be used for signal detection) or combined with a pentode (which may be used to drive the loudspeaker). If the equipment is a tape recorder, which requires a large amount of audio frequency amplification in its circuits, then double-triodes, consisting of two voltage amplifiers in one envelope, may be pressed into service. Despite the apparent anomaly that voltage amplifier triodes are not normally manufactured as single units at the time being, the combinations in which they appear can be readily incorporated in conventional equipment designs.

This situation did not hold true in the earlier days of radio, when valve development had not reached its present level, and it was quite common practice to use single triode voltage amplifier valves. Noteworthy among the earlier types is the valve type 6J5, this consisting of a single indirectly heated triode fitted to an octal base. This valve still appears in current manufacturers' lists as a "maintenance type". Since it is mounted on an octal base it is much more bulky than a triode of similar performance in a modern valve combination.

[1] Pentodes will be discussed in a later article.

All valves are given type numbers and, where necessary, a brief explanation of each type number will be given as it appears in these articles. The 6J5 type number just mentioned employs the American coding system, in which the first character is a number defining the filament or heater voltage.

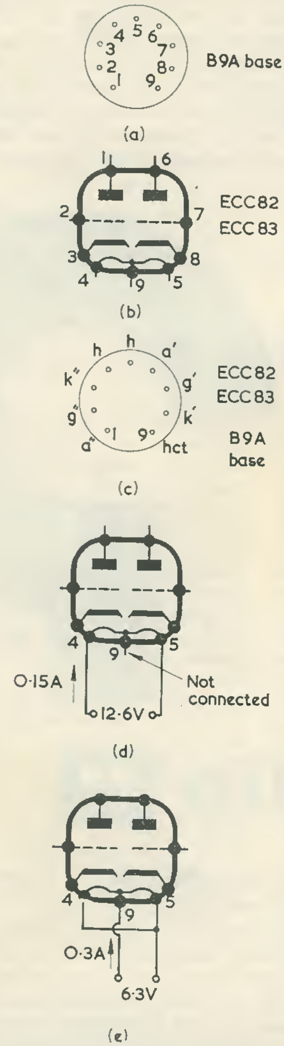


Fig. 333 (a). The B9A base has nine pins, numbered in clockwise order with the pins pointing towards the observer

(b). Illustrating the pins to which the electrodes of the ECC82 and ECC83 connect. These double-triodes are also manufactured under the type numbers 12AU7 and 12AX7 respectively

(c). An alternative method of showing pin connections for the ECC82 and ECC83

(d). The ECC82 and ECC83 may be heated from a 12.6 volt supply by connecting to the heater in the manner shown here

(e). Alternatively, the two halves of the heater may be connected in parallel and run from a 6.3 volt supply

The 6 in 6J5 refers to a rated heater voltage lying between 5.6 and 6.6 volts. In practice, the rated heater voltage for the 6J5 is 6.3, this being a heater voltage which is very frequently encountered in valves intended for use in mains-driven equipment. All other commonly encountered valves using the American code whose type number commences with the figure 6 also have heaters rated at 6.3 volts. The first number is followed in the American coding system by a letter, or letters, which are allocated in sequence to new valves as they are introduced to the market. The letter (or letters) has no significance to the user, apart from the obvious one of identification.[2]

A second number follows the letter (or letters) and this is intended to define the number of "useful electrodes" which are brought out to the external circuit. With the 6J5, the 5 applies to the heater, the cathode, the grid, the anode, and an outside screen which is fitted in some versions of the valve. It should be added that, apart from giving a useful indication of heater or filament voltage, the American valve coding system does not provide a great deal of information about the valve concerned.

We have stated that present-day triodes are normally combined with another valve or valves in a single envelope. It is possible to find currently produced triodes which are not so combined, but these are intended for use in special applications and not as a.f. voltage amplifiers.

ECC82 and ECC83

The two most commonly encountered double-triodes which may be employed as voltage amplifiers in present-day equipment are the ECC82 and ECC83. These valves comprise two similar triodes in the one envelope, and they are of the "all-glass" construction in which the valve pins protrude directly from the glass. Both the ECC82 and ECC83 have the B9A base. The B9A base has 9 pins, these being numbered in a clockwise direction, as shown in Fig. 333 (*a*), with the pins pointing towards the observer. The greater spacing between pins 1 and 9 prevents the valve being inserted in its holder in any position other than the correct one.

Both the ECC82 and ECC83 have the same pin connections to the electrodes and these are illustrated in Fig. 333 (*b*). Fig. 333 (*c*) shows an alternative method of indicating the electrodes to which each pin connects. In this diagram, letter "k" stands for "cathode".

Since these valves have two triodes in the one envelope, the electrodes of one triode have to be distinguished from the electrodes of the other when showing a pin connection diagram such as

[2] A minor exception which applies to octal valves is that, if there are two letters and the first is S, the valve is a single-ended near-equivalent of a double-ended type having the same type number without the S. Thus, the 6SK7 (an r.f. amplifying pentode) is a single-ended near-equivalent of the double-ended 6K7. A single-ended valve, in this context, is one having all connections brought out to the pins at the bottom, whilst a double-ended valve is one which has one connection brought out to a metal top-cap at the top of the valve in addition to those brought out to the pins.

that of Fig. 333 (*c*). In this diagram a "dash" is added after the electrode letters for one triode and two "dashes" after the electrodes of the other.

In Fig. 333 (*c*) we encounter the abbreviation "hct", which stands for "heater centre-tap". The provision of a heater centre-tap is an unusual feature in valves intended for operation in mains-driven equipment and it considerably increases the versatility of the two valves under discussion. Either valve may be heated by connecting a 12.6 volt supply to pins 4 and 5 with no connection to pin 9, as in Fig. 333 (*d*), or by connecting a 6.3 volt supply to pin 9 and pins 4 and 5 joined together, as in Fig. 333 (*e*). When connected for 12.6 volt operation, the heater current is 0.15 amp and, when connected for 6.3 volt operation, it is 0.3 amp. The ECC82 and ECC83 may, in consequence, be operated from a 6.3 or 12.6 volt supply, as required. Heaters in radio equipment are frequently connected in series instead of in parallel, whereupon it becomes necessary for all the heaters to be rated at the same current. The ECC82 and ECC83 may be fitted in a "chain" of heaters whose rated current is either 0.15 amp or 0.3 amp by making the appropriate connections to the heater pins.

The type numbers ECC82 and ECC83 follow European coding practice. In this, the first letter defines heater voltage or current, with E standing for 6.3 volts (the alternative 12.6 volt method of heater connection being ignored). The letter or letters which follow indicate the general class of valve, with letter C representing a triode. As there are two triodes, there are two C's in the type number. The following figure indicates the type of base, with figure 8 representing B9A.[3] The final figure, or figures, indicates a design or development number and has no significance, apart from identification, for the user.

The ECC82 and ECC83 are also manufactured under the American code numbers 12AU7 and 12AX7 respectively. In these the initial 12 indicates a rated heater voltage of approximately 12.6 (which is *actually* 12.6 with these two valves) whilst the final 7 indicates that seven "useful electrodes" are brought out to external connections (these electrodes consisting of one heater, two cathodes, two grids and two anodes). It will be noted that the American coding ignores the 6.3 volt heater application.

As we saw last month, the performance of a voltage amplifier may be found by drawing a loadline across its I_aV_a curves, and it will be of interest if we now carry out this process with, firstly, the ECC82 and, then, the ECC83. The I_aV_a curves for a single triode of the ECC82 are shown in Fig. 334 (*a*), and we may undertake the exercise for an h.t. voltage having the typical figure of 250.[4] A representative anode load resistor would be 100kΩ whereupon, following the procedure we saw in last month's article, we can draw a loadline from the 250 volt point on the V_a axis to the 2.5mA point on the I_a axis. We choose 2.5mA because this is the current which would flow through the load for zero anode voltage.

The loadline is included in Fig. 334 (*a*), and visual inspection indicates that the spacing between the points where the curves cross the loadline appear to be more equal to the left of the −5 volt curve. It would be reasonable, in consequence, to arbitrarily pick a quiescent operating point at −3.5 volts, as has been done in the diagram. Our choice of quiescent operating point results in a quiescent anode voltage having the rather

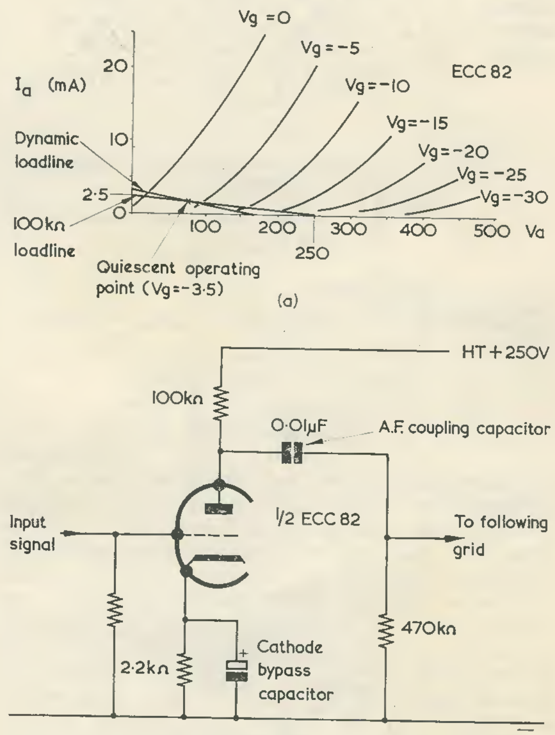


Fig. 334 (a). Adding a 100Ω loadline for 250 volts h.t., and a subsequent dynamic loadline, to the I_aV_a curves of a single triode of the ECC82. The quiescent operating point is chosen at —3.5 volts for V_g (as judged between the V_g=0 and V_g=—5 curves). I_aV_a curves for the ECC82 are usually issued with 5 volt spacing between V_g parameters, which makes results obtained from the loadline construction approximate only. (The curves shown here and in Fig. 335 (a) are presented for purposes of illustration and may contain slight inaccuracies. Readers wishing to work with the curves for the valves concerned should use those issued by the valve manufacturers)
(b). One triode of an ECC82 connected in a circuit which corresponds to the dynamic loadline of (a). The heater is omitted for simplicity. The a.f. coupling capacitor has the typical value of 0.01μF

[3] If the first figure after the letter or letters is 1, the figure immediately following this indicates the base type.
[4] The IaVa curves appearing with this article are intended for purposes of illustration only and may contain slight inaccuracies. Readers wishing to carry out accurate work should employ the curves issued by valve manufacturers in their literature.

low figure of 80, which is slightly below the range of 0.4 to 0.8 of the h.t. supply voltage which was mentioned last month. The low anode voltage figure is not undesirable, however, if the choice of quiescent operating point ensures that the anode signal is not too distorted a copy of the signal applied to the grid.

If the valve is used in a conventional circuit we have to take the following grid resistor into account, and this could have a typical value of 470kΩ. 100kΩ and 470kΩ in parallel give a resistance of 82kΩ, and the dynamic loadline, with a slope equal to this resistance, is then drawn through the quiescent operating point. The results given by this loadline appear to be reasonably acceptable by visual inspection. Since our quiescent operating point is at −3.5 volts, the positive excursion of the input signal cannot exceed this figure without the onset of positive grid current. At the same time, a negative grid excursion of as much as 8 volts approximately can take place before the valve is cut off. The valve could, therefore, handle an input signal of slightly less than 3.5 volts peak without introducing an excessively high level of distortion. Lower distortion should be offered at reduced input signal levels.

As we have stated, the quiescent operating point is at −3.5 volts and this corresponds to an anode current of approximately 1.6mA, as read from the diagram. If we are using cathode bias, this anode current will then flow through the bias resistor. Since we require a bias of 3.5 volts (to bring the valve to the quiescent operating point) the value of the bias resistor (from $R=\frac{E}{I}$) is 2.2kΩ.

To check voltage gain we may examine the anode voltage change corresponding to a change in grid voltage from −5 to zero. The change in anode voltage is approximately 75 volts, whereupon the voltage gain, under working conditions, is $\frac{75}{5}$, or 15.

Fig. 334 (*b*) shows one of the ECC82 triodes in a working circuit, this incorporating component values which correspond to the dynamic loadline of Fig. 334 (*a*).

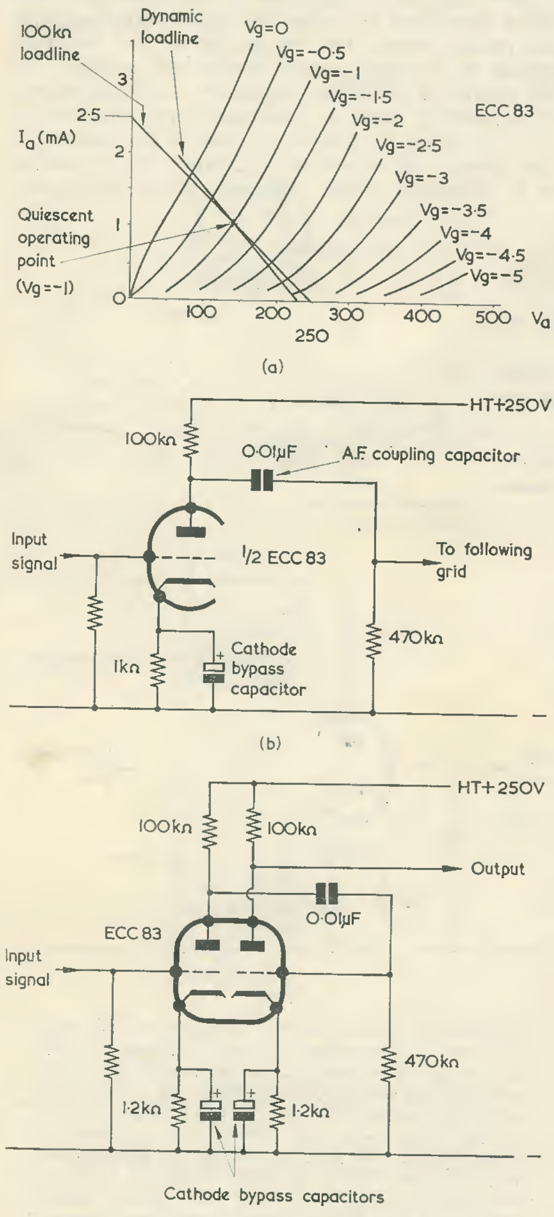


Fig. 335 (a). The loadline construction for one triode of an ECC83
(b). The ECC83 triode in a working circuit corresponding to the dynamic loadline drawn in (a)
(c). If the two triodes of the ECC83 are connected in cascade, as shown here, the overall voltage gain is 2,500 times

In Fig. 335 (*a*) we repeat the process, using the I_aV_a curves of one of the triodes of an ECC83. An anode load resistor of 100kΩ would, again, be a representative value, and we draw the loadline for an h.t. voltage of 250. A quiescent operating point at −1 volt appears reasonable, after which we draw a dynamic loadline with a slope of 82kΩ, to take into account a following grid resistor of 470kΩ. As may be seen, input signals up to a peak value of 1 volt are handled without excessive distortion. The quiescent operating point corresponds to 1.1mA anode current, and so the cathode bias resistor needs to be 900Ω. A value of 1kΩ would be adequate in practice, and the valve, with component values, is shown in Fig. 335 (*b*).

An examination of Fig. 335 (*a*) shows that, along the dynamic loadline, a change in grid voltage of 1 (from $V_g=-0.5$ to $V_g=-1.5$) brings about a corresponding change in anode voltage of 50. Thus, the voltage gain of the ECC83 triode is 50, a significantly higher figure than that for the ECC82. If we were to connect the two triodes of the ECC83 in cascade, as we do in Fig. 335 (*c*), the total gain will be 50 x 50, or 2,500. The two triodes of the ECC82, similarly connected, would give an overall gain of 15 x 15, or 225.

By comparing the ECC82 and ECC83 triodes we have found that the ECC83 triode offers greater gain in a working circuit than does the ECC82. From the I_aV_a curves it may be seen also that the ECC82 cuts off at a considerably greater negative grid voltage than does the ECC83, and this latter factor can be of advantage in some applications.

In Fig. 334 (*b*) and Figs. 335 (*b*) and (*c*), the cathode bias resistors are bypassed by electrolytic capacitors. As we saw in the August 1965 issue, a cathode bypass capacitor needs to have a low reactance at the frequencies being handled if cathode degeneration is not to occur. A suitable practical value for the capacitor in the diagrams just mentioned would be 25μF, which corresponds to a reactance of approximately 120Ω at 50 c/s. In all the circuits, the voltage dropped across the bias resistor is relatively quite low, and in each case the capacitor could be a component having a rating of, say, 6 volts working.

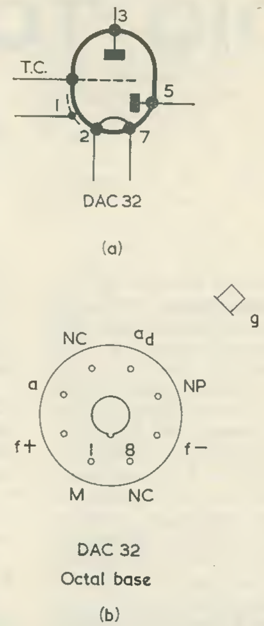


Fig. 336 (a). Circuit symbol for the DAC32, a battery operated triode voltage amplifier combined with a diode
(b). The DAC32 is mounted on an octal base, and has the pin connections shown here

DAC32

It will be helpful, next, to briefly examine a battery voltage amplifier triode, and see what differences exist between this and a triode intended for mains-driven equipment. However, voltage amplifier triodes for operation from batteries in domestic equipment have not been in general use for a number of years, and it is necessary to select rather an early valve if this class of triode is to be represented.

Figs. 336 (*a*) and (*b*) show the symbol and pin connections for a typical example, this being the DAC32. As will be seen, the DAC32 consists of a diode-triode, and it is fitted to an octal base. The circuit symbol for the DAC32 is given in Fig. 336 (*a*), the letters "T.C." in this diagram indicating that the grid connection is made via a metal top cap. Fig. 336 (*b*) shows the octal base, with pins numbered 1 to 8 in a clockwise direction, and with pins 1 and 8 on either side of the locating key of the centre spigot. The letters "f" stand for "filament", whilst "a_d" denotes the diode anode. The letters "NC" mean that no connection is made to the pin concerned, and "NP" indicates that no pin is fitted to the base at the point designated. The letter "M" stands for external metallising on the glass envelope, which provides a screen for the valve.

The filament supply required by the DAC32 is 1.4 volts at 50mA. In practice, the filament is designed to run from a dry cell whose voltage is nominally 1.5, but which will, during the useful life of the cell, average at around 1.4. Valves in this category draw a small anode current and are intended to operate from h.t. voltages of the order of 90 only. A typical anode load value would be of the order of 250kΩ, resulting in a voltage gain of around 30.

It should be noted that the filament pins for the valve are designated positive and negative in Fig. 336 (*b*), and that the filament supply should be applied with the polarity indicated. The grid resistor may be connected to the negative filament pin. Ignoring the effect of "contact potential", the result of this connection is that the negative end of the filament has the same potential as the grid whilst the positive end is 1.4 volts positive of the grid, with the consequence that an effective average grid bias of about −0.7 volt appears at the grid relative to filament. The diode anode is mounted at the negative end of the filament.

In the coding, DAC32, the letter D indicates that filament voltage lies in the range 0.5 to 1.5, whilst the A indicates a single diode and the C indicates a triode. The following number, 3, applies to an octal base. An equivalent valve with American coding is the 1H5, the figure 1 applying to a filament voltage in the range of 1.6 or less, and the figure 5 applying to 5 useful electrodes (filament, grid, anode, diode anode and, in some versions of the valve, screen).

Next Month

In next month's issue we shall consider a final factor which affects triode performance, this being Miller Effect. We shall then proceed to examine the triode as oscillator.

RADIO TOPICS . . .

by Recorder

A very popular feature in *The Radio Constructor* over the last few years has been the ingenious designs produced by Sir Douglas Hall, who seems to be able to get transistors and valves to do pretty well everything except actually jump through the hoop.

Sir Douglas's article "Simplicity And Sensitivity With 3 Transistors", which appeared in the November 1965 issue, has resulted in a letter from Mr. T. W. Hudson, Technical Adviser to the Civil Service Motoring Association Ltd. Since the points raised by Mr. Hudson have a general interest, I thought it would be a good idea to start off this month by quoting his letter.

Simplicity and Sensitivity

"Car radio circuitry," writes Mr. Hudson, "being just a side-line of my duties as Technical Adviser to this, the largest private Motoring Association in the World, with some 150,000 members, I can still be interested in something 'different'. So I found an odd moment to put your 3-transistor circuit together. The results are quite astonishing!

"After constructing the circuit precisely as your article directed, I then experimented with a 5in 3 ohm speaker, using a Repanco step-down transformer which I happened to have. This resulted in a vast improvement in tone and volume. I have not (yet) had time to check the 'matching' of this Repanco TT46 transformer, but no doubt a primary of 75/80 ohms, with secondary of 3 ohms, would be a very useful modification to this circuit—always provided that size is not critical!"

In reply to Mr. Hudson's letter, Sir Douglas Hall mentions that a larger loudspeaker will, of course, always give greater volume and, by producing more bass, better quality. But it would appear that Mr. Hudson has chosen exactly the right output transformer for his modification as, with a 3Ω speaker, it provides a remarkably good match to the output transistor. The primary resistance of the TT46 is lower than that of the original 80Ω speaker, with the consequence that the output transistor has, also, an increased emitter-collector voltage.

"I have," writes Sir Douglas, "tried a TT46 with an 8 x 5in speaker and, as I expected, noted the big improvement in volume and quality. The receiver was designed as a miniature, but I strongly recommend Mr. Hudson's modification if size is not important."

Variable Voltage P.S.U.

The accompanying photograph illustrates the newly introduced Lektrokit LKU-331 general purpose power supply unit, manufactured by A.P.T. Electronic Industries Ltd. As many readers will be aware, A.P.T. Electronic Industries make the well-known Lektrokit prefabricated chassis system, and it is interesting to note that the use of Lektrokit metal work in this power unit has enabled it to be offered at the competitive price of £33 net.

The power supply unit provides a variable voltage over the range 0–30 volts d.c. in three switched steps, with continuous control covering 10 volts in each step. Monitoring is by meter with a bold open scale for quick accurate setting. The unit, which is stabilised, has a fully floating output and it may be used with either pole connected to earth, or in series with any other voltage source up to 500 volts d.c. from earth.

A maximum current of 0.5 amps may be drawn from the unit, and over-current protection is provided by a trip circuit which can be set to a predetermined value by a variable control on the front panel. If this value is exceeded the output clamps to zero.

Standard Lektrokit colours of light grey for the front panel and dark hammer grey for the side and top covers give an attractive finish. Design has been aimed towards obtaining a compact construction, and the complete unit occupies only a 5in square of bench space.

The address of the manufacturer is A.P.T. Electronic Industries Ltd., Chertsey Road, Byfleet, Surrey.

Just a Passing Thought

With, by the time these notes appear, a vague possibility of

warmer weather in the offing, we can perhaps look back on a winter, during which the Central Electricity Generating Board has not always been able to meet its commitments, with a fairly dispassionate degree of detachment.

Taking this objective view, it can be easily seen that the voltage reductions in which the C.E.G.B. indulges at periods of stress produce power savings that are considerably greater than a first consideration might lead us to believe. If we look upon all the current-consuming appliances in this country as one gigantic R, then the power which has to be fed into the Grid is $\frac{V^2}{R}$

A reduction in voltage therefore results in a power saving which corresponds to the *square* of the voltage.

It would follow from this that a 2% reduction in voltage gives a 4% saving in power. And that a 10% reduction in voltage gives a 100% saving in power; whereupon no generators are needed at all.

Microwave Tunnel Diode

Those fascinating devices, tunnel diodes (do you remember the series of articles by J. B. Dance way back in our issues for November 1960 to January 1961?) continue to crop up in new applications from time to time, and it is of interest to record that Mullard Ltd. are now manufacturing the first microwave tunnel diode to be produced in the U.K. This is the outcome of work by scientists at the Wembley Laboratories of Associated Semiconductor Manufacturers Ltd., which is the manufacturing and development Company for Mullard semiconductors.

The diode is already in use as a low-noise amplifier in the receiver of the new solid-state microwave communications link of G.E.C. Telecommunications Ltd., which can handle 960 telephone channels or one colour television signal.

The diode is designed for use in low-noise amplifiers at frequencies up to S-band (2 to 4 Gc/s) and samples are available with minimum cut-off frequencies of 6, 8 and 10 Gc/s (type numbers AEY13, AEY15 and AEY16 respectively). A Gc/s, or gigacycle per second, is equal, by the way, to 10^9 cycles per second, or 1,000 Mc/s.

Negative resistance of the diode is typically 50Ω, whilst peak-point current and peak-point voltage are 2mA and 50mV, with a typical series resistance of only 0.75Ω. The valley voltage is 300mV, and the peak/valley ratio is typically 8.

These characteristics can give an amplifier with a noise figure of 3.8dB, as compared with about 4.5dB for an amplifier using other tunnel diodes.

An additional feature of the Mullard diode is its improved robustness, which is achieved by using a tin/arsenic alloying bead only 0.015mm in diameter. This reduces the amount of electrolytic etching required to produce the small junction capacitance essential in a device of this type.

The housing for this tiny diode measures only 1.5mm in diameter by 1.4mm long. The requisite low inductance has been partly achieved by making short connections of rectangular cross-section to connect the p-n junction to the housing. The use of rectangular cross-section foil, rather than circular cross-section wire, also increases the mechanical strength of the device.

Keeping Things Cool

If, like me, you enjoy dabbling with experimental transistor circuits, you must almost inevitably bump into the situation where an application requires just a little more dissipation from a small transistor than the manufacturer's literature says it should give when mounted in free air. In many cases, the answer to this problem is to use one of the lobed radiation fins stocked by Henry's Radio Ltd.

These fins have been available over the last twelve months or so, but I must confess that I've only started using them recently. And I've found them so extremely convenient that I feel a special reference to them here would not be out of place.

The type of fin I've been using myself is intended for TO5 transistors (although it should fit other transistors whose cases have nearly the same diameter) and it has a circular corrugated metal construction having a maximum outside diameter of about $\frac{5}{8}$in and a length of $\frac{1}{2}$in. The fin does not form a complete circle and, to fit it on, you simply insert a screwdriver blade in its slot, twist slightly to increase the internal diameter, and then spring it on to the transistor case, where it stays in position snugly and reliably. An extremely useful and reliable little device.

Henry's Radio also have a similar fin whose dimensions are $\frac{5}{16}$in outside diameter by $\frac{1}{2}$in long, and which is intended for TO18 cases (or cases with nearly the same diameter). Both fins are quoted for a thermal "resistance" of 0.05° C/mW and are priced at 1s. 6d. And, as I said just now, they're just the job for those little transistor applications where a wee bit of extra dissipation is called for.

EMI WINS SPANISH CONTRACTS

EMI Electronics Ltd has been awarded two contracts worth a total of £76,000 to supply and install central control and network switching equipment for the Spanish Television network.

Under the first contract, worth some £66,000, EMI engineers will install equipment for a complete central control at Television Espanola's newly-completed production centre at Prado del Rey, near Madrid. The equipment will coordinate the outputs of nine studios, extensive video tape recording and telecine facilities and remote signals.

The installation, due to be operational by next spring, provides presentation and engineering control for the simultaneous transmission of two programmes. It also incorporates equipment for control and distribution of three independent sets of pulses for the various programme areas.

Facilities are provided for switching married sound and vision, and all vision programme switching will be carried out using EMI's plug-in semi-conductor modular equipment. Special effects equipment will also be included and a storage system will allow up to 10 picture sources to be pre-set on each programme.

The second contract, worth about £10,000, is for the supply and installation of equipment for Television Espanola's switching centre in Madrid. This installation will provide facilities for networking programmes from the production centres in Prado del Rey and Barcelona, as well as local programmes and remote outside broadcasts.

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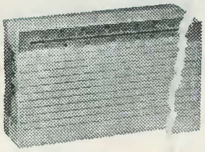
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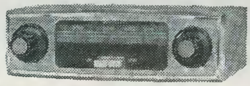
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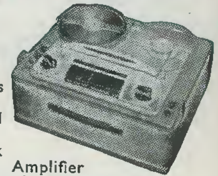
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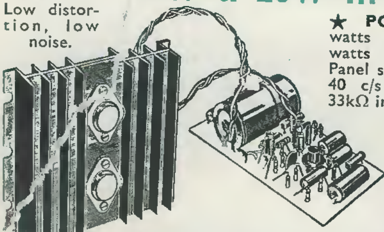
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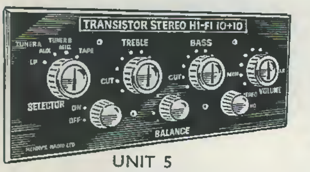

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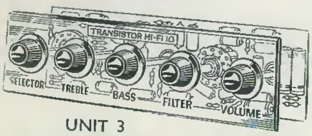

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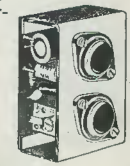
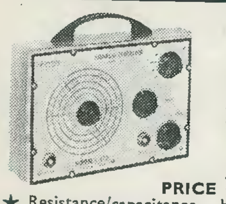
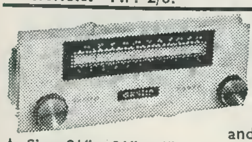
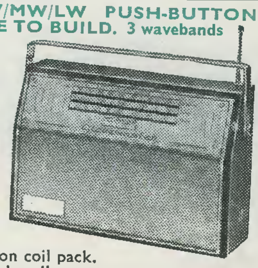
★ Size only 2¾" x 2" x 1½".
★ 5 watt 18 volt, 1½ watt 12 volt.
★ For 3 to 5 ohm speakers.
★ 7mV into 1kΩ 30 c/s to 16 kc/s.

PRICES BUILT
1½w 65/- P.P. 1/6 — 5w 79/6 P.P. 1/6

● **Mono PREAMPLIFIER**
Full range of controls, inputs for mics, p.-u., tuner, etc. Output 6–10mV. Suitable for any sensitive transistor amplifiers as above. 7½/12/18V operated. **Price** built/tested incl. panel **79/6.** P.P. 2/6.

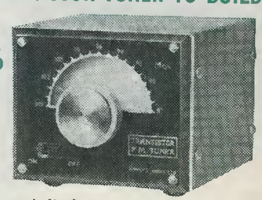
HI-FI ALL MAKES AVAILABLE—New Hi-Fi Demonstration Room Opening Shortly

TRANSISTOR PORTABLE TEST EQUIPMENT

All units size 6⅜" x 4⅝" x 2¾".
★ RF generator, 150 kc/s to 350 Mc/s in 8 ranges. RF, Mod. RF, AF outputs.
PRICE **£9.10.0** P.P. 2/6
★ Resistance/capacitance bridge. **£8.5.0.** P.P. 2/6.
★ Audio generator 10 c/s–100 kc/s. 4 ranges. **£16.15.0.** P.P. 2/6.

VHF/FM TUNER TO ASSEMBLE

★ Two pre-built plus metal work and front panel. Total Cost **£12.17.6.** P.P. 2/6.
★ Size: 9½" x 3½" x 4".
★ 88 to 108 Mc/s tuning.
★ 100mV to 100kΩ output
★ 6-Transistor printed cct. superhet design.

NEW SW/MW/LW PUSH-BUTTON PORTABLE TO BUILD. 3 wavebands
TOTAL COST **£8.19.6** P.P. 3/6

The only *fully* Tunable 3-waveband radio for home construction.
★ Push-button coil pack.
★ 1 watt push-pull output.
★ Ferrite aerial/Telex. aerial/special car coils.
★ Printed circuit 6-transistor design.
★ SW 17/50m. LW 1100/1900m. MW 195/550m.
★ Car aerial and tape sockets.
★ Attractive sturdy cabinet with handle. Size 11" x 7½" x 3¼". Black fabric with chrome fittings.

LET US QUOTE PARTS FOR YOUR CIRCUIT, SEND LIST FOR QUICK REPLY

VHF/FM TRANSISTOR TUNER TO BUILD
TOTAL COST **£6.19.6** P.P. 2/6 (complete with frontplate) (Goldsprayed cabinet **20/-** extra).


★ 5-Transistor 4 diodes.
★ Printed circuit superhet.
★ Geared tuning 87 to 105 Mc/s FM.
★ RF stage and double tuned IFT's.
★ Output up to 1 volt peak up to 100kΩ.
★ 9 volt 9mA supply.
★ Size in cabinet 4" x 3½" x 2¼".
★ All parts sold separately.

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