15 5P.

THE Radio Constructor

RADIO
TELEVISION
AUDIO
ELECTRONICS

VOLUME 18 NUMBER 11
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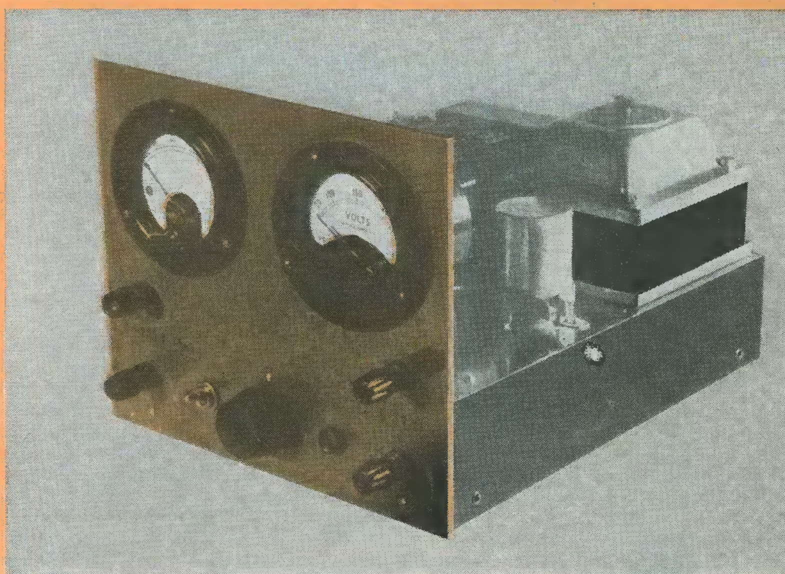
TWO SHILLINGS & THREEPENCE

June 1965

VARIABLE H.T. SUPPLY



Beginner's Amplifier ★ Stereo Balance Meter ★ Mains Failure Alarm ★ Principles of Laser Operation

THE EDDYSTONE HIGH STABILITY AMATEUR BANDS COMMUNICATIONS RECEIVER

–the EA 12

The Eddystone "EA12" receiver is specially designed and built to give the extremely high performance, allied with ease of control, necessary for communications on the amateur bands under present-day conditions. With the many refinements included, this model will produce first-class results with all modes of signal.

The first oscillator is crystal controlled. The oscillator which is tuned simultaneously with the first intermediate frequency section has very high stability, as is so essential with reception of s.s.b. and c.w. signals. The correct degrees of selectivity for optimum performance are obtained in the second intermediate frequency (100 kc/s) stages.

A more than adequate degree of bandspread is provided by the superb slow-motion drive (140/1 reduction ratio) in conjunction with the wide linear scales, each of which covers 600 kc/s. A crystal calibrator and cursor adjuster permit accurate frequency resolution.

Other features to note—full coverage on six amateur bands; switched sideband selection; fine tuning control (s.s.b.); crystal filter; deep slot filter; noise limiter effective all modes; large "S" meter; two AGC time-constants; independent gain controls; stand-by sensitivity control; bright scale illumination; robust construction; modern styling and fine finish.

£185

Comprehensive information obtainable from any Eddystone Distributor or from the Manufacturers:

STRATTON & CO.LTD. EDDYSTONE WORKS. BIRMINGHAM 31.

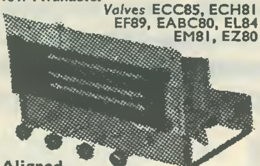
Telephone: PRIORY 2231-4 Telegrams: STRATNOID BIRMINGHAM Telex: 33708

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 11¼" 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 Spakers 10" Rola, 27/6. 13½" x 8" E.M.I. Fidelity, 37/6. 12" R.A. with conc. Tweeter, 42/6. Carr. 2/6.

ANOTHER TAPE RECORDER BARGAIN

Manufacturers' end of production Surplus Offer

A 24 gns. Tape Recorder offered at the bargain price of only **15 gns.** plus 10/– carr. Supplied in 3 Units already wired and tested. A modern Circuit for quality recording from Mike Gram or Radio, using latest B.S.R. Twin Track Monardeck Type TD2. Valve line-up—EF86, ECL82, EM84, EZ80 and Silicon Diode. **Send for detailed list—3d. stamp.**

Complete Kit comprising items below

BARGAIN PRICE 15 Gns. + 10/– Carr.

2-tone Cabinet and 7" x 4" Speaker. Size 14" x 3" x 7½"	£3 5 0 + 5/– Carr.
Wired Amplifier complete with 4 Valves, front Panel, Knobs, etc.	£5 19 6 + 3/6 Carr.
B.S.R. Monardeck Type TD2	£7 7 0 + 4/6 Carr.
Accessories: Mike, Tape, empty Reel, screened Lead and Plugs, Instructions, etc.... ...	£1 0 0 + 2/– Carr.

Jack Plugs. Standard 2¼" Igranic Type, 2/6. Screened Ditto, 3/3. Miniature scr. 1¾", 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.
Grundig Continental. 3 p. or 5 p. plug, 3/6. Sockets, 1/6.

Soldering Irons. Mains 200/220V or 230/250V. Solon 25 watt Inst., 22/6. Spare Elements, 5/6. Bits, 1/3 65 watt, 27/6 etc.
Alumin. Chassis. 18g. Plain Undrilled, folded 4 sides, 2" deep, 6" x 4", 4/6, 8" x 6", 5/9, 10"x 7". 6/9, 12" x 6", 7/6, 12" x 8", 8/– etc,
Alumin. Sheet. 18g. 6" x 6", 1/–, 6" x 9", 1/6, 6" x 12", 2/–, 12" x 12". 4/6 etc.

RECORDING TAPE

Famous American Columbia (CBS) Premier quality tape at NEW REDUCED PRICES. A genuine recommended Quality Tape—TRY IT Brand new, boxed and fully guaranteed. Fitted with leader and stop foils.

Standard		Double Play		Long Play	
5" 600'	13/–	1,200'	31/6	900'	17/6
5¾" 900'	16/–	1,800'	37/6	1,200'	19/6
7" 1,200'	21/–	2,400'	47/6	1,800'	28/6

SPECIAL OFFER. 3" Message tape 150', 3/9; 3" L.P. 225', 4/9; 3" D.P. 300', 6/6. P. & P. per reel 6d.

Post & Package per reel, 1/– plus 6d. each for additional reels.
TAPE REELS. Mnfrs. surplus 7", 2/3; 5¾", 2/–; 5", 2/–; 3", 1/3; Plastic spool containers, 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		

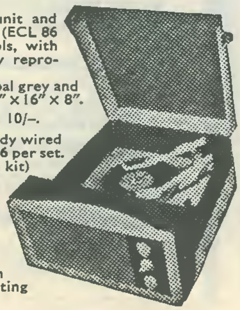
Ersin Multicore Solder 60/40, 4d. per yard. Cartons 2/6, etc.

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. 10/–.

Illuminated Perspex escutcheon, 7/6 extra. Ready wired 30/- extra. 4 Contemporary legs (6" or 13") 12/6 per set. 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/–.

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 11¾" x 4" x 5¾". A recommended Fidelity Unit for use with Mullard "3-3" or "5-10" Amplifiers. Available only at present as built-up units, aligned and tested ready for use.
Bargain Price £12.10.0. Carr. 5/–. This popular unit will be available in kit form within the next few weeks. Circuit and constr's details, 2/6.

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. 6/6. 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.

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.
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. 3/– 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 Ring, 1" dia., **9d.** each; 1⅛", 1/– each; Brown or Ivory with Gold Centre, 1" dia., **10d.** each; 1⅛", 1/3 each. LARGE SELECTION AVAILABLE.

TRANSISTOR COMPONENTS

Midget I.F.'s—465 kc/s $\frac{7}{16}$" diam.	5/6
Osc. Coil—$\frac{7}{16}$" diam. M/W.	5/3
Osc. coil M. & L.W.	5/9
Midget Driver Trans. 3.5:1	6/9
Ditto O/Put Push-pull 3 ohms	6/9

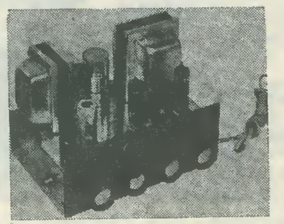
Elect. Condensers—Midget Type 15V 1mfd–50mfd, ea. 1/9. 100mfd. 2/–.
Ferrite Aerial—M. & L. W. with car aerial coupling coil, 9/3.
Condensers—150V. wkg. .01 mfd. to .04 mfd., 9d. .05 mfd., .1 mfd., 1/–. .25 mfd., 1/3. .5 mfd., 1/6, etc.
Tuning Condensers. J.B. "00" 208+176pF, 8/6. Ditto with trimmers, 9/6. 365pF single, 7/6. Sub-min. ¾" DILEMIN 100pF, 300pF, 500pF, 7/–.
Midget Vol. Control with edge control knob, 5kΩ with switch, 4/9, ditto less switch, 3/9.
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.

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. 48 hr. Alignment Service 7/6. P. & P. 2/6.

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

3 OHM AND 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 £6.19.6. Carr. 5/–. **Wired and tested 8 gns.**
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.**

CONTROL PANEL KIT
Bass, Treble and Volume controls with 4-position selector switch for radio, tape and pick-up and 11" x 4" escutcheon panel.
Amplifier Kit and Control Panel Kit £11.19.6. Ditto ready wired £14.19.6.

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".
Complete Kit £5.19.6. Carr. 3/6. **Ready built £7.19.6.**

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

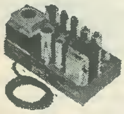
70 Brigstock Road, Thornton Heath, Surrey
THO 2188. *Hours; 9 a.m.–6.m., 1 p.m. Wed. Terms C.W.O. or C.O.D. Post and Packing up to ½ lb. 9d., 1 lb. 1/3, 3 lb. 2/3, 5 lb. 2/9, 8 lb. 3/6.*

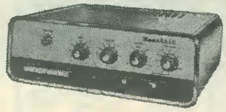
Choose Heathkit models for value and performance

Heathkit DAYSTROM

Easy-to-follow instruction manuals tell you how to build any model

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

MA-12


S-99


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

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 **£27.19.6** Assembled **£37.19.6**

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**

A wide range of American equipment available under direct mail order scheme. Full details and catalogue 1/– post paid.

INSTRUMENTS


IM-13U

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

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

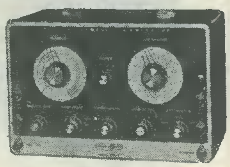

V-7A

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

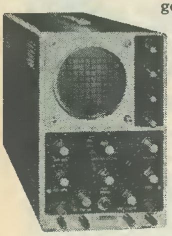

RF-1U

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

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


HFW-I

T.V. ALIGNMENT GENERATOR. Model HFW-1. Offers max performance at lowest cost. Covers 3.6 to 220 Mc/s fundamentals. Electronic sweep oscillators. Built in marker generators (5 Mc/s crystal). **£34.18.0** Kit **£44.10.0** Assembled


IO-12U

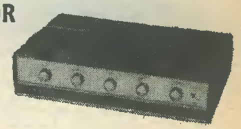
5″ GENERAL-PURPOSE LABORATORY OSCILLOSCOPE. Model IO-12U. This outstanding oscilloscope, with its professional specification and styling, fulfils most laboratory and service requirements. Vertical frequency response 3 c/s to over 4.5 Mc/s, sensitivity 10mV r.m.s. per cm. at 1 kc/s. T/B covers 10 c/s–500 kc/s. Kit **£32.12.6** Assembled **£41.10.0**

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

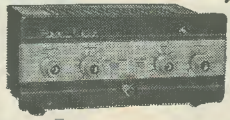
ELECTRONIC SWITCH. Model S-3U. Converts a single beam 'scope to double beam operation at low cost. Kit **£12.18.0** Assembled **£18.10.0**

TRANSISTOR TESTER, IM-30U. Gives complete d.c. analysis of NPN, PNP Transistors and Diodes. Large, easy-to-read meter. Kit **£24.18.0** Assembled **£35.10.0**

NEW! De-luxe ALL TRANSISTOR 20+20W STEREO AMPLIFIER
AA-22U.



At last a British amplifier, with high power at reasonable cost, capable of delivering full power at all frequencies in the audio range. Handsome, fully finished walnut veneered cabinet. New, compact, professional slim-line styling. Kit **£43.18.0** Assembled **£68.16.0**

S-33


AT-6


GOLDRING LENCO TRANSCRIPTION PLAYER. Model GL-58. With G-60 pick-up arm and Ronette 105 cartridge. **£20.1.3** incl. P.T.

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

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

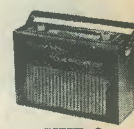
HI-FI MONO AMPLIFIER. Model MA-12. 10W output, wide freq. range, low distortion. Kit **£11.18.0** Assembled **£15.18.0**

R.P.M. INDICATOR (Electronic Rev. Counter). A must for the motoring enthusiast. For 4 cylinders, pos. or neg. earth. 12V. Send for details. (Assembled only) **£8.19.0**

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

TRANSISTOR RADIOS

"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-2

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.


UXR-1

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.

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


UJR-1

MANY OTHER BRITISH MODELS

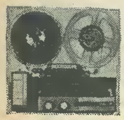
Covering a wide range of models for the home, workshop or service bench or laboratory. Why not send for Free Catalogue?

Enjoy Yourself and Save Money with these Kits

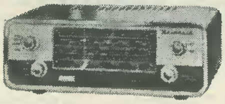
No previous experience required to build any Heathkit model

Heathkit DAYSTROM

TAPE AMPLIFIERS — TAPE DECKS — CONTROL UNITS



TRUVOX

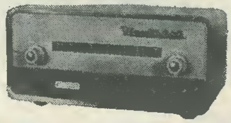


AM/FM

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

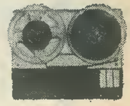
TRUVOX D-93 TAPE DECKS. High quality stereo/mono tape decks.
D93/2, ½ track, **£36.15.0** **D93/4,** ¼ track, **£36.15.0**

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—£21.16.6). Printed circuit board, 8 valves. Covers L.W., M.W., S.W., and F.M. Built-in power supply. Total Kit **£26.10.0**



FM-4U

MAGNAVOX NEW DECK



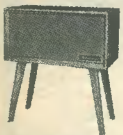
HI-FI FM TUNER. Model FM-4U. Also available in two units. R.F. tuning unit (£2.15.0 incl. P.T.) with I.F. output of 10.7 Mc/s, and I.F. amplifier unit, with power supply and valves (£13.3.0). Total Kit **£15.18.0**

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

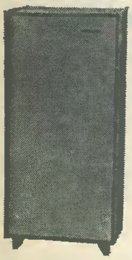
MONO CONTROL UNIT. Model UMC-1. Designed to work with the MA-12 or similar amplifier requiring 0.25V or less for full output. 5 inputs. Baxandall type controls. Kit **£8.12.6** Assembled **£13.12.6**

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

SPEAKER SYSTEMS



SSU-1



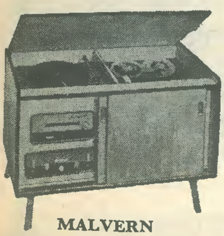
MFS

HI-FI SPEAKER SYSTEM. Model SSU-1. Ducted-port bass reflex cabinet "in the white". Two speakers. Vertical or horizontal models with legs, Kit **£11.12.0,** without legs, Kit **£10.17.6** incl. P.T.

COTSWOLD "MFS" SYSTEM. Designed to give best possible results where floor space is at a premium. This minimum floor space model is based on standard Cotswold. Size: 36" high x 16¼" wide x 14½" deep.
Kit **£23.4.0** Assembled **£30.15.0**

THE "COTSWOLD". This is an acoustically designed enclosure 26" x 23" x 15½" housing a 12" bass speaker with 2" speech coil, elliptical middle speaker together with a pressure unit to cover the full frequency range of 30–20,000 c/s. Capable of doing justice to the finest programme source, its polar distribution makes it ideal for really Hi-Fi Stereo.
Kit **£23.4.0** Assembled **£30.15.0**

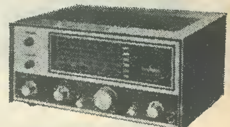
HI-FI CABINETS



MALVERN

A wide range of equipment cabinets is available to meet the differing needs of enthusiasts. Designed for max. operating convenience or for where room space is an overriding consideration, this range includes kits, ready assembled cabinets or fully finished cabinets, and has at least one model to suit your requirements. Send for full details.
Prices from **£7.15.0** to **£44.2.0** incl. P.T.

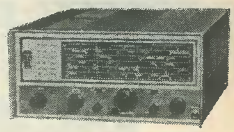
"AMATEUR" EQUIPMENT



RA-1

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

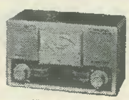
THE "MOHICAN" GENERAL COVERAGE RECEIVER. Model GC-1U. With 4 piezo-electric transfilters, variable tuned B.F.O. and Zener diode stabiliser, this is an excellent fully transistorised general purpose receiver for Amateur and Short wave listeners. Printed circuits, telescopic aerial, tuning meter and large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



RG-1

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

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



HM-11U

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

AMERICAN HEATHKIT "AMATEUR" EQUIPMENT

A wide range of American Amateur SSB equipment is now available in the U.K. Why not send for full details of range, for example:

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

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

SB-300E

SEND FOR FREE BRITISH HEATHKIT CATALOGUE

American catalogue also available 1/- post paid

Deferred terms available in U.K. over £10. Extended terms over £75. Send for details.

DAYSTROM LTD DEPT. RC. 6 GLOUCESTER

Without obligation please send me (Tick here)
FREE BRITISH HEATHKIT CATALOGUE ....
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(Please write in BLOCK CAPITALS)
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ADDRESS ....
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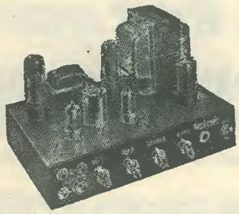
THE GOLDENAIR "THIRTY"
HI-FI AMPLIFIER

A high quality 30-watt amplifier developed for use in large halls and clubs etc. Ideal for bass, lead or rhythm guitars, schools, dance halls, theatres and public address. Suitable for any type of mike or pick-up. Valve line-up: two EF86; one ECC83; one GZ34; two EL34. Four separate inputs are provided with two volume controls. Bass and Treble controls are incorporated. Amplifier operates on standard 50 c/s mains. 3 ohm and 15 ohm speakers may be used. Perforated cover with carrying handles can be provided if required, price now 25/–.
Customers are invited to see and hear this amplifier at our shop premises at Lambert's Arcade or our new York shop. Send S.A.E. for illustrated leaflet. Available in kit form, price **£11.19.6.** Constructional notes 5/– extra. Carriage 15/– to be sent with order.

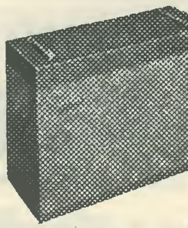


CARAVAN RADIOS

These well made radios were designed for the Government for forces entertainment. Contains 6K8, 6K7, 6Q7, and 6V6 output. Has choke smoothing, and slow motion tuning. Printed scale. 200–550 metres. In good condition. Complete with built-in 6V power back and 8" high quality speaker, all contained in a sturdy wooden cabinet. Ideal for use with your caravan or car. Will work from standard 6V car battery or easily converted for mains operation. Price **£3.19.6,** p/p 10/–.

RE-HOUSE YOUR AMPLIFIER

Heavy Duty Amplifier Cabinet size 28" x 20" x 10". Attractive 2-tone finish. Will take most amplifiers and two 12" loudspeakers. Robust construction. Manufacturer's surplus to clear at **£7.19.6,** p/p 10/–.



2-WAY RADIOS

Compact trans/receiver that can be held in the hand. Size approx. 15" x 4" x 4". Range up to three miles under favourable conditions. Uses miniature valves and self-contained standard batteries. Easy to operate, economical to run. Ideal for authorised fixed or mobile operation. A G.P.O. licence should be obtained. Available in kit form, at **10 gns.,** p/p 10/–. Already built **12 gns.,** p/p 10/–.

WANTED

WE WISH TO PURCHASE FOR SPOT CASH, RADIO COMMUNICATION EQUIPMENT: TRANSMITTERS, COMMUNICATION RECEIVERS, TRANSCEIVERS (Government surplus, Commercial and Foreign). WE ARE SURE THAT MANY ENTHUSIASTS HAVE UNWANTED EQUIPMENT TAKING UP SPACE AND COLLECTING DUST. SO LOOK AROUND AND TURN YOUR REDUNDANT EQUIPMENT INTO CASH. OFFERS MADE FOR ANY SUITABLE EQUIPMENT. SEND FULL DETAILS STATING TYPE, MAKE AND CONDITION, WITH S.A.E. FOR QUOTATION TO BUYING DEPT.

MORSE KEYS

Morse key assembly. Key with base, cover and terminals. Complete with lead. **6/11,** p/p 2/–. 2 Morse Keys for **12/6** post free.

YORK SHOP

Extensive new shop premises now open at

97 Walmgate, York

Large selection of radio and electronic components and equipment. Full range of communication equipment in stock. Callers welcome.
Open 9 a.m.–5.30 p.m. weekdays, 9 a.m.–6 p.m. Saturdays. Half-day Wednesday.

COMMUNICATION RECEIVER R1155

This famous Bomber Command receiver covers 75 kc/s to 18 Mc/s in 5 ranges. The sets are easily and simply adapted for mains operation. In very good condition and in perfect working order. Fitted with latest type super slow motion tuning assembly. Price only **£7.19.6,** p/p 10/–. Limited stock only.

MONSTER PARCEL No. 3

Six crocodile clips. One portable mains soldering iron, 6 phono plugs, 6 coils of multi-cored solder, 6 valves, 3 TV aerial plugs, 12 British octal valve holders, 12 wafers, 3 car aerial plugs, 3 sheets of 10" x 6" paxolin, 6ft. copper rod aerial, 3 sturdily made panel mounting fuse holders, 24 new resistors, 6 assorted pots, 1 operators unit, a very useful piece of equipment. All this for only **25/–,** p/p 3/6.

OC71
2/11,
p/p 6d.

OC44
3/11,
p/p 6d.

OC45
3/11,
p/p 6d.

XD202,
diode
1/6,
p/p 6d.

DYNAMOTOR

Run all your mains A.C./D.C. equipment from your car battery. 6V input gives 250V output, or 12V input gives 500V output at 30 watts. Very low battery drain. Size only 5½" x 3½". A must for the caravanner. ONLY **25/–,** p/p 3/6.

M.A.T. Transistors. M.A.T. 100, 7/9; M.A.T. 120, 7/9; M.A.T. 121, 8/6; Ferrite slab aerials suitable for Transistor sets, 3/–, p/p 6d.

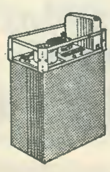
SURPLUS HANDBOOKS

19 set Instruction Handbook 3/6 each, p/p 6d.
1155 Instruction Handbook 3/6 each, p/p 6d.
H.R.O. Instruction Handbook
3/6 each, p/p 6d.
Frequency Meter, BC 221 Instruction Handbook 3/6 each, p/p 6d.
46 Walkie Talkie Set Circuit and Notes
3/6 each, p/p 6d.
38 set A.F.V. Instruction Handbook
Price **3/6** each, p/p 6d.
R.F. Unit 24 Circuit Diagram and Details
Price **1/6,** p/p 3d.
R.F. Unit 25 Circuit Diagram and Details
Price **1/6,** p/p 3d.
R.F. Unit 26 Circuit Diagram and Details
Price **1/6,** p/p 3d.
Receiver R1355 Circuit Diagram and Details
Price **1/6,** p/p 3d.
Receiver R1224A Circuit Diagram and Details
Price **1/6,** p/p 3d.
R.1116/A Circuit Diagram and Details
Price **1/9** p/p 3d.
Wave Meter Class D Handbook, Mk. I, II III Price **3/6,** p/p 6d.
18 set Mark III circuit details and notes.
Price **3/6,** p/p 6d.

Tank Aerials. Fully interlocking copper sections one foot in length. Will make ideal dipoles, car or scooter aerials. Price 6 sections complete with canvas carrying case 3/6, p/p 1/6. Additional sections 6d. each. Please include sufficient postage.

19 set Trans/Rec. Mains Power Pack. Operate your 19 set receiver straight off the mains. Ready built power unit, complete with modification and fitting instructions. Price **59/6** p/p 3/6. Please state Model, MK. 2 or MK. 3.

WIRELESS SET No. 38 AFV



A lightweight walkie-talkie with transmitting range 5 to 10 miles and frequency coverage 7.4 to 9 mc/s. Operates from 12V and 120V external dry batteries. Large, clearly numbered tuning control, with tuning lock. In good condition. ONLY **£4** per pair, p/p 5/–.

OPERATORS UNIT

Huge purchase enables us to offer at give away price operators unit containing standard jack socket 250 mfd. electrolytic condenser, 4-way telephone socket, midget selenium rectifier, etc. Price **3/6** post free, or 2 for **6/6** post free.

RESISTOR COLOUR CODE INDICATORS

Enables you to determine value of a resistor at a glance. A must for the constructor. Saves time. Price **1/6** each, p/p 3d.

High quality Paxolin Sheets. Strong high quality Paxolin sheets. Size 10½ x 8½ x 1/10". Three for five shillings, p/p 1/–. Six for 10/– post free. Twelve for 18/6 post free.

Trawler Band Receiver. A compact 4 semiconductor receiver. Complete with personal listening earpiece. Receives amateur and maritime stations. You will be amazed at the stations that can be received on this set. Works from standard batteries. Available in kit form with full completion instructions. Price **49/6,** p/p 1/6.

Postage rates apply U.K. only. S.A.E. with all enquiries
New walk round store open in Lambert's Arcade, Lower Briggate, Leeds 1, next to Halfords Cycle Shop. Open all day Saturday.
All mail orders to our Briggate House address.

Terms
Cash with order
5/– extra on C.O.D. orders
No C.O.D. under 30/–

SONA

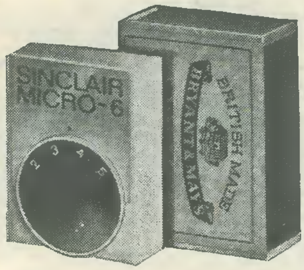
Send 1/– for lists
Trade supplied
Orders from
abroad welcomed

SONA ELECTRONIC CO (DEPT RC5) BRIGGATE HOUSE, 13 ALBION PL. LEEDS 1.

SINCLAIR X-20

INTEGRATED 20 WATT P.W.M. AMPLIFIER & PRE-AMP

MICRO-6



THE SMALLEST AND MOST PRIVATE SET ON EARTH

Smaller than a matchbox, this world-famous receiver brings in stations from all over Europe. It performs with fantastic efficiency in cars, buses, trains and steel-framed buildings, yet measures only $1\frac{4}{5}$" x $1\frac{3}{10}$" x $\frac{1}{2}$". Wherever you use it, it can interfere with no one else in even the most public places. The highly stable six-stage circuit provides A.G.C. and bandspread for easy Luxemburg reception. Tunes over medium waveband. Building this smart minute set is easy. Its performance is wonderful.

All parts inc. 3 M.A.T. transistors, case, lightweight earpiece and instructions come to **59/6**

MALLORY MERCURY CELL
ZM.312 (2 required), each 1/11
Pack of six, 10/6

For all you have ever wanted

COSTS LESS, HAS GREATER

The Sinclair X-20 integrated Pulse Width Modulated 20 watt amplifier and pre-amp outdates every amplifier in its class for power, for quality, for size and cost. Having successfully pioneered P.W.M. for constructors, the Sinclair research team have built further advances into X-20 to make it the most advanced audio amplifier in the world. It has a 95% energy conversion factor at full output. It has shown no sign of stress or strain after being continuously run at 40% overload for 12 hours. You can add tone, volume (mono or stereo) and equalisation systems to choice and thus ensure correct matching to the input source. With brilliant transient response, flat frequency response from 20 to 20,000 c/s and enormous power, the X-20 will give you all you will ever require from an audio amplifier, yet it measures only $8\frac{1}{4}$ x $3\frac{1}{4}$ x 1" and requires no heat sink. The saving in cost is enormous, and the entire unit can be built and installed in an evening.

CIRCUIT DESCRIPTION

The Sinclair X-20 uses a pulse repetition frequency between 65 to 75 kc/s, having a perfect square wave formation in which constant amplitude is maintained at all times irrespective of the extent the A.F. modulation. Special silicon epitaxial planar transistors having a cut-off of 60 Mc/s are used in the output stage. With rise and fall times of less than 0.2 microseconds they ensure a fantastically high energy conversion factor of at least 95%. Barely a watt is dissipated in the output transistors when the X-20 is giving an output of 20 watts R.M.S. The complete linearity of the integrator together with the careful design of the modulator ensure absolutely negligible distortion right up to maximum output. Two negative feed back loops in the pre-amp define gain and maintain a completely flat response from 20 to 20,000 c/s. A low-pass filter cutting off above 20 kc/s in the output makes the amplifier widely tolerant of the type of load to which it is connected.

What users say about SINCLAIR P.W.M. AMPLIFIERS

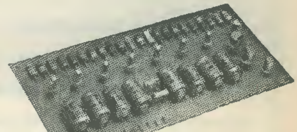
"The results were so remarkable that I purchased a further kit to replace my valve stereo system."
S.M., Glemsford, Suffolk

"It is everything you claim it (X-10) to be, it is so good that I can hardly believe it is true. Thanks for a wonderful instrument."
K.D., Abbeymount, Edinburgh

"The amplifier delighted myself and others with its beautiful crisp quality."
W.L., Leeds, 2

For those wanting the same quality with less power

SINCLAIR X-10



The X-10 uses P.W.M. with integrated pre-amplifier and offers the same outstanding advantages as the X-20 but with 10 watts peak output. It measures only 6" x 3". Thousands of these units have been built and are in regular use. For 12–15 volts D.C. operation. Tone control system added to choice.

Complete kit with 11 transistors and X-10 Manual **£5.19.6**

Ready built and tested **£6.19.6** *X-10 power supply unit* **£2.14**

SINCLAIR RADIONICS LTD.,
COMBERTON, CAMBRIDGE Telephone: COMBERTON 682

Years ahead in design, efficiency and quality

from a hi-fi amplifier, yet it

POWER AND IS EASY TO BUILD

20 WATTS R.M.S.

FROM A UNIT ONLY $8^1/_4$" x $3^1/_4$" x 1"

plus these vital features

- ★ Easily built in an evening
- ★ No. of transistors—12
- ★ Output transistors—Silicon epitaxial planars
- ★ Frequency response—20 to 20,000 c/s ±1dB
- ★ Total harmonic distortion at 10 watts R.M.S.—0.1%
- ★ Input sensitivity—1mV into 5-K ohms
- ★ Signal-to-noise ratio—better than 70dB
- ★ 20 WATTS R.M.S. MUSIC POWER OR 15 WATTS R.M.S. CONTINUOUS POWER INTO 7.5Ω
- ★ 15 WATTS R.M.S. MUSIC POWER OR 12 WATTS R.M.S. CONTINUOUS POWER INTO 15Ω
- ★ For use with any type of pick-up, microphone, radio tuner, tape pre-amp, etc.
- ★ Makes an ideal P.A. amplifier, guitar amplifier, etc.
- ★ Built-in low pass filter cutting off above 20 Kc/s
- ★ Power required—36Vdc at 700mA.

Weighs 4½ ozs!

Complete kit of parts with X-20 manual

£7.19.6

Ready built and tested **£9.19.6**

X-P.2 power supply unit for up to 2 X-20's **£4.19.6**

X-20 MANUAL

Included with every X-20 P.W.M. amplifier. Details choice of tone and volume control systems, mono and stereo, and also selector switching circuits. The manual also explains the unique principles used in this remarkable amplifier. Available separately, 2/– post free.

FULL SERVICE FACILITIES ALWAYS AVAILABLE TO ALL SINCLAIR CUSTOMERS

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for which I enclose Cash/Cheque/Money Order value £..........s..........d.

NAME..

ADDRESS..

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Guarantee

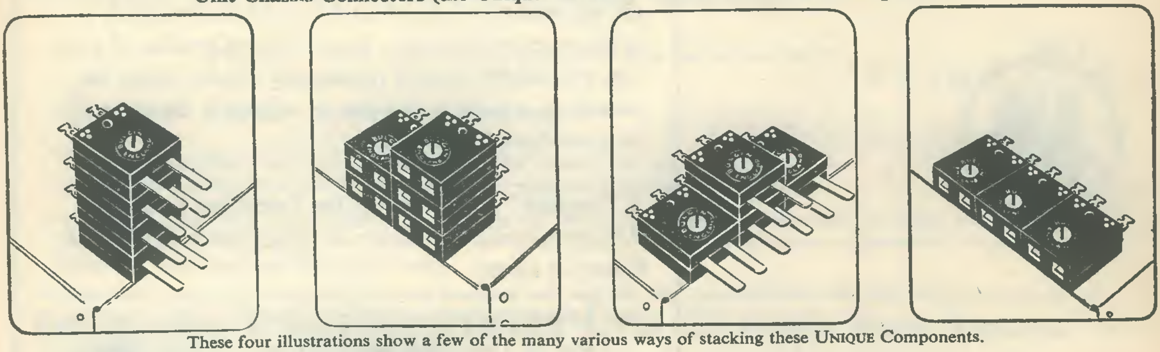
Should you not be completely satisfied with your purchase when you receive it from us, your money will be refunded in full and at once without question. Please quote R.C.6 should you prefer to write your order instead of cutting out this coupon.

HOME RADIO (MITCHAM) LTD.

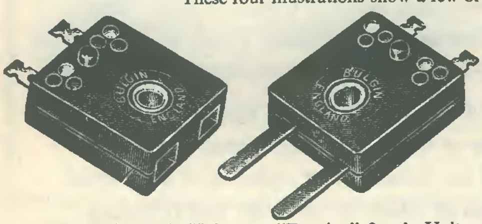
Once again we are presenting a page from our catalogue in the hope that it will make you eager to see the other 199 pages. You will notice that this particular page is filled with Bulgin Components, and we are delighted to say that this is only one of many pages devoted to Messrs. A. F. Bulgin products. After all, if Bulgin Components are the choice of the connoisseur they are the choice of Home Radio, and ultimately we hope your choice too! Post the Coupon below . . . today.

Mains Connectors—*Continued* Maker: **Bulgin**

Unit-Chassis Connectors (the Unique "Domina" 2-Pole Units for Multi-pole Uses)



These four illustrations show a few of the many various ways of stacking these UNIQUE Components.

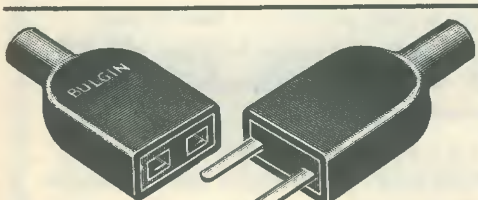


"Domina" 2-pole Unit-Socket List No. P491 "Domina" 2-pole Unit-Plug List No. P490

ELECTRICAL DATA

Cat. No.	2-pole Unit=	Max. amps. at Up to 6–12 v. ∼	Max. amps. at Up to 250 v. ∼	Size	Price s. d.
P490 :	Plug	10 amp.	5 amp.*	$\frac{7}{8}$ in. × 1 in. × $\frac{3}{8}$ in.	1 9
P491	Socket	10 amp.	5 amp.*	$\frac{7}{8}$ in. × 1 in. × $\frac{3}{8}$ in.	2 0

* For rupturing when loaded. Otherwise 10 amp., ∼ or = at 250 v.

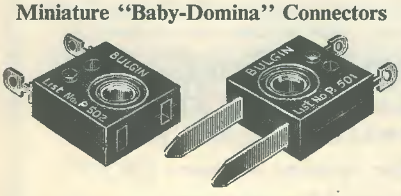


Rubber Cover List No. P/N9452 Rubber Cover List No. P/N9452

Cat. No.	Price s. d.
9452	1 3

New P.V.C. Black Insulation Covers for BULGIN "Domina" Connectors to enable safe external flex connexions, thus widening their use to many more applications. They quickly slip on to the plug and socket members, holding extremely tightly once in place. List No. (Cover only) 9452.

Miniature "Baby-Domina" Connectors



List No. P502 (Socket) List No. P501 (Plug)

ELECTRICAL DATA

Cat. No.	2-pole unit	Max. amps. at max. proof-test v., 50 ∼ Up to 6–12 v. ∼	Up to 250 v. ∼ between poles	Size	Price s. d.
P501	Plug	6 amp	3 amp.*	$\frac{11}{16}$ in. × $\frac{21}{32}$ in. × $\frac{5}{16}$ in.	2 0
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WORKSHOP AMPLIFIER

POWER SUPPLY FOR THE BEGINNER

By E. GOVIER

When equipping his workshop, the beginner usually commences by building a spare power supply and follows this with a simple amplifier for general purpose work or for a.f. signal tracing. In the unit described in this article, which has been specifically designed for the beginner, the writer combines both of these functions in a single design

The beginner, once having gone through the process of building several receivers, both battery and mains operated, t.r.f. or superhet, usually arrives at the stage where a commencement must be made on equipping his workshop with the first necessities for efficient operation. One of the very first things needed is a spare power supply, this being required (*a*) to produce the necessary supplies for ancillary equipments such as a pre-selector, crystal oscillator and frequency standard, or (*b*) to power experimental receivers or other equipment under construction or test. A simple amplifier is very often needed for use (1) as the a.f. and output stages of an experimental receiver, or (2) as an a.f. signal tracer.

With the unit described here, both of these circuits have been incorporated on one chassis. Once completed, it may be placed on a shelf above the workbench, where it will be very frequently called upon to "earn its keep". The speaker is mounted on the front panel, this also being fitted with a panel lamp assembly to provide an indication of whether the unit is switched on or off. The volume control is also mounted on the panel and incorporates the mains on/off switch.

When the unit is required simply as a power supply for small equipments, such as a pre-selector, etc., whose h.t. current requirements are not more than about 40mA, then the amplifier valve (V_1) may be left in position—this drawing 32mA under quiescent conditions. If the power supply is required for larger units, such as a complete receiver or a further amplifier, then V_1 should be removed from its holder. In this condition, all the power supply current is available for the equipment under test or construction. The total power supplies available under these conditions are 250 V.h.t. at 75mA and 6.3V a.c. at 2.85A.

The audio output power given by the amplifier section is 2.5 watts—more than enough for the average workshop. The amplifier is remarkably hum free, this being due to the fact that a good quality l.f. choke is included, together with adequate reservoir and smoothing capacitor values. In addition, a second form of smoothing is included in the h.t. positive input line to the amplifier section.

Circuit

The circuit is shown in Fig. 1 and is reproduced in such a manner that the white circuit symbols may be blacked-out with a ball-point pen as each connection is made, thus obviating possible errors and assisting the beginner in that the actual practice of construction can be related to circuit representation.

A coaxial input socket is provided on the front panel and this connects, via C_1, to the volume control R_1. This latter component is of the type which incorporates a double-pole on-off switch, the latter being shown as S_1 in the a.c. mains input to the power supply.

The required amount of signal is tapped off R_1 by its slider and is fed, via a length of coaxial screened cable, to the grid of $V_{1(a)}$. The outer metal braiding of this coaxial cable must be earthed to the chassis at the input socket end. Bias for the triode amplifier of $V_{1(a)}$ is supplied by the cathode components R_2 and C_2. H.T. is supplied to the anode via R_5, the amplified audio signal being passed to the pentode power output section, $V_{1(b)}$, via the coupling capacitor C_5. Bias for this section is supplied by C_3 and R_3, the resistor R_4 being the grid leak. The resultant amplified audio signal appears across the primary of the output transformer T_1, this being connected in the anode circuit of $V_{1(b)}$, and is coupled thence to the speaker.

The resistor R_6 and the electrolytic capacitor C_4 form a second smoothing circuit for the amplifier section, and contribute materially to the ripple-free performance of this amplifier.

The colours shown around the output transformer, T_1, refer to its wire connections. The same applies to the colours shown around the mains transformer, T_2.

The power supply section will be seen to be fully isolated from the mains supply by the mains transformer T_2, the primary of which has tappings for either 200, 220 or 240V a.c. input. The transformer also has a 5V 2A heater tapping (not shown for reasons of clarity). In the present design, both this 5V and the 6.3V centre-tap wires are unused, being taped securely so that they can make no connection to chassis or any other wire.

All the components used in the power supply section are adequately rated and it will be found to run cool even after prolonged periods of use.

Construction

The panel and chassis drilling details are shown in Fig. 2 (*a*) and (*b*), Fig. 2 (*c*) being for the chassis rear apron.

The first task is to drill the front panel as shown in Fig. 2 (*a*). To hole A will be fitted the coaxial input socket (½in diameter), to B the volume control/a.c. mains switch (⅜in diameter), to D the indicator lamp (⅜in diameter), and to C the speaker (4in diameter). The latter is shown here as a circular cut-out, over which an expanded metal grille may be later fitted. However, the cutting of a large circular hole is somewhat difficult for those without workshop facilities and it may prove an easier proposition for the beginner to simply drill a series of holes, ¼in in diameter, in a geometrical pattern (similar to the Union Jack) in which

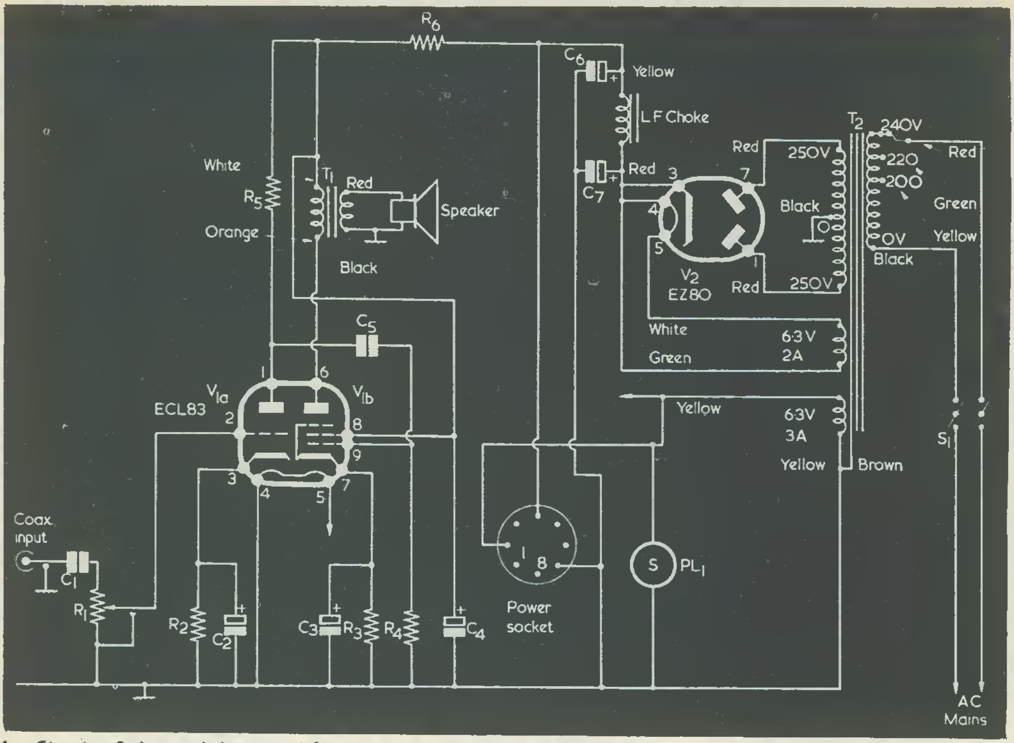


Fig. 1. Circuit of the workshop amplifier/power supply. Having completed each wiring and soldering operation in conformity with the instructions in the text, the white lines in this circuit diagram should be "blacked-out" with a pen as operations proceed. In this way the beginner will learn the relationship between circuit representation and actual practical construction

Components List

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

R_1 1MΩ log track with switch S_1
R_2 1.8kΩ
R_3 470Ω
R_4 220kΩ
R_5 100kΩ
R_6 1.5kΩ 2 watt

Capacitors

C_1 0.01μF tubular (Mullard)
C_2 10μF electrolytic 12V wkg.
C_3 25μF electrolytic 25V wkg.
C_4 8μF electrolytic 350V wkg.
C_5 0.01μF tubular (Mullard)
*C_6 32μF electrolytic 450V wkg.
*C_7 16μF electrolytic 450V wkg.
**Both contained in single can,* 16μF *reservoir, with can negative*

Valves

V_1 ECL83 (Mullard)
V_2 EZ80 (Mullard)

Valveholders

B9A with centre spigots (2 off)
I.O.

Chassis and Panel

Panel 7 x 8in, chassis 7 x 7 x 2½in (H. L. Smith & Co. Ltd.)

Transformers

T_1 Type 117E (H. L. Smith & Co. Ltd.)
T_2 Pri. 0–200–220–240V; Secs. 250–0–250V, 75mA; 6.3V (centre-tapped) 3A; 6.3V 2A, type 3104A (H. L. Smith & Co. Ltd.)

Speaker

5in round, 3Ω

L.F. Choke

20H, 100mA, 300Ω, type 101J (H. L. Smith & Co. Ltd.)

Panel Lamp Assembly

Red, with 6.3V 0.15A bulb (H. L. Smith & Co. Ltd.)

Miscellaneous

Nuts and bolts (4 and 6BA), wire, rubber grommets, solder, earth tag, mains input cable, coaxial plug and socket, 4-way tagstrip (end tags earthed)

case the metal mesh will not be required. Having drilled the panel, place this against the chassis front apron and, using holes A and B as markers, drill two similar holes in the chassis apron. Hole A, for the coaxial input socket, will require two fixing holes and the component itself should be used as a template for these, the two holes being made with a ⅛in drill.

Fig. 2 (*b*) shows the positions of both V_1 and V_2, C_6, C_7, the l.f. choke and the mains transformer T_2. All of these are mounted on the chassis deck. The output transformer T_1, shown in dotted lines, is mounted below the chassis. Only the large central holes for the two valveholders should be cut at this stage, and these should have a diameter of ¾in. This operation is best carried out with the aid of a chassis cutter and Allen key. The hole for the smoothing capacitors C_6, C_7, together with that for the power outlet socket (shown in Fig. 2 (*c*) at F), should next be dealt

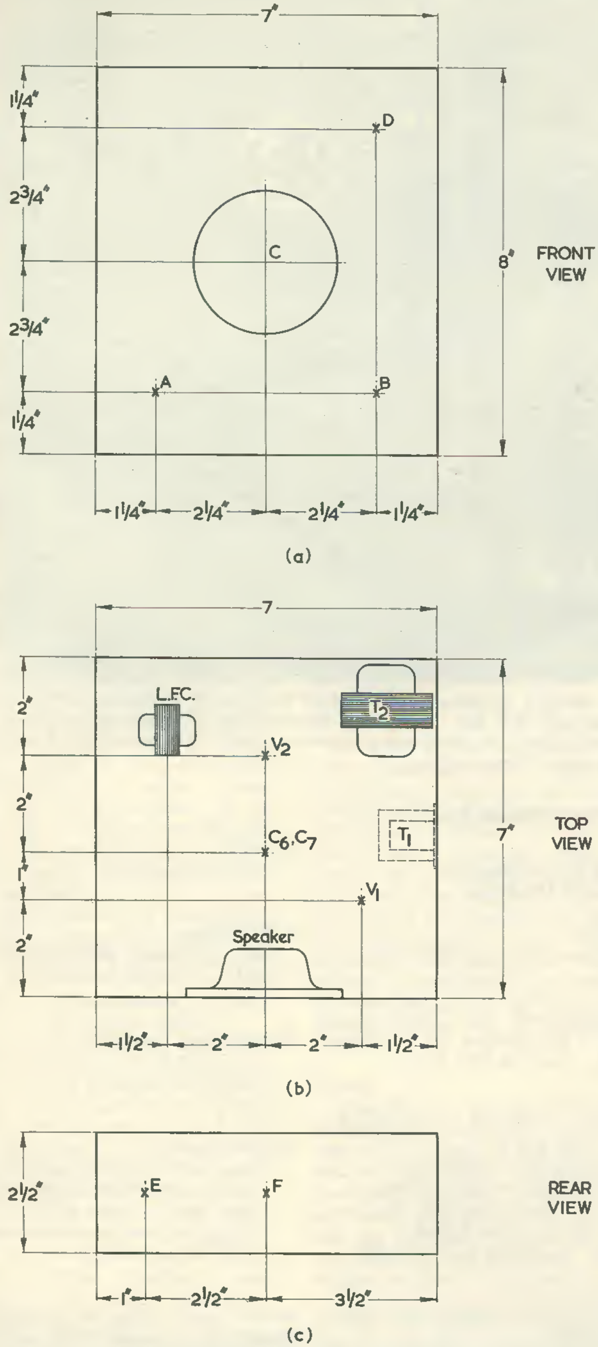


Fig. 2 (a). Front panel drilling dimensions. Holes A, B, C and D are for fitting the coaxial input socket, volume control and on/off switch, speaker and panel indicator lamp respectively
(b). Chassis dimensions showing the location of the main components
(c). Chassis rear apron. Hole E is fitted with a grommet for the mains input supply lead. Hole F is for the power outlet socket

with, these having a diameter of 1⅛in. A chassis cutter is, once again, preferable here.[1]

The l.f. choke should now be placed on the chassis deck and used as a template to mark and drill holes required for its four fixing feet and the hole required for its two leads to pass through the chassis deck, this latter hole being fitted with a small rubber grommet. The mains transformer T_2 should now be similarly dealt with. In this instance two large rubber grommets are required to carry the various leads through the chassis. Do not mount any of these components into position as yet, except for the rubber grommets.

The chassis should now be turned upside down and the component T_1 used as a template, on the *outside* of the chassis side apron, for marking and drilling the holes for its four fixing feet. It is a much easier proposition to carry out this task with T_1 temporarily held outside rather than inside. Hole E (Fig. 2 (*c*)) should now be drilled ⅜in diameter and fitted with a rubber grommet, this hole taking the a.c. mains input lead.

Secure the mounting clip to the smoothing capacitors C_6, C_7 and, using this as a template, mark the two fixing holes and drill, using a 3/16in drill. Obtain the valveholder for V_2, orient this such that pins 1 and 9 are nearest the hole for the smoothing capacitors and, using a ⅛in drill, make the two holes using the valveholder itself as a template. Similarly deal with the valveholder for V_1, orienting the component such that pins 1 and 9 are nearest the centre of the chassis. Do not fit these valveholders yet. Hole F on the rear chassis apron should now have the international octal valveholder fitted, drilling the two fixing holes using a ⅛in drill and securing into position using two 6BA nuts and bolts. Orientation here is unimportant. The 4-way tagstrip (Fig. 7) should now be fitted alongside V_1 valveholder hole such that it is parallel with and occupies a position about 2½in from the side of the adjacent chassis apron. Drill the two holes required and secure into position using 6BA nuts and bolts.

At a point 1¼in from the side of the chassis, under the pilot light and as near the front as possible, should be drilled a ¼in hole in the chassis

[1] Chassis cutters and Allen keys are available from Home Radio (Mitcham) Ltd., 187 London Road, Mitcham, Surrey. That required for the B9A valveholder is as follows: chassis cutter Cat. No. TL10 with Allen key Cat. No. TL12. That for the smoothing capacitors and the power outlet socket is chassis cutter Cat. No. TL14 with Allen key Cat. No. TL15C.

deck, this being fitted with a small rubber grommet to take the two leads required for the panel light assembly. Mark a point on the chassis some 3½in from either side and, at a position just to the rear of the speaker (when mounted), drill a ¼in hole, fitting this with a small rubber grommet. This hole will take the speaker leads from the output transformer T_1.

Now that the drilling is complete, commence to mount the remaining components into position, dealing first with the two valveholders (ensuring correct orientation) and following this by securing the smoothing capacitors (with the red tag nearest V_2). Next come T_1 on the chassis side apron (inboard), the l.f. choke and the mains transformer T_2. Note that an earthed soldering tag should be mounted under one of the securing nuts for V_2 valveholder —see Fig. 3. The valveholders will require 6BA and the smoothing capacitors 4BA nuts and bolts.

To the front panel fit the coaxial input socket and, under one of its securing nuts (6BA) fit an earthed solder tag. Also to the front panel mount the volume control R_1 and the pilot lamp assembly, following lastly with the speaker. The coaxial socket nuts and bolts, together with the volume control securing nut, will securely hold the panel to the chassis.

Care should be taken when feeding the various leads from the mains transformer through the two large rubber grommets to ensure that these grommets do not become displaced. It is a good idea here to place the chassis on the bench such that it is standing on the side apron nearest T_2 and, with the transformer a short distance away, feed the wires through the grommets one at a time, slowly moving the transformer nearer and nearer the chassis deck as this process continues, until it may be finally secured to the deck.

Wiring-up the Power Supply

The best plan for the beginner is to commence by carefully wiring up the circuit around T_2. In this manner, leads carrying a.c. potentials may be routed close to the chassis deck and kept well away from a.f. signal leads, thereby considerably reducing the probability of induced a.c. hum.

Fig. 3 shows the connections to V_2 valveholder, and the first job is to wire into circuit the mains transformer T_2. Follow the instructions in the text carefully and relate the individual drawings to the circuit of Fig. 1.

The yellow/black wire (6.3V centre-tap) is unused in this circuit and therefore the bare wire end should be carefully taped so that it makes no connection to the chassis and then tucked in the corner of the chassis out of the way.

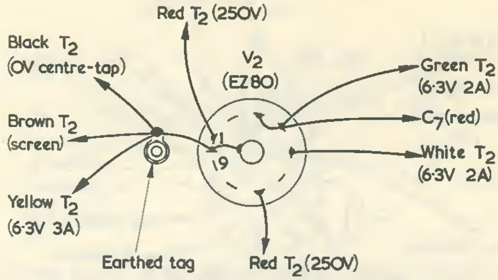


Fig. 3. Wiring diagram of V_2 (rectifier) valveholder. This is shown in an "opened-out" form for reasons of clarity

One of the thick yellow wires should be soldered to the earth tag alongside V_2 valveholder, first removing the enamel covering of the copper wire and thoroughly tinning this prior to soldering to the tag. The other thick yellow wire should be similarly dealt with and soldered to pin 5 of V_1 valveholder (see Fig. 5). These two connections are those of the 6.3V 3A heater supplies.

The green and white thick wires should next be similarly dealt with, the white wire being soldered to pin 5 and the green wire to pin 4 of V_2 (see Fig. 3). These connections are those of the 6.3V 2A rectifier heater supply.

The brown and black wires are now connected to the earth tag alongside V_2 valveholder. These connections are those of the transformer screen and OV h.t. secondary centre-tap of T_2 respectively. The earth tag should next be connected to the central metal spigot of V_2 and the associated tag as shown in Fig. 3.

One red lead is now soldered to pin 1 and the other red lead to pin 7 of V_2. These are the remaining connections to the h.t. secondary winding of T_2. Pins 3 and 4 of V_2 should now be connected together with a short length of bare wire.

Completing the wiring of V_2 valveholder, take a short length of red p.v.c. covered wire, solder one end to pin 4 of V_2 and the other end to the red tag of the reservoir capacitor (C_7).

The mauve wire (5V heater supply) should now also be taped and tucked away so that the bare end does not come into contact with the chassis. Neither this, nor the 6.3V centre-tap is shown in the circuit of Fig. 1 for reasons of clarity. The connections to the primary winding of T_2 will be dealt with at a later stage.

Fig. 4 shows the connections to the smoothing and reservoir capacitors C_6 and C_7, one connection to which, to the red tag, has already been made. The chassis connection shown in the circuit diagram has automatically been made by way of the fixing clip to the metal can.

The l.f. choke should now have one wire soldered to the red tag and the other wire to the yellow tag (C_6). It does not matter which way round the l.f. choke is connected.

From the yellow tag connect a length of red p.v.c. covered wire to pin 4 of the power outlet socket on the rear apron of the chassis. Also to the yellow tag of C_6 solder a further length of red p.v.c. covered wire, connecting the other end to tag 3 of the tagstrip associated with V_1 (see Fig. 7).

The remaining connections in the power supply are those for the a.c. mains input. The green and yellow wires from the transformer should

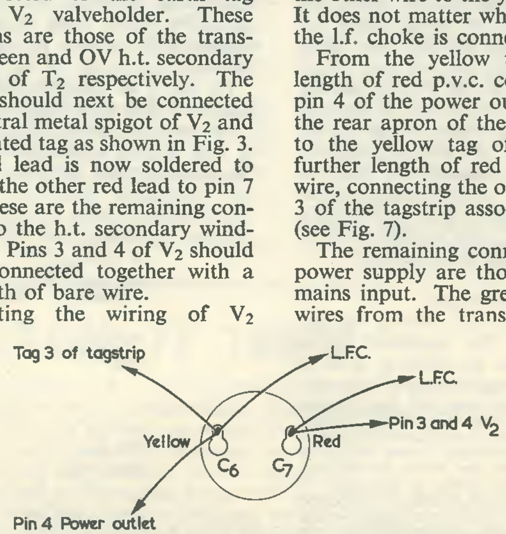


Fig. 4. The connections required to the smoothing and reservoir capacitors C_6, C_7. The chassis connection is automatically made via the securing clip and the metal can of the component itself

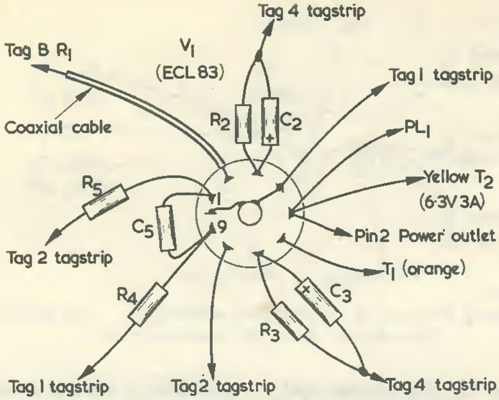


Fig. 5. Wiring diagram of the amplifier section (V_1). Note here that, where a component designation is shown with a rectangular representation, it should be soldered into circuit at that period of construction

be *separately* taped, ensuring that the bare wire ends do not make contact with each other on the chassis, and tucked out of the way. The black wire should now be soldered to tag 2 of the volume control (see Fig. 6) and the red wire to tag 1 of the volume control. To tags 3 and 4 of the same component should be secured the respective a.c. mains input wires.[2] Before doing this, however, the mains input cable should be fed through the rubber grommet on the rear chassis apron and, making due allowance for its wires to reach the volume control switch, a knot tied in the cable such that it occupies a position immediately behind the grommet. This knot will ensure that any undue strain later placed on the cable will not pull the wires away from the volume control switch, the knot taking the strain.

The wiring of the power supply section is now completed. Carefully check the connections made so far and "black out" the related portions of the circuit diagram of Fig. 1. The remaining connections to the power outlet socket and to the pilot lamp assembly will be made at a later stage in the proceedings.

Wiring-up the Amplifier

Fig. 5 shows the wiring to the valveholder of the amplifier valve V_1. Commence by joining, with a short length of bare wire, the central metal spigot and its tag to pin 4 of V_1, continuing to tag 1 of the tagstrip. To pin 1 solder one end of C_5 (0.01μF), and connect the other end to pin 9. Also to pin 9, solder one end of R_4 (220kΩ, red, red, yellow) the other end of this resistor being soldered to tag 1 of the tagstrip.

To pin 1, solder one end of R_5 (100kΩ brown, black, yellow) the other end connecting to tag 2 of the tagstrip. To pin 3 of V_1 solder one end of both R_2 (1.8kΩ, brown, grey, red) and C_2 (10μF electrolytic, 12V wkg.). Note that the positive end of C_2 must be connected to pin 3. It is a good idea here to first twist the end wires of these two components and solder them together prior to connecting them to the valveholder tag. The other ends of these two components connect to tag 4 of the tagstrip.

To pin 5 of the valveholder connect one end of a length of yellow p.v.c. covered wire. The other end of this wire is soldered to pin 2 of the power outlet socket—this latter connection being the 6.3V heater supply outlet. Also to pin 5 of the valveholder solder one end of a further length of yellow p.v.c. covered wire, feed this through the small rubber grommet below the panel lamp assembly and connect this end to one of the assembly tags —it does not matter which tag is used.[3]

To pin 6 of V_1 connect the orange wire from the output transformer T_1.

To pin 7 of V_1 connect one end of both R_3 (470Ω, yellow, violet, brown) and C_3 (25μF electrolytic, 25V wkg.) noting the polarity of the latter component. The other ends of both R_3 and C_3 then connect to tag 4 of the tagstrip.

To pin 8 of V_1 connect one end of a short length of red p.v.c. covered wire, the other end of which connects to tag 2 of the tagstrip (see Fig. 7).

The green and yellow wires of T_1 (not shown in Fig. 1 for reasons of clarity) should be joined together, soldered, covered with adhesive tape, and then tucked away under the transformer. The red and black wires from T_1 should now be fed through the rubber grommet on the chassis deck and soldered one to each tag of the speaker—it does not matter which way round these wires are connected to the speaker. One of these leads should be soldered to tag 4 of the tagstrip.

The next step is to complete the wiring to the volume control, R_1, and Fig. 6 shows the required connections to this component—some of which have already been completed.

[2] The connections described here assume that the unit will be run from 240–250 volt mains, as will in most instances be the case. For a.c. mains voltages below 240, the appropriate tap into the mains transformer primary should be made, as indicated in Fig. 1. This will mean employing the green 220 volt or yellow 200 volt transformer wire, as applicable, instead of the red 240 volt wire, the latter being taped up. The constructor should ensure that the tags of S_1 in Fig. 6 give the switching circuit shown in the inset to this diagram.—EDITOR.

[3] Some panel lampholders may have one tag common with the mounting bracket (and, thence, with chassis) whereupon connection to such a tag would short-circuit the heater winding of the mains transformer. Whatever type of lampholder is employed, ensure that the lead from pin 5 of V_1 valveholder connects to a tag which is *not* at chassis potential.—EDITOR.

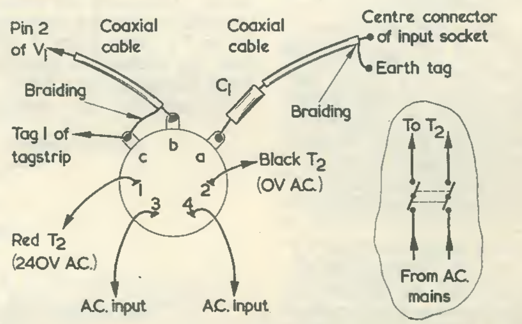


Fig. 6. Details of the wiring to the volume control and on/off switch (R_1). Ensure that tags 1, 2, 3 and 4 of the particular component employed provide the correct switching facility, as shown in the inset

To tag A connect one end of C_1 ($0.01\mu F$). The other end of this capacitor connects to the input socket on the front panel by way of coaxial cable. It should be noted that the wire end of C_1 which connects to the volume control must be cut as short as possible, the other end of this capacitor being similarly treated. This second end connects to the centre wire of a length of coaxial cable, the outer braiding of which is earthed to the earth tag mounted under one of the securing nuts of the coaxial input socket itself. The centre wire connects to the centre connection of the socket.

To tag B of R_1 solder one end of a further length of coaxial cable as shown, the outer metal braiding of this being soldered to tag C of R_1. The centre wire at the other end of this coaxial cable is connected to pin 2 of V_1.

Tag C of R_1 is now joined to tag 1 of the tagstrip via a short length of black p.v.c. covered wire. The wiring of the volume control is complete.

Turn next to Fig. 7 and complete the wiring at the tagstrip.

To tag 1 solder one end of a short length of black p.v.c. wire, connecting the other end to pin 7 of the power outlet socket. This latter connection is the h.t. negative chassis side of the heater and output.

Between tags 2 and 3 of the tagstrip connect R_6 (1.5kΩ 2 watts, brown, green, red).

To tag 2 solder the white wire from the output transformer T_1. Also connect to this tag the positive end of C_4 ($8\mu F$ electrolytic, 350V wkg.). Solder the other end of C_4 to tag 4 of the tagstrip.

To tag 4 of the tagstrip solder one end of a length of yellow p.v.c. covered wire. This wire is fed through the small rubber grommet under the panel lamp assembly and soldered to the remaining tag of the assembly.

This completes the wiring of the amplifier stage. A careful check should now be made to the wiring of this stage, the instructions in the text being again followed together with the point-to-point diagrams and the circuit of Fig. 1.

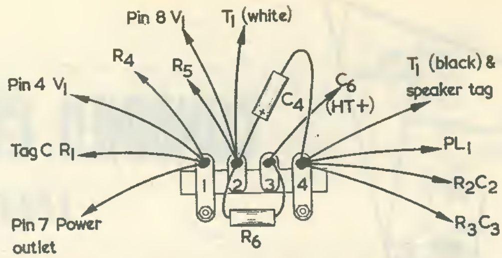


Fig. 7. Wiring details of the 4-way tagstrip. Note that both tags 1 and 4 should be bolted to the chassis

Testing the Completed Unit

The two valves should be fitted into their respective holders and the unit plugged into the mains supply and switched on. The two valves will be seen to light up as the heaters glow. Turn the chassis upside down and, with the aid of a meter (if available) take the voltage readings as shown in the accompanying table. The volume control R_1 should be at the minimum position, no connection being made to the coaxial input socket.

The meter used to obtain the figures shown has a sensitivity of 20,000Ω/volt and the readings were taken after an initial warm-up time of 5 minutes had elapsed.

As a first rough check that the amplifier is working, slightly advance R_1 and place a finger on the central coaxial input tag. A hum will be heard from the speaker, this becoming louder as R_1 is advanced to its maximum position.

The amplifier stage will be found to consume, under quiescent conditions, approximately 32mA.

In addition to its usage as a general purpose workshop amplifier, the unit may also be employed as an a.f. signal tracer. The additional requirements for this purpose are a short length of coaxial cable, one end of which is fitted with a coaxial plug for connection to the unit, whilst the centre wire of the other end terminates in a probe. The latter may be home-made from an old ball-point pen or obtained new from a retailer.[4] A short length of p.v.c. covered wire, each end being fitted with a crocodile clip, will also be required.

When a.f. tracing with a receiver or amplifier, the two chassis should be connected together by the clip lead, the probe coaxial cable being plugged into the coaxial input socket. The probe itself is then applied to the various audio points in the equipment under test, thereby ascertaining the presence of audio voltage. Care should be exercised, however, to ensure that the equipment under test is fully isolated from the mains supply, i.e. via a mains transformer, and that it is *not* of the a.c./d.c. type having the chassis live to one side of the mains supply.

TABLE

Circuit Point	*Voltage*
H.T.+ C_6 (yellow tag)	310
R_6/T_1 (tag 2 tagstrip)	262
V_1 (pin 1)	145
V_1 (pin 3)	1.5
V_1 (pin 6)	245
V_1 (pin 7)	13.2

[4] A suitable test prod, Cat. No. TP25, is available from Home Radio (Mitcham) Ltd., coloured either red or black. The colour should be stated when ordering.

NEW MULLARD TV TUBES

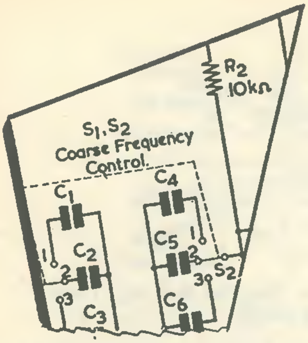
Improved picture contrast with no increase in the price of the tube is the result of a decision made by Mullard in collaboration with leading setmakers to deepen the tint of the faceplates of their current range of television picture tubes.

By tinting the glass of the TV tube faceplate the level of ambient room or window lighting normally reflected by the tube is attenuated by the tinted glass both on its way to the phosphor screen and after reflection. Such light has therefore less effect on the television picture with the result that the contrast ratio is improved.

This decision will make the company's new range of Panorama direct vision tubes the most advanced available. Already, annoying reflections from room lighting have been greatly reduced by eliminating the need for a separate protective screen. Now, with the deeper tint, reflections from the face of the tube itself are also reduced.

The Mullard Panorama range for 1965 includes the 19in (A47-11W) and the 23in (A59-11W).

Radiant Screen mono-panel tubes with the deeper tinted faceplates will be marketed under the following type numbers: 19in A47-14W (previously AW47-91); 23in A59-15W (previously AW59-91).



COMBINED CHOKE and CAPACITOR

INPUT POWER SUPPLY

SUGGESTED CIRCUIT No. 175

By G. A. FRENCH

It is quite probable that many of us are not greatly concerned with h.t. rectifier power supply circuits, and that we tend to look upon these as essential but otherwise not particularly interesting adjuncts of mains-powered equipment. Recently, however, the "Understanding Radio" feature in this magazine has dealt in detail (in the four issues from January to April of this year) with the basic operation of these circuits, with the result that the present writer, at any rate, has found himself devoting quite a little attention to the question of rectifier circuits using choke input and capacitor input filters. As was pointed out in the "Understanding Radio" articles, the choke input filter offers a rectified supply with a high degree of regulation, the rectified voltage from a full-wave circuit (assuming no resistive losses) being 0.9 times the r.m.s. voltage across half the mains transformer secondary. When a capacitor input filter is used the regulation becomes poorer, but it is possible to obtain rectified voltages which are much higher than the r.m.s. value of the voltage across half the transformer secondary. Under no-load conditions these rectified voltages may be 1.4 times that r.m.s. value. Thus, both types of input filter have their advantages and disadvantages.

It does not seem to be generally realised that, with the aid of one extra rectifier, it is possible to achieve the best of both worlds, and to obtain a circuit in which a single mains transformer supplies both a choke input filter *and* a capacitor input filter. The output from the choke input filter then has the high level of regulation which is associated with such a filter, whilst the output from the capacitor input filter circuit has the higher voltage given by filters of this type. The two outputs could then be fed to different parts of an item of equipment according to whether these require a well regulated supply or one which offers a high voltage at relatively low cost.

The circuit which provides these facilities is described in this month's article. It is not original, and has, indeed, been the subject of a United States patent. The writer first saw a short reference to it in the January 1965 issue of the Soviet journal *Radio*, this acknowledging its source of information to the May 1963 issue of *Radio-Electronics*.* The circuit takes advantage of basic first principles in a delightfully simple and ingenious manner and, for this reason alone, deserves to be far more widely known than is at present the case. It is, in fact, because it is so little known that the writer now includes it in the present series of articles.

The Circuit

The circuit of the dual-filter power supply appears in Fig. 1. As may be seen, the a.c. mains is applied to the primary of a transformer, the h.t. secondary of which is centre-tapped and feeds a full-wave rectifier, V_1, in conventional manner. The cathode of the full-wave rectifier connects to the choke and capacitor C_1, and this part of the circuit functions in the normal manner given by a conventional full-wave rectifier with a choke input filter. A well regulated direct voltage appears across C_1.

Also connected to the cathode of V_1 is a second rectifier, V_2. The rectified voltage appearing at the cathode of V_1 has the waveform shown in Fig. 2, and consists of positive half-cycles as illustrated. These positive half-cycles are applied to the anode of V_2, which then allows C_2 to charge up in the same way as does a reservoir capacitor following a conventional full-wave rectifier. Thus, a voltage higher than the r.m.s. voltage across half the transformer secondary appears across C_2, this rising to 1.4 times that r.m.s. voltage

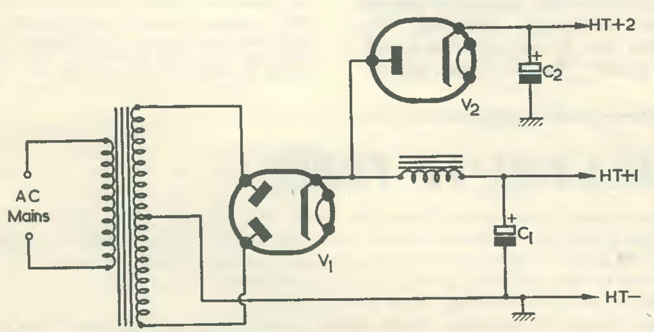


Fig. 1. Rectifier circuit incorporating both a choke input and a capacitor input filter. The HT+1 output has the high degree of regulation offered by a choke input filter, whilst the HT+2 output has the higher voltage and poorer regulation typical of the capacitor input filter

*In the issue of *Radio-Electronics* referred to, the circuit is listed under U.S. Patent No. 3,053,991. No originator or assignee is quoted and the device "may be manufactured or used by the U.S. Government without payment of royalties".

under no-load conditions. The voltage across C_2 is similar to that which would be given by a normal full-wave circuit with capacitor input filter.

The fact that the rectified voltage across C_2 may rise to a higher level than that applied to the choke does not affect the operation of the choke input filter. This is because rectifier V_2 is non-conductive except for the periods when the potential on V_1 cathode is higher than that on the upper plate of C_2.

An important feature of the circuit is that the peak inverse voltage applied to V_2 is only the peak value of the alternating voltage across *half* the transformer secondary. This fact can be readily ascertained by examining the waveform shown in Fig. 2, where it may be seen that the highest inverse voltage for V_2 appears between half-cycles, at the instants when its anode is at zero potential with respect to chassis. Under no-load conditions, C_2 will then cause the cathode of V_2 to be positive of the anode by the peak value of the voltage across half the transformer secondary, and this represents the peak inverse voltage applied to V_2.

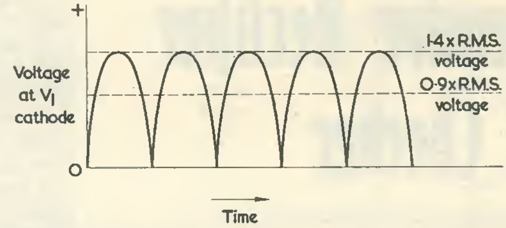


Fig. 2. The waveform at the cathode of V_1 consists of positive half-cycles (with respect to chassis) as shown here. The r.m.s. voltage referred to in the diagram is that which appears across half the transformer secondary. The output from the choke input filter is 0.9 times the r.m.s. voltage (assuming no resistive losses) whilst the output from the capacitor input filter may rise, under no-load conditions, to 1.4 times the r.m.s. voltage

This peak inverse voltage is, of course, half the figure which would have been given had V_2 functioned as, say, a half-wave rectifier.

Fig. 1 shows no smoothing circuits after C_1 and C_2 but these may, of course, be added following normal practice. C_2 should have approximately the same value as would be needed in the reservoir capacitor of a conventional full-wave circuit offering the rectified voltage and current required. Both the secondary of the transformer and V_1 should have maximum current ratings equal to or greater than the sum of the two h.t. output currents, whilst V_2 need be rated only for the rectified current drawn from the capacitor input filter.

Valve diodes are shown in Fig. 1, partly because they help in explaining the functioning of the circuit. Equivalent results would still, of course, be given if they were replaced by suitable selenium or silicon rectifiers.

CAN ANYONE HELP?

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

CR300.—G. C. Dobbs, 95 Earl Street, Grimsby, Lincs.—borrow or buy manual or circuit.

* * *

Grundig TK20 Tape Recorder.—D. Bowers, 95 Grenfell Avenue, Saltash, Cornwall—loan of circuit, also any information on microphone used with this unit.

* * *

Component Details.—F. D. Cosgrove, 2 Police House, Wethered Road, Marlow, Bucks.—information and circuit details of set of three M and LW coils in cans 1 x 1¼ x 2½in bearing identification CP93296 (aerial), CP93295 (intervalve) and CP93294 (oscillator), purchased in London about 4 years ago.

Transmitter Type 53.—M. Brereton, 38 Burma Road, London, N.16—loan or purchase of handbook or circuit for this equipment, ref. No. 10D/1310.

* * *

Emerson E708.—E. Shaw, "Sunningdale", Village Lane, Washington, Co. Durham—alignment instructions wanted.

* * *

Browneng (USA) Impedance Bridge Type 200-1.—V. Haines, 166 Welling Way, Welling, Kent—manual or any data.

* * *

Crystal Calibrator No. 7 Mk. II.—W. Bourke, 33 Victoria Street, Rutherglen, Lanarkshire, Scotland—circuit or any other information.

HERTFORD B.B.C. 2 RELAY STATION

The B.B.C. has placed a contract with Messrs. F. Hitch and Co. Ltd., of Ware, for the erection of the building for the UHF television station to be built at Bengeo, Hertford. This is one of the first group of fill-in stations being provided for viewers who, although they live within the service area of the B.B.C.-2 station at Crystal Palace, find that reception is unsatisfactory because of the screening effect of high ground or other obstacles.

Work on the Hertford station is expected to be completed in time for the service to start this summer. About 23,000 people in Hertford and Ware will be served by the new station.

Inexpensive Rectifier Checker

By Qutaiba Bassim El-Dhuwaib

Editor's Note

The rectifier checker described in this article employs an ingenious principle to test solid-state rectifier diodes having a high peak inverse voltage rating. These would include silicon diodes such as the BY100 h.t. rectifier, and it is possible that selenium h.t. rectifiers could also be tested. The checker should *not* be employed to test crystal diodes (OA71, etc.) as their p.i.v. will in many cases be exceeded, and they may break down. To obtain a figure of minimum p.i.v. in the rectifiers to be tested, that offered by the Fig. 3 circuit with a good rectifier could be checked by an oscilloscope.

We present this article because of the ingenuity of the circuit employed. We should add that the neon and mains supply voltage employed by the writer are different from those available in the U.K. and readers are advised that it may be necessary to adjust the value of one of the capacitors in the circuit of Fig. 3 to obtain satisfactory results. Variations in striking voltage from neon to neon may similarly necessitate such adjustments.

One often needs to check a power rectifier or to identify its anode and cathode, if unmarked.

Although one can judge whether a diode is good or bad by comparing its forward and backward resistance by an ohmmeter, such checks are not always reliable. In consequence, the writer designed the checker described here.

Basic Circuit

The basic idea behind the instrument is demonstrated by the circuit of Fig. 1. In this diagram, a source of alternating voltage gives a sine wave output of r.m.s. voltage E. If no current is drawn, no voltage will be dropped across C, and E volts will appear across terminals X and Y. Taking terminal Y as a reference point, the voltage on terminal X will swing from $+\sqrt{2}$ E to $-\sqrt{2}$ E.

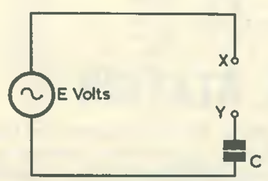


Fig. 1. When a rectifier is connected across terminals X and Y, capacitor C functions as a reservoir capacitor

If we now place a diode across the terminals we will have a half-wave rectifier with C acting as a reservoir capacitor. Assuming a perfect diode, C will be charged to $\sqrt{2}$ E volts and the voltage across it will be added to that appearing across the diode. Terminal X will now swing, with respect to terminal Y, from zero potential to $2\sqrt{2}$ E volts. This assumes a perfect diode, and a practical diode having a low back resistance will cause the capacitor to discharge slightly on non-conducting half-cycles, with the result that peak potential will be less than $2\sqrt{2}$ E volts.

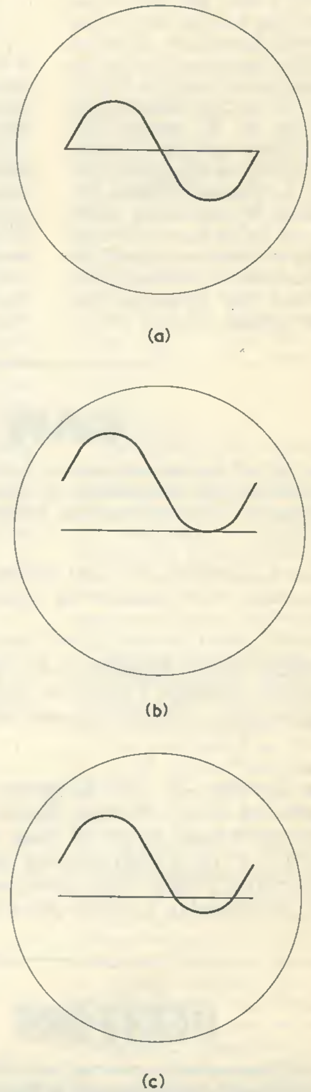


Fig. 2. Waveforms showing the voltage at terminal X with respect to Y when (a) no rectifier is connected, (b) a perfect rectifier is connected, (c) a rectifier having a low back resistance is connected

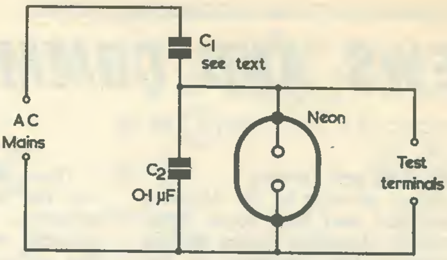


Fig. 3. The rectifier circuit finally employed

The author's rectifier checker

Fig. 2 illustrates the associated waveforms, and shows the voltage at terminal X with respect to terminal Y. In (*a*) we see the case where no diode is connected across the terminals and, in (*b*), the case where a perfect diode is connected to these terminals. Fig. 2 (*c*) shows the result of connecting a diode having a low back resistance.

The basic circuit of Fig. 1 could be used as a diode checker by connecting a neon bulb across terminals X and Y and ensuring, primarily, that $\sqrt{2}$ E is less than the striking voltage of the neon. If no diode, or an open-circuit diode, is connected to terminals X and Y, the voltage across the neon will be insufficient to cause it to strike. Connecting a perfect diode will raise the peak voltage across the neon to $2\sqrt{2}$ E, whereupon it will strike on each half-cycle to indicate a good rectifier. A rectifier having a low back resistance causes a peak voltage less than $2\sqrt{2}$ E to be applied to the neon and (if E, capacitor C, and the neon striking voltage have the requisite values) the neon will not strike. Thus, the circuit can indicate open-circuit diodes and diodes having a back resistance lower than a figure governed by the values of E, capacitor C, and the neon striking voltage.

Working Circuit

The writer made up the circuit shown in Fig. 3, in which capacitors C_1 and C_2 form a potential divider and drop the mains voltage to that required for optimum results with the neon employed. At the writer's local mains voltage of 115, C_1 had a value of 0.03µF, and it is recommended that this be dropped to 0.015µF for mains voltages around 240. The neon employed was an NE-51.*

An alternative approach would be to use the circuit of Fig. 1 with a mains transformer. The secondary of this transformer, which should offer the appropriate voltage, then replaces the a.c. generator.

The writer's unit, which employs the Fig. 3 circuit, is shown in the illustration. With the neon employed in this, one electrode glows when a good diode is connected one way round, and the other electrode glows when the diode is reversed. Thus, by suitably marking the test terminals and positioning the neon bulb, it is also possible to find the polarity of the rectifier.

*This is an American type. Readers wishing to experiment with the circuit could try results with the Hivac type 16L, available from Henry's Radio Ltd. Adjustments in the value of C_1 may be needed to accommodate this neon.—EDITOR.

POLICE POCKET RADIO TELEPHONES

Cossor Communications Company Limited announce the receipt of an order from the Home Office for 300 of their VHF pocket radiotelephone designated the Police Pocket Radiotelephone type CC2/8H. This extremely compact equipment is easily contained in a pocket and thus almost total concealment is obtained, only the miniature microphone and earpiece being external.

The equipment, which has been designed in conjunction with the Home Office, has a high output power relative to its size and being fully transistorised has a low battery consumption. Commercial versions of the equipment are available and in service.

NEWS AND COMMENT . . .

Transmitting and Driving ?

A recent decision by the Minister of Transport may have some repercussions on Amateur Radio Mobile operation. The Minister, in the interests of road safety, proposes amending the Motor Vehicles (Construction and Use) Regulations to make it an offence for a driver of a vehicle to speak into radio transmitting equipment while the vehicle is in motion.

When the new scheme for installing radio telephones is introduced this summer exemption from the foregoing provisions is to be granted to Fire Brigades, Ambulances and Police, where in any event there is usually additional personnel to handle the radio gear, and to taxis using microphones which are not held in the hand.

What the effect will be on Amateur Radio Mobile transmission we do not know at the time of writing. We have heard transmissions on the amateur bands by mobile operators who are driving their cars at the same time. Whether they have hand-held microphones or not we, of course, do not know. We do know however that the Amateur Radio Mobile Society regularly draws the attention of its members to the necessity for constant vigilance in safety measures and encourages the use of microphones attached to the vehicle or to harness; this is a very creditable policy.

If Amateur Radio Mobile operation is to continue as "mobile" as distinct from "portable operation" some agreement will no doubt have to be negotiated by the "powers that be".

Stereophonic Note

Following the extension, by the B.B.C., of the Third Network Music Programme into the afternoons, it is no longer possible for them to radiate the special test tones and programme test material for the experimental pilot-tone stereophonic transmissions from Wrotham which have been taking place on three afternoons a week. Instead, it has been decided to include experimental pilot-tone stereophonic items as part of the Music Programme transmissions from Wrotham on 91.3 Mc/s on Mondays from 2.30 to 3 p.m. and on Thursdays from 11 to 11.30 a.m.

These experimental transmissions are for the benefit of the radio industry, but listeners who have suitable stereophonic receivers and live within the service area of the Wrotham station or of the station at Swingate, near Dover, which picks up the Wrotham transmissions and re-radiates them on 92.4 Mc/s, may care to take part in the experiment by listening to them stereophonically. All other listeners to the Music Programme, whether on v.h.f. or medium wave (including those using an ordinary v.h.f. receiver tuned to Wrotham or Swingate) will be unaffected by this experiment and will hear the programme in the ordinary way.

3D by Lasers

Three-dimensional pictures, generated in space by the beam of a laser, have been demonstrated in the United States.

These 3-D images, when recorded on films, are called holograms and have been known to science for only a few months. The technique of producing them was developed by E. N. Leith of the University of Michigan. It represents a new experimental application of the laser.

Holograms differ entirely from the usual two-dimensional pictures produced on slides, films and television. The hologram itself appears to be only a greyish, mottled photographic film. But when illuminated by a laser, it forms an image having height, width and depth, which can be peeked around like a solid object hanging in space.

A hologram is made by illuminating an object with light from a laser in such a way that both the light reflected from the object and light directly from the laser beam are recorded on photographic film.

When the film is viewed with light of a single wave length, the original object springs to life because the hologram splits the light waves into an array that duplicates the light coming from the object originally.

Dr. John W. Coltman, of Westinghouse Research Laboratories, who demonstrated the holograms, said, "It has been possible to build hologram devices which recognise shapes, indicating instantly on a printed page the positions of pre-selected words. Thus, in a sense, we have an embryonic example of a machine that can read."

Helping Deaf Children

Hi-fi stereo headphones are now helping deaf children to learn to speak. Connected to a microphone and a small amplifier, these headphones can produce enough undistorted volume to enable a severely deaf child to listen to his own first efforts at forming sounds and words.

To meet this need, and for other applications in sound studios and language laboratories, Standard Telephones and Cables Limited have introduced a new combined headphone/microphone unit at a price much lower than normal.

The S.T.C. headphones are padded for comfort and can handle without distortion, sounds exceeding the "threshold of pain" level for a normal ear. Since the earphones are wired for binaural use, the volume to each ear can be adjusted individually to suit the degree of deafness. In addition, instructions can be given to a group of children with each child's headphones connected to a common amplifier.

The S.T.C. headset has been tested by the Royal National Institute for the Deaf who in their report say "The S.T. & C. High Quality stereo earphones are well made and comfortable to wear. The acoustic output is sufficient for severely deaf persons and the frequency response is good. The boom microphone should be valuable for educational purposes."

A deaf child learning to speak with the aid of an S.T.C. headset

understanding radio

THE COMPLETE DIODE DETECTOR CIRCUIT

By W. G. Morley

In last month's issue, we introduced the diode as a detector of amplitude modulated signals, showing how its rectifying action enabled the amplitude modulation of a transmitter to be heard in a pair of high resistance headphones. The diode circuit also included an r.f. transformer connected to an aerial and earth and having its secondary tuned to a medium wave station by means of a variable capacitor, and an effective fixed capacitor given by the self-capacitance of the headphones themselves.

We shall now continue with our discussion of the diode in this application.

Resistive Load

In the simple detector circuit we introduced last month, the diode functioned, in combination with the self-capacitance of a pair of headphones, in much the same manner as does a power rectifier with a reservoir capacitor. An average a.f. voltage appeared across the headphones, this varying in sympathy with the original modulating signal at the transmitter. Whilst the signal was being received, one terminal of the headphones was already positive of the other terminal (depending upon which way round the diode was connected) due to the rectifying action of the diode.

This simple receiving circuit is not very ambitious, and it would be much more desirable to apply the output of the detector to an audio frequency amplifier, so that an amplified version of the signal may be fed to a loudspeaker. To accomplish this change, we must first of all replace the headphones by a more convenient form of load, and this can be a resistor as illustrated in Fig. 283 (*a*.) Since we are now using an amplifier it also becomes convenient to introduce a common chassis connection, and to connect this to earth. By removing the headphones we have also removed their self-capacitance, and so we add a low-value physical capacitor C_1, as shown, to take its place. C_1 has a capacitance which offers a high reactance at a.f. and a low reactance at r.f. Assuming the requisite component values, the signal appearing across the load resistor, R_1, will now be the same as that which appeared across the headphones.

This signal is not yet, however, suitable for application to an a.f. amplifier. There are two reasons for this. The first of these is that a significant amount of the original radio frequency still appears across the load.[1] It is undesirable to pass this radio frequency on to the a.f. amplifier because it may then be amplified in company with the audio frequency and result in incorrect operation. (This point applies mainly to valve amplifiers. As is explained later, it is not always applicable to transistor amplifiers.) In consequence it is necessary to provide a means of filtering out the radio frequency. The second of the two reasons why the signal cannot be applied direct to the amplifier is that a direct voltage due to rectification of the signal appears across the resistor, and this can upset working conditions in the input circuit of the amplifier. So the direct voltage has to be disposed of as well.

[1] If Fig. 281 (published last month) is examined, it will be seen that the voltage across the load and parallel capacitance varies (as the capactiance charges and discharges) at the original radio frequency. The headphones, which in Fig. 281 constituted the load, could not respond to this radio frequency, whereupon it had no noticeable effect in that instance.

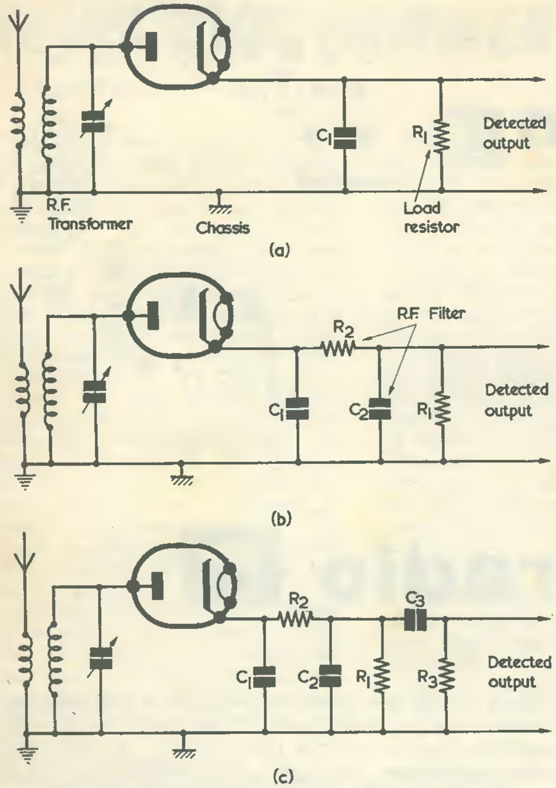


Fig. 283 (a). Employing a load resistor instead of a pair of headphones after the diode. Capacitor C_1 replaces the self-capacitance of the headphones
(b). Adding R_2 and C_2 to filter out the radio frequency voltage across C_1
(c). Capacitor C_3, which has a low reactance at audio frequencies, ensures that the direct voltage across R_1 is not passed to a subsequent a.f. amplifier

The radio frequency in the detected signal may be filtered out by means of the two additional components shown in Fig. 283 (*b*). In this diagram R_2 and C_2 form a low pass filter, and they have values which cause almost complete attenuation of the radio frequency signal with very little loss of the audio frequency signal. Normally, R_2 would be about one-tenth of the value of R_1. Capacitor C_1 follows the diode in the same way as it did in Fig. 283 (*a*), and the circuit is very similar in principle to a power rectifier circuit using a reservoir capacitor and subsequent smoothing components.

All that now remains is to remove the direct voltage across the load resistor, and this may be achieved by the simple process of adding a series capacitor, as in Fig. 283 (*c*). This capacitor, C_3, has a value which causes it to offer a low reactance at audio frequencies. At the same time, it prevents the passage of direct current. A further resistor, R_3, is added after the capacitor, its purpose being to ensure that the average voltage on the right hand plate of C_3 is at chassis potential. The result is that the audio frequency signal finally applied to the amplifier swings positive and negative of chassis potential, as in Fig. 284 (*b*), instead of being always positive of chassis, as in Fig. 284 (*a*). Resistor R_3 will usually serve a second function in the amplifier itself, but we need not concern ourselves with this point at the time being.

Circuit Variations

An alternative method of connecting up the diode circuit of Fig. 283 (*c*) is shown in Fig. 285 (*a*). This functions in exactly the same manner as that of Fig. 283 (*c*), as may be readily gathered by examining the section of the new circuit which includes the tuned circuit, the diode and C_1, as we do in Fig. 285 (*b*). Fig. 285 (*b*) shows that the diode is in series with C_1, which once more functions in similar manner to a reservoir capacitor, the only unfamiliar feature being that we have inserted the chassis connection at the diode side of the capacitor instead of the tuned circuit side. The detected signal, with its attendant r.f. and direct voltage, appears across C_1 in just the same manner as it did in the circuit of Fig. 283 (*c*). The components C_2, C_3, R_2 and R_3 of Fig. 285 (*a*) filter out the radio frequency and prevent the direct voltage being passed to the subsequent amplifier in the same manner as did the similarly identified components in Fig. 283 (*c*). Note that, with the circuit of Fig. 285 (*a*), the application of an r.f. signal causes the upper end of R_1 to go *negative* of chassis. This is to be expected, as a study of the conditions in Fig. 285 (*b*) will show.

The circuit of Fig. 283 (*c*) has the advantage that one plate of the tuning capacitor in the tuned circuit is at chassis potential. If the tuning capacitor is a variable component intended for adjustment from a front panel, and if it has the normal construction in which its moving vanes are at the same

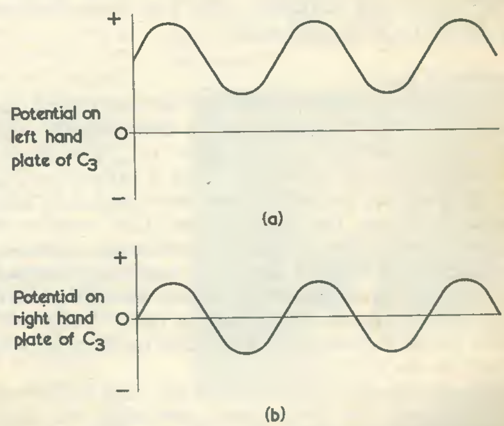


Fig. 284 (a). The detected a.f. voltage on the left hand plate of C_3 in Fig. 283 (c) may, typically, have the form shown here. Voltage is with respect to chassis
(b). Resistor R_3 ensures that the average voltage on the right hand plate of C_3 is at chassis potential

potential as its metal frame and spindle,[2] the circuit of Fig. 283 (*c*) then allows the moving vanes to be connected to chassis. This is very convenient, as it enables the tuning capacitor frame to be mounted directly to the metalwork of the chassis without any necessity for insulation.

The circuit of Fig. 285 (*a*), on the other hand, has the advantage that the diode cathode is at chassis potential. If the valve is a battery type having a filament (which then becomes the cathode) this enables a single battery to heat the diode filament in company with the filaments of any other valves in the equipment in which the diode circuit appears (the remaining filaments also being at chassis potential). If the valve is a mains type whose heater, following normal practice, is powered by a 50 c/s alternating supply (obtained from the mains supply by way of, for example, a mains transformer) the chassis connection for the cathode ensures that no 50 c/s hum voltage is applied across the load resistor by way of the self-capacitance between the diode's heater and cathode.[3] The circuit of Fig. 285 (*a*) is employed almost invariably as a detector circuit following the tuned secondary of an i.f. (intermediate frequency) transformer.[4] The i.f. transformer secondary winding is normally tuned, and has either a small trimmer or a fixed capacitor in parallel with the winding (whereupon resonant frequency is adjusted by an iron dust core) with the result that the desirability of having one plate of the tuning capacitor at chassis potential does not arise.

It is possible to fit a *volume control* to any of the detector circuits we have considered here, and this may be done by making either R_1 or R_3 a potentiometer, as shown in Figs. 286 (*a*) and (*b*) respectively. These are based on the circuit of Fig. 285 (*a*), but R_1 or R_3 could similarly be made a potentiometer, with identical results, in Fig. 283 (*c*). These volume controls function by controlling the proportion of the detected a.f. which is fed to the subsequent amplifier for reproduction over the loudspeaker. A small carbon-track potentiometer is normally employed. Since the response of the ear to sound amplitude is approximately logarithmic, the potentiometers of Figs. 286 (*a*) and (*b*) should employ tracks having a logarithmic (or log) law.[5] Equal degrees of shaft rotation of such potentiometers will then give the impression of equal changes in the loudness of the sound reproduced by the loudspeaker.

Component Values

We have not, up to the present, concerned ourselves with the values of the components employed in the detector circuits we have discussed.

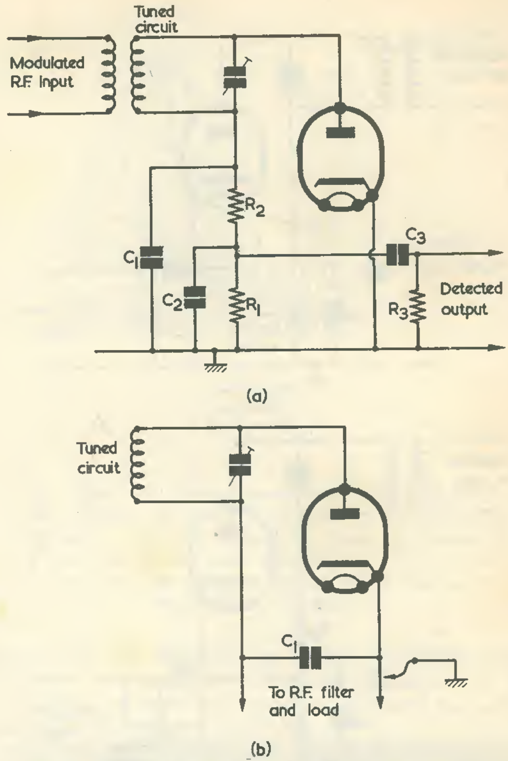


Fig. 285 (a). An alternative method of connecting up the diode. In this case, the tuned circuit would usually be the secondary of an i.f. transformer. The resistors and capacitors carry out the same functions as the similarly numbered components in Fig. 283 (c)

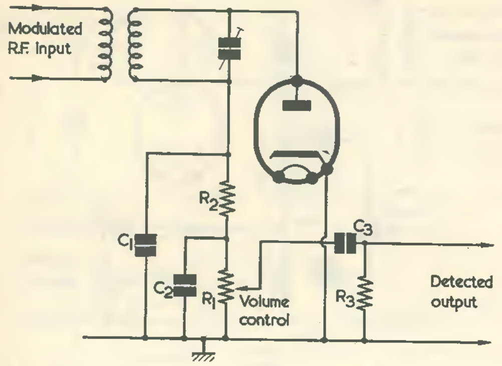
(b). The similarity with Fig. 283 (c) may be shown by considering only the tuned circuit, the diode and C_1. In this case the chassis connection is to the diode side of C_1, whereas in Fig. 283 (c) it is to the tuned circuit side of C_1

Such component values are not excessively critical, but there are two important points which have to be observed if the detector is not to introduce distortion with some amplitude modulated signals. Since the mathematics involved in both of the cases now to be discussed is somewhat complex, we shall not give a full description here but will only describe the basic problems and show how they may be satisfactorily met in practice.[6]

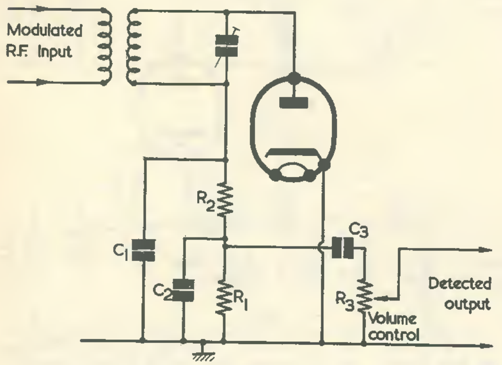
Dealing with the first point, if either the circuit of Fig. 283 (*c*) or that of Fig. 285 (*a*) is examined, it may be seen that two loads are presented to the diode. Ignoring the filter resistor R_2 (whose value is much lower than R_1) there is, firstly, a "d.c. load", this being given by R_1. Secondly, there is an "a.c. load", this being given by R_3 in parallel with R_1. The term "a.c." applies, in this instance, to

[2] See "Understanding Radio" in the July 1962 issue.
[3] As we shall see later, many valves have several electrode structures, including that for a diode, in one envelope, these all sharing a common cathode. It is convenient for this common cathode to be at chassis potential (so far as r.f. and a.f. are concerned) whereupon the circuit of Fig. 285 (*a*) becomes preferable.
[4] See "Understanding Radio" in the November 1963 issue.
[5] The resistance between the slider and the starting end of a log law track in a potentiometer varies as the logarithm of shaft rotation.

[6] Readers requiring detailed analyses of the a.c./d.c. diode load ratio and the effects of filter capacitance which are next dealt with will find these described in some text books. Excellent treatments are given in the books, "Thermionic Valve Circuits" by Emrys Williams (Pitman), and "Radio Designer's Handbook" by F. Langford-Smith (Iliffe).



(a)



(b)

Fig. 286. Introducing a volume control to the detector circuit. In (a) R_1 is made the volume control, whilst in (b) it is R_3 which performs this function

the modulating audio frequency, and the "a.c. load" consists of R_3 in parallel with R_1 because C_3 has a low reactance at audio frequencies. Thus, when the incoming r.f. signal is unmodulated, a steady direct voltage is built up across R_1 by the normal process of rectification, and no voltage appears across R_3. When the signal is modulated, however, the varying component of the signal appears across both R_3 and R_1 which, in parallel, then form the load for this varying component. It can be shown that the existence of these differing loads may cause distortion, the distortion becoming more severe as modulation depth increases. The distortion becomes more severe, also, as the difference between the values of the two loads increases, To keep distortion at an acceptably low level. therefore, it is necessary for the ratio of "a.c. load" to "d.c. load" to become close to unity, and this may be achieved by giving R_3 a much higher value than R_1. The "a.c. load" given by R_3 and R_1 in parallel then comes closer in value to the "d.c. load" given by R_1 on its own. In practical circuits it is usual to make R_3 some four or more times greater than R_1, and this gives acceptable results with broadcast a.m. transmissions of normal modulation depth.

When R_1 is made a volume control, as it is in Fig. 286 (*a*), the ratio between the "a.c. load" and the "d.c. load" is more liable to approach unity at low volume settings. This is demonstrated in Fig. 287. At low volume settings the "d.c. load" is, as before, given by R_1, but the "a.c. load" is now given by the upper section of the volume control track, $R_{1(a)}$, in series with the parallel combination of R_3 and the lower section of the track, $R_{1(b)}$. It will be appreciated that, as the slider approaches the bottom end of the track, the "a.c. load" value becomes closer to the "d.c. load" value. When the slider is at the top, maximum volume, end of the track, conditions revert to those of Fig. 285 (*a*), in which the "a.c. load" is given by R_3 in parallel with R_1. Many domestic sound radio receivers are normally operated with the volume control only partly advanced whereupon, with the Fig. 286 (*a*) circuit, the possibility of distortion from differing load values becomes low. The possibility of distortion increases at the maximum volume setting, but this usually corresponds to the reception of weak signals, where some distortion may be considered tolerable. Even when R_1 is made a volume control, however, it is still normal practice to make R_3 some four or more times greater in value than R_1.

A disadvantage resulting from making R_1 a volume control instead of R_3 is that the direct voltage resulting from signal rectification appears across its track in addition to the detected a.f. voltage. When the slider of a carbon-track potentiometer which has been in use for some time is adjusted, the resistance tapped off does not change infinitely smoothly but, instead, in small separate "jumps". This effect is the result of wear on the track due to the mechanical abrasion given by the slider. If, as with R_1, a direct voltage appears across the track, the small "jumps" in resistance given as the shaft rotates result in similar "jumps" in the direct voltage applied to C_3, with the result that a "rushing" noise is heard from the subsequent loudspeaker as the control is adjusted. Because of this effect, a potentiometer employed in the R_1 position will give evidence of "noisy" operation at an earlier stage in its life than would occur if it were connected in the R_3 position. This shortcoming is not sufficient to outweigh the advantages of making R_1 the volume control, but it does emphasise the need for using a good-quality component in this position if a long effective life is to be assured.

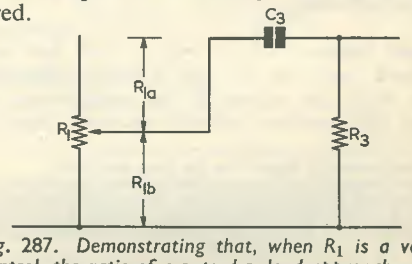


Fig. 287. Demonstrating that, when R_1 is a volume control, the ratio of a.c. to d.c. load approaches unity as volume is reduced

Instead of referring to the "a.c. load" and the "d.c. load", the effect given by adding R_3 and C_3 across R_1 may be alternatively described as "a.c. shunting" or "a.c. loading" of the diode load. This is a difference of terminology and does not affect the points just made. Since the direct voltage across the diode load increases when a signal is being tuned in (because the receiver's tuning adjustments cause the signal to correspond with the resonant frequencies of its tuned circuits and, hence, to be passed to the diode at greater amplitude) this voltage is sometimes employed to operate a *tuning indicator* or to provide *automatic gain control* (or *a.g.c.*)[7]. Such tuning indicator and a.g.c. circuits may also apply "a.c. shunting" across the diode load and care has to be taken in design to ensure that this is not sufficient to introduce distortion. Fortunately, these additional circuits normally require negligible current for operation, and they may in consequence be coupled to the diode load by way of high value resistors. For the present it will be adequate to state that such resistors should have values considerably higher than the diode load if the "a.c. shunting" effect of a.g.c. and tuning indicator circuits is to be kept at a low level.

The second point which must be observed, if distortion with some amplitude modulated signals is not to occur, has to do with the values of the capacitor immediately following the diode and the further r.f. filter capacitor. Referring to our circuits of Figs. 283 (*c*) and 285 (*a*) these capacitors are C_1 and C_2 respectively. Since the value of R_2 is much lower than that of R_1 we shall, for the present discussion, assume that this resistor is omitted, whereupon we have a diode load R_1, and a single "reservoir" capacitor C_1, as was shown in Fig. 283 (*a*).

Fig. 288 illustrates a portion of the modulated r.f. signal applied to the diode, and it is assumed that conditions are such that the distortion about to be described takes place. It will be seen that, up to line WX, capacitor C_1 charges on each half-cycle and discharges between half-cycles, as is required for correct detection. After line WX, however, the modulating voltage causes the r.f. signal to decrease rapidly in amplitude. This decrease is so rapid that the capacitor cannot discharge sufficiently quickly to "follow" it, and the subsequent r.f. peaks appear *below* the discharge curve for the capacitor and the load resistor. Until line YZ is reached, therefore, the voltage across the load resistor does not correspond with the modulation at all, and there is obvious distortion of the modulating a.f. signal. It should be noted that this effect only takes place on "downward-going" modulation (i.e. modulation which causes the amplitude of the carrier to decrease). With upward-going modulation the capacitor must

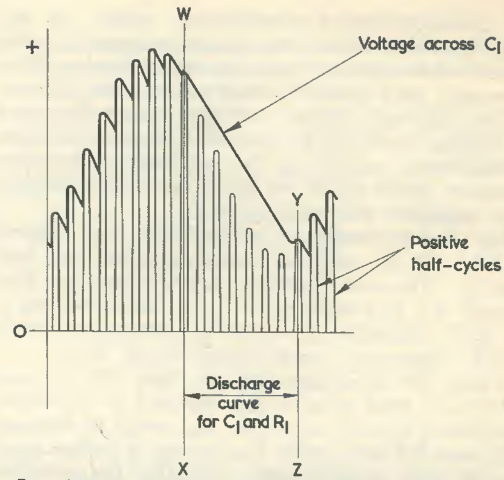


Fig. 288. If, during downward-going modulation, the reduction in carrier amplitude is too fast to be "followed" by C_1 discharging into R_1, distortion of the type shown here takes place. To assist the explanation, the positive half-cycles of the carrier are shown in this diagram

inevitably be charged on each half-cycle peak, and the detected waveform cannot revert to the discharge curve which appears between lines WX and YZ.

As is to be expected, the possibility of this type of distortion occurring is dependent upon (*a*) the value of the capacitor immediately following the diode, (*b*) the value of the load resistor, (*c*) the frequency of the modulating a.f. and (*d*) the depth of modulation. An increase in capacitance value causes a slower discharge between half-cycle peaks, as also does an increase in load resistance; and the risk of the condition of Fig. 288 occurring becomes greater. At the same time, an increase in modulating frequency causes an increase in the steepness of downward-going modulation; and an increase in modulation depth has a similar effect. Again the risk of distortion, as in Fig. 288, increases.

Fortunately, the higher audio frequencies appear at relatively low amplitude in normal speech and music, with the result that the modulation depth of such frequencies is, in practical transmissions, quite low. It becomes possible, therefore, to employ values for C_1 and R_1 (see Fig. 283 (*a*)) which could quite definitely result in the distortion appearing when the higher audio frequencies (around 7 kc/s and above) are transmitted at high modulation depths, knowing that, in practice, such frequencies and modulation depths would hardly ever be applied to the detector.[8]

It might be thought that the risk of distortion

[7] An automatic gain control circuit causes the amplification provided by receiver stages preceding the diode detector to be reduced as the direct voltage across the diode load increases. The result is that the detected a.f. passed to the a.f. amplifier tends towards a constant amplitude despite widely varying strengths in the signals picked up by the aerial. The effects of fading are also reduced.

[8] A considerable further easing of the situation is provided by the fact that many receivers, particularly the superhet, have tuned circuits preceding the diode which cause the sidebands corresponding to the higher audio frequencies (see last month's article) to be very heavily attenuated. Thus, the modulation frequencies which could cause the distortion are largely suppressed before they reach the diode.

on downward-going modulation could, in any case, be obviated by the simple process of using a low value capacitor and low value load resistor. However, such a step would reduce the *efficiency* of the detector (direct voltage output for peak r.f. voltage input) by an unnecessarily large amount. Compromise values can be reached for practical instances which allow for good detection efficiency with negligible risk of distortion.

For the purposes of explanation, we referred to Fig. 283 (*a*) with its single capacitor and load resistor. The same remarks apply when the filter resistor R_2 and capacitor C_2 are included, as in the later diagrams, capacitor C_2 adding effectively to the "reservoir" capacitance offered by C_1.

When the diode circuits of Figs. 283 (*c*) and 285 (*a*) are used in valve (as opposed to transistor) equipment, typical values for R_1 would lie between 0.15 and 0.5MΩ, with R_3 having a value some four or more times greater. Usually, the amplifier circuit following R_3 imposes a restriction on the maximum value of this resistor, and a fairly common design approach consists of giving R_3 the maximum value dictated by the amplifier circuit, and of ensuring that R_1 is about one quarter, or less, than this. The filter resistor, R_2, may normally have a value which is approximately one-tenth of R_1. The two capacitors C_1 and C_2 are not exceptionally critical provided that they are not so large as to cause distortion, or so low as to reduce detection efficiency. Typical values for both these components, in combination with the resistor figures just mentioned, are 100 to 200pF for radio frequencies below 5 Mc/s or so. At higher radio frequencies it is possible to use lower values of capacitance without a consequent reduction in detection efficiency, and the capacitors may then have values of 50pF or less. C_3 would usually have a value around 0.01μF.

The figures just quoted apply to valve equipment. With transistor equipment, the a.f. amplifier circuit normally presents a much lower input impedance than occurs with valve equipment and, whilst the basic detector circuit of Fig. 283 (*c*) or Fig. 285 (*a*) would still be used, the resistor values are about one-hundredth of the values mentioned above, with the values of the capacitors increased by around the same amount, to present correspondingly low reactances. The ratios between R_3 and R_1, and between R_2 and R_1, will also normally be observed. However, the situation here does not represent an exact parallel with valve equipment because the diode itself will not be a valve. It will, instead, be a semiconductor device (a germanium diode or a "crystal diode") which offers the same rectifying action as the valve diode, and which has a low effective resistance on conducting half-cycles. Many diode detector circuits in transistor receivers also obviate the filter components R_2 and C_2, employing a single diode load with a single capacitor immediately after the diode. This is because the transistors employed in the following a.f. amplifier have a limited frequency response and offer no useful amplification at radio frequencies, whereupon there is no point in ensuring that such frequencies are entirely filtered from the detector output.

Next Month

In next month's article we shall examine other aspects of the diode.

The "Athenian" 4-Band Superhet Receiver

Part 3 – A Design for the Beginner, 16—2,000 Metres

By **James S. Kent**

In this concluding instalment, the author describes the finishing of the front panel, together with the setting and alignment of the receiver

HAVING COMPLETED THE WIRING OF THE RE-ceiver as described last month, the next task is to finish the front panel in order that a pleasing appearance may be imparted and that all the panel-mounted controls function correctly.

With all the knobs, dials, pilot lamp lens and phone jack removed from the panel, the first task is to clean the aluminium in order to remove the finger marks that have by now very probably marred its shiny appearance. Obtain a clean piece of rag, damp this slightly with petrol and rub the front of the panel until all finger marks are removed. *Warning*—great care should be taken when using petrol—the cleaning process should be carried out preferably in the open air and most certainly away from any naked flame. Do not smoke whilst performing this task and, if possible, use lighter fuel in preference to ordinary petrol. The application of lighter fuel is rather easier from the tin in which it is supplied.

Once cleaned, apply a thin coat of black enamel (or any other colour preferred) to the panel face, the quick drying type of enamel being recommended. Once this has dried, apply a further coat, thinly and evenly, as a finishing coat. For those who have access to a small spraying appliance, two coats of cellulose would be a better proposition.

Prior to applying the second coat, however, a suitably sized hole should be drilled to accommodate the "Athenian" motif (see Part 1). As soon as the second coat is applied, firmly press into position the motif and pass through the small hole contained in the rear projection of this a small length of wire, twisting this wire back upon itself in order to hold the badge in its final position on the panel.

When the panel is thoroughly dry, commence to fit the knobs in the following manner. That of the wavechange switch should be fitted such that the white pointer agrees approximately with that shown on the cover illustration.[1] The b.f.o. pitch control knob should be fitted to its spindle such that the white pointer is at the furthest left-hand point when the moving vanes are fully meshed. Fit the function knob such that the positions finally given are as shown in the cover illustration. The audio gain on/off control should be so fitted that maximum gain is at the extreme right-hand position of the white pointer. Fit into position the phone jack and the pilot lamp lens.

The bandset dial should be fitted to the spindle such that the dial reading at the top is slightly in excess of 100° when the moving vanes are fully meshed. Deal similarly with the dial of the bandspread capacitor. With both dials at 100°, carefully position the Perspex cursors, one at a time, so that the hair-line of the cursor accurately matches the dial reading. Mark on the front of the panel the two fixing holes required for each cursor and secure these into position, remembering to use the small stand-off washers at the front of the panel in order to gain the necessary clearance required for the two dials to rotate freely. Secure to the spindles of each capacitor the two black knobs by means of the screws provided.

The remaining task is now to apply Panel-Signs Transfers (white) and these are obtainable from most radio component stockists or direct from the publishers of this magazine—Set No. 3 is that required. Apply the transfers as directed on the back of the envelope in which they are supplied. The transfers take up the positions shown in the heading illustration, or see the front cover illustration of the April issue.

Testing the Receiver

In the following, the writer assumes that the beginner owns, or has access to, a multimeter. The procedure to be followed by those not owning a meter will be described later.

Before inserting any valves, ascertain that no h.t. short-circuits are evident by unsoldering the wire from C_{28} to tag 9 of tagstrip 1 at C_{28} and that from C_{28} to tag 4 of tagstrip 2 also at C_{18}. Take a resistance, or continuity, reading from these two wire ends to chassis. Should any reading result, then an h.t. short-circuit exists and must be cleared before proceeding further. Reconnect these two wires.

[1] See cover of April 1965 issue.

TABLE I

(Quiescent conditions, R_{19} minimum setting, function switch at a.m., range 2 selected, all voltages with respect to chassis)

Valve	*Pin*	*Voltage (d.c.)*	*Current (mA)*
V_1	1	70	3.9
	3	2.35	
	6	275	1.85
	7	−1.1	
	8	100	5.5
V_2	1	50	1.8
	3	1.25	
	6	248	3.4
	7	—	
	8	—	
V_3	1	120	1.2
	3	1.3	
	6	220	22.0
	7	11.8	
	8	235	3.9
V_4	1	240 (a.c.)	
	3, 4	295	
	5	295	
	7	240 (a.c.)	

To check the continuity of the heater line, connect the meter between pin 8 of the power outlet socket and pin 4 of V_1 when a continuity reading should result.

Plug the valves into their respective holders, turn the chassis such that the underside is exposed, insert the mains input plug into the a.c. supply, connect to the speaker and switch on. After allowing the receiver to warm up for a few moments, make the d.c. voltage readings as shown in Table I, with R_{19} at minimum setting and the function switch at a.m. The readings obtained should agree roughly (plus or minus some 10 to 20%) with those shown. It should be remembered, however, that the figures quoted will only provide a guide; variations in component tolerances and even the applied mains voltage—which can vary considerably at times—will affect in some degree the readings obtained. All the readings shown were obtained with a 20,000Ω/volt-meter. Pins 7 and 8 of V_2 will, of course, read zero until switched to the c.w. position (function switch) and the readings for this position are shown in Table II. Table III shows the d.c. voltages obtained at various points in the circuit. Referring again to Table I, it should be noted that two of the readings with respect to V_4 are those taken on the a.c. range of the meter. The current readings were taken by inserting the meter, set to the appropriate range, in series between the valve pin concerned and the connecting component. For example, when

TABLE II
Voltage and Current

(Quiescent conditions, R_{19} minimum setting, function switch at c.w., all voltages with respect to chassis)

Valve	*Pin*	*Voltage (d.c.)*	*Current (mA)*
V_2	3	1.7	
	6	265	2.0
	8	86	4.6
	9, 7	−1.8*	

*Variable to 2.5V according to setting of C_{15}

TABLE III
Voltages

(Quiescent conditions, R_{19} minimum setting, function switch at a.m., all voltages with respect to chassis)

Component(s)	*Voltage*
C_{28}	280 (47mA) (49 at c.w.)
R_{13}/R_{12}	195
Pin 1 IFT_1	270
Pin 1 IFT_2	248 (270 at c.w.)

dealing with pin 1 of V_1, insert the meter between pin 1 and R_1.

For those who have just obtained a meter and are taking readings for the first time, it should be emphasised here that for *current* readings, all connections to the meter should be set up *before* switching on the set. Once the meter has settled to a steady reading and this has been noted, the receiver should be switched off and the process repeated to obtain other readings elsewhere in the circuit.

For those beginners who do not have access to a meter, plug in the valves, switch on and observe the valve heaters glowing. Switch off, turn the receiver over so that the under-side of the chassis is uppermost and again switch on. Watch closely to ensure that no h.t. short circuits are evident, this usually becoming visible by a resistor or resistors in the h.t. circuit becoming heated and either "bubbling" or emitting a slight amount of smoke. Should this unfortunate effect be visible, switch off immediately and ascertain where the short circuit is taking place. The resistor concerned will normally give an indication of the position in the circuit where the fault is occurring. For example, if R_{11} in the heptode anode circuit of V_2 becomes overheated, then it is very likely that either pin 1 or 3 of the i.f. transformer (IFT_2) is touching the chassis or that C_{11} itself is faulty. Once the fault has been cleared, the aerial and earth should be connected and a signal obtained on the medium waveband.

Alignment

A fairly weak medium wave signal should now be carefully tuned in. A weak signal is required so that any subsequent adjustments to the receiver will be aurally apparent. With the set switched to a.m., carefully adjust the cores of both IFT_1 and IFT_2, in that order, to obtain the maximum signal strength. Repeat this process several times to achieve the best results. Only slight variations of the i.f. cores should be necessary as these components are pre-aligned before leaving the factory.

Switch to the SW1 band, fully engage the bandset and bandspread variable capacitors (dials at 100) and adjust the aerial coil core (see Fig. 7 published last month) for maximum signal. Tune next to the far end of this band and adjust the aerial trimmer for similar results. Repeat this process several times until no further improvements are obtainable.

Deal similarly with the bands SW2, MW and LW.

It is not recommended that beginners should adjust the oscillator coil cores or trimmers, these merely altering the frequency of the oscillator. Slight variations of the oscillator trimmers may be made by those with more experience. For those who are confident or who have access to a signal generator then the normal lining-up procedure should, of course, be followed. The coil pack is pre-aligned as received, slight adjustments being required for frequency coverage owing to the inclusion of the bandspread capacitor $C_{3(a), (b)}$.

Having lined-up the receiver on the a.m. position, the final task is to align the b.f.o. circuit. This is best carried out on the range SW2. Select an unmodulated c.w. signal (preferably) and slowly rotate the core of the b.f.o. coil until oscillations are heard. Ensure that the b.f.o. pitch control C_{15} is set at the midway position, and adjust the core to resonance. If this process is correctly carried out, variation of C_{15} either side of the midway position will result in the c.w. signal altering the pitch of the note. In some cases, a slight variation of the above-chassis core of IFT_2 may result in more satisfactory reception of c.w.

The receiver will be found to perform extremely well, good results being achieved on the short wave ranges. A good earth connection is necessary for best results and an outdoor aerial of the inverted L type, some 66ft long and having a coaxial downlead will prove to be an ideal arrangement for general purpose listening. The aerial should be erected as high as possible and away from trees, gutterings or other earthed or metal objects.

Once in operation, the beginner will be able to spend many happy hours logging stations and compiling a graph of frequency readings obtained from stations having known (or announced) frequencies. The positions of the amateur bands will soon also become apparent, whereupon such contacts, especially on the 80 or 160 metre bands, will provide much enjoyable listening for the enthusiast.

(*Conclusion*)

IN YOUR WORKSHOP

This month Smithy the Serviceman, aided as always by his able assistant Dick, turns his attention to a subject which may shortly be occupying all our minds — colour television

"BUT THIS", wailed Dick, "is awful."

Smithy resolutely gritted his teeth and concentrated on the items in his stock list.

There was silence for a while.

"It's terrible."

Doggedly, Smithy refused to allow his attention to wander.

"It's shattering."

Smithy suppressed a sigh.

It had been a trying morning. He had a very heavy backlog of paper-work to catch up on, and he had been hoping for a few quiet hours without interruptions in order to clear it all up. Towards this end he had exercised the low cunning which responsibility breeds in the best of us, and had presented his outraged assistant with two television receivers having faults of such incomprehensible obscurity that even that garrulous young man should have been crushed into silence. But, much to Smithy's chagrin, Dick sailed through the two of them and, after half an hour, was loudly demanding more work. All that remained at the moment was an old mains sound receiver which needed a new dial cord, and Smithy passed this on to Dick together with a pile of American technical magazines which he kept in the Workshop for emergencies of this nature. For the next twenty minutes an atmosphere of blessed tranquillity descended on the Workshop, broken only by an indignant comment from Dick about "set-designers who string up dial cords like Clifton Suspension Bridge" and, later, a heavy thud as Dick adjusted the magazines to a position suitable for comfortable reading.

And, then, the comments had started.

Things To Come

"Dash it all, it's appalling."

Once more, Smithy added up a column of figures and, once more, got the answer wrong.

"Not only that," bemoaned Dick, "it's absolutely *diabolical*!"

"For the love of goodness," exploded Smithy, throwing his pen down on the bench, "can't you do *anything* without nattering about it all the time?"

Startled, Dick turned round from his magazines to face the wrathful face of the Serviceman.

"What's wrong?" he enquired innocently.

"What's *wrong*?" roared Smithy. "Here am I trying to concentrate on getting a bit of stock ordered in so that you can earn the grossly inflated wage you receive every Friday, and all you can do is to keep chuntering away about something being awful and terrible and diabolical!"

"And so I should," retorted Dick hotly. "The way that receivers are getting more and more complicated these days means that their servicing will soon be beyond my capabilities altogether. I won't even be *able* to pick up that measly pittance which you fondly imagine represents a working wage. Instead of that, I'll be out on the dole, mate. No job, no money, no future and no prospects!"

Dick brooded for a long moment on the injustices which beset him.

"Still," he remarked darkly, "there's always the streets."

"There's always the *what*?"

"The streets," repeated Dick, his voice vibrant with self-pity. "In a year or two's time you won't see me bashing away at the old TVs at all. I'll be out on the streets there with the other boys, out on the dust-cart emptying bustbins so's I can earn a humble crust."

Smithy stroked his chin thoughtfully.

"Do you know," he said judiciously, "that's not a bad idea, at that. There's some really good lolly to be picked up on the old dustbin round these days. *And* you get the odd fluff at Christmas."

"Fluff?"

"Tips," explained Smithy. "The only snag is the fish-heads, of course, but still you can't have everything."

Dick looked at the Serviceman suspiciously.

"You're accepting what I said," he remarked hurriedly, "just a little too readily for my liking. Let's change the conversation."

"As you like," said Smithy obligingly. "Now for goodness' sake tell me what it is that's upset you, so that I can get back to my work."

"It's these American magazines," replied Dick, his voice rising with indignation. "All the articles are about colour TV!"

"What's wrong with that?"

"They carry on," continued Dick, in an incredulous tone, "as though repairing colour TV sets is just an accepted part of a service engineer's day."

"So it is, over there," replied Smithy. "Dash it all, they've had colour TV for over ten years now. With a bit of luck we'll see it in this country ourselves fairly soon."

"Luck?" repeated Dick unbelievingly. "You call it *luck*? Blimey, Smithy, how on earth am I going to cope with servicing colour TV sets? It's as much as I can do to fix ordinary black and white ones."

"I certainly wouldn't argue with that last remark," commented Smithy unfeelingly. "However, you'll soon find that servicing colour TVs isn't, in actual fact, all that much harder than servicing black and white sets. What's putting you off is the unfamiliarity of colour TV design and circuits. Once you've actually handled a few colour TVs and found out what to expect from them, you'll soon gain confidence."

"I've never even *seen* a colour TV set!"

"Not to worry," replied Smithy soothingly. "There'll be quite a few knocking around when a service gets under way. In the meantime, what you want to do is to start genning up on the basic theory of colour so that you've got a good idea of how the sets are supposed to work. Also, you want to get used to a few of the terms that are employed."

Colour Terms

"Ah," said Dick, in a gratified tone, "you're talking now! These articles I've been looking at refer to 'luminance' and 'chrominance' and all sorts of other weird things. With words like that I'm lost before I even begin!"

"Fair enough," said Smithy. "Well, I suppose there'll be no harm in my going over some of these for you. To start off with, you have to remember that a colour television system is obviously intended to transmit a colour picture, and so it is first of all necessary to find what terms are needed to define the colours themselves. The first word to consider here is 'hue'. In colour television, 'hue' describes the basic colour itself. If we have a red colour we say that its hue is red also. At the same time, if we have a pink colour, we still say that its hue is red. The reason for this is that the pink colour is really red to which white has been added. The same applies to blue. If we add white in gradually increasing quantities to a deep blue it changes gradually to a lighter and even lighter blue until, eventually, we have added so much white that the colour is almost white itself. Nevertheless, so far as colour television is concerned, all these shades have a blue *hue*. You can repeat the exercise with green, yellow and purple. Their *hues* remain unaltered however much lighter you make them by adding white."

"I think I see what you mean," replied Dick thoughtfully. "Would I, for instance, be correct in saying that all the colours from very deep green to very pale green all have a green *hue*?"

"That's right," said Smithy. "If you go from very deep green to very pale green by adding white, then your hue is green all the time. You'll notice that, in this respect, the words 'hue' and 'colour' don't mean exactly the same thing. Anyway, that's enough about 'hue', so let's get on to a second term. This is 'saturation'."

"That sounds", said Dick, "like August Bank Holiday to me!"

"Saturation," continued Smithy, ignoring his assistant's comment, "defines the depth of a colour or, to be more accurate, its freedom from dilution by white. In consequence, a deep green is said to be more saturated than a light green, and a deep blue is said to be more saturated than a light blue. In other words, we reduce the saturation of a colour by adding white to it, and increase the saturation by subtracting white from it."

"There must surely come a time", interrupted Dick, "when you can't subtract any more white from the colour at all."

"That's quite true," agreed Smithy. "When you reach that point you say that the colour is 'fully saturated' or '100% saturated'. As you probably know, it's possible to display the colours of the spectrum by splitting up white light with the aid of a prism. (Fig. 1.) The prism offers different degrees of refraction for the different wavelengths in the white light, so these all get spread out in the form of the spectrum display. All the colours in this display are completely free from white light and they are, therefore, 100% saturated. You can't get colours any deeper or more saturated than those in the spectrum."

"I've just realised something," said Dick excitedly. "If you know the hue of a colour and its degree of saturation you are at once able to identify it for reproduction at a different place."

Dick picked up a note-pad and scribbled a sketch on the top sheet. (Fig. 2.)

"Let's say", he continued, "that we have a light green colour which is 30% saturated, and which we want to reproduce at a distant point. All we have to do is to send a signal to the remote point which says that the hue is green and that the saturation is 30% and we've got the message over. At the receiving end we just take the green as it appears in the spectrum, add white to it so that its saturation drops down to 30% and, blow me, we've got exactly the same colour as was put out at the transmitting end!"

Smithy looked at his assistant's sketch in astonishment.

"There are times," he remarked, "when you're so bright that you get me quite worried."

"I'm a real gone kiddy, you know," replied Dick modestly. "I'm a bomb!"

"You're noisy enough for one, I'll admit," conceded Smithy. "But I will certainly agree that, whilst that sketch of yours doesn't give all the information you'd find in a proper colour diagram, you are perfectly right in saying that you can identify any colour by referring to its hue and its saturation. That is, indeed, one of the things which you do in colour television. You send out a separate signal from the transmitter which contains the hue and saturation information, and this is known as the 'chrominance' signal."

" 'Chrominance'," repeated Dick, with satisfaction. "That's one of the words which was baffling me in these magazine articles just now. There's another word too: 'chroma'."

" 'Chroma'," said Smithy, "is merely a slang abbreviation for 'chrominance'. Incidentally, we haven't quite finished with the saturation business yet. I was referring just now to saturation in terms of the lightness or deepness of a colour but, to be really accurate, it's better to look upon saturation purely in terms of the addition or subtraction of white. You can also use the word 'desaturate'. A colour becomes less saturated, or more *desaturated*, if you add white to it."

Smithy had become completely lost in his subject. He pushed his papers, now forgotten, to the back of his bench as he concentrated on his next point.

"Another aspect of a colour," he continued, "is its 'brightness' or 'luminance'. This defines the light energy it radiates. You can have two colours of exactly the same hue and saturation, but one will be brighter than the other if it radiates more light energy. A bright green lamp can radiate more energy than a dim green lamp but the colours they produce may both have the same hue and saturation. Some people get a little confused between brightness and saturation, and so you should always remember that saturation defines colour and that brightness defines the amount of light the colour radiates. In colour television it's a little more usual to use 'luminance' rather than 'brightness', but both words mean exactly the same thing."

Colour Signals

"That seems O.K. up to now," said Dick. "But there are a lot of other things in these articles which I don't understand. There are, for instance, Y signals, R-Y signals and all sorts of other queer signals!"

"Ah, yes," said Smithy. "Well, these signals are what you encounter when you get down to the basic methods of colour transmission. You are bound to have heard by now that there are three systems for colour television, these being the American N.T.S.C. system, the French SECAM system and the German PAL system. The last two systems are developments from the N.T.S.C. system and so, whenever you start looking into colour TV, it's very desirable to start off by considering the N.T.S.C. system first."

"Is that the system that's in use in America at the time being?"

"It is," confirmed Smithy. "And it's been employed in Japan for several years as well. Technically, it represents an example of superb design and forward thinking, and the major credit for its introduction goes to Radio Corporation of America, who did the pioneer work on it. Now, let's get down to those signals of yours."

Smithy settled himself more comfortably.

"To begin with," he remarked, "a colour television system has to be fully compatible."

"I know what *that* means," interrupted Dick. "It means that you should be able to receive a colour transmission on a black and white set and a black and white transmission on a colour set."

"Exactly," confirmed Smithy. "So we'll now see how this is done. The colour television camera at the transmitter has to provide us with colour and brightness signals, and it can do this by having three camera tubes, one being behind a green filter, one behind a red filter and one behind a blue filter. (Fig. 3 (*a*).) The tubes are all positioned and focused up so as to be in complete registration. That is to say, each tube scans exactly the same part of the scene which is being transmitted as do the others. If the section of the scene being transmitted is a saturated green then only the green tube will give an output, if it's a saturated red then only the red tube will give an output, and if it's a saturated blue then only the blue tube will give an output. If it's a saturated colour between any of these, then you'll get an output from more than one tube. For instance, a saturated purple will result in an output from both the blue tube and the red tube. Fair enough?"

"Definitely," said Dick. "I suppose that, at the receiving end, you display corresponding strengths of red and blue, and these combine together to give you the original purple."

"That's my boy," approved Smithy. "I can see that this is one of your good mornings."

"I tell you," replied Dick, complacently. "Why do you refer to the application of *saturated* colours to the camera."

"That," replied Smithy, "is a very good question, but I'll have to go through one further step before I answer it. If the bit of the scene being scanned by the camera is white, you get an output from all three tubes."

"Do you? Why?"

"Because white light", replied Smithy, "consists of all the colours of the spectrum combined together.

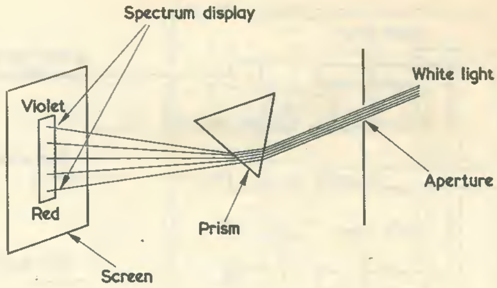


Fig. 1 (a). If white light is passed through a prism, differing degrees of refraction for the different wavelengths in the light cause the colours of the spectrum to be displayed
(b). The principal colours in the spectrum take up the approximate positions shown here

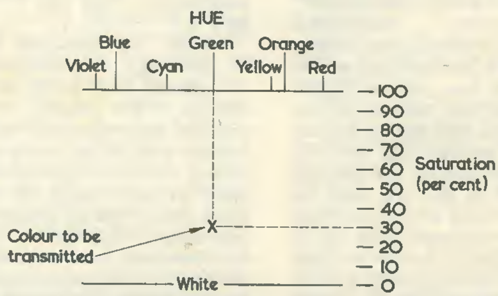


Fig. 2. Dick's suggested idea for transmitting information on a colour by reference to its hue and saturation. In this case the colour to be transmitted is a 30% saturated green. At zero saturation all colours are white, as indicated

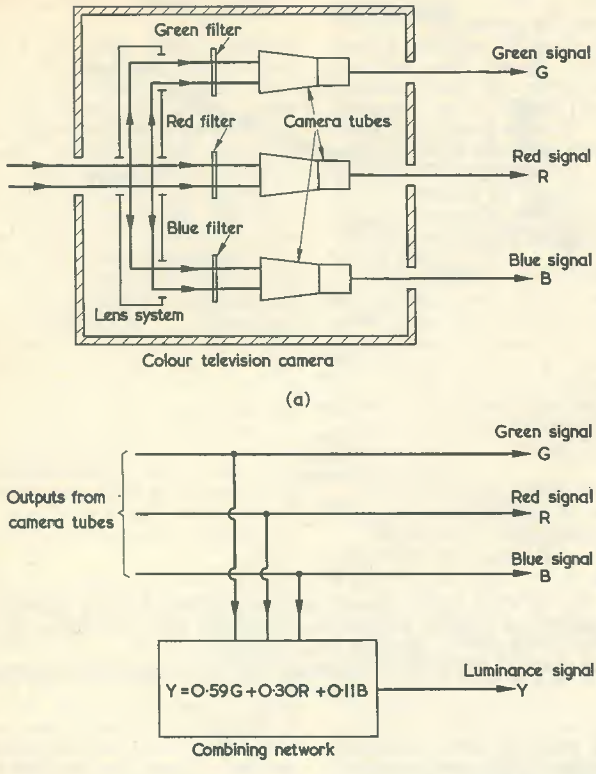


Fig. 3 (a). Schematic layout for a colour television camera. The scene to be transmitted is applied, by way of a lens system and coloured filters, to three camera tubes. G, R and B outputs are then given, as shown (b). The luminance signal is also obtained from the G, R and B outputs, these being combined together in the ratios (shown here in decimal form) indicated in the combining network

This fact is proved when you obtain the spectrum colours by passing white light through a prism. I should add that, in a *truly* white light, all the spectrum colours are at equal strength, or as nearly equal as makes no difference."

"I see," said Dick. "Incidentally, I'd forgotten all about that prism!"

"Not to worry," commented Smithy. "Now, a desaturated colour is one in which white has been added to the saturated hue, and so if you apply a desaturated colour to the television camera you get an output corresponding to the hue, plus an output corresponding to the amount of white that's in it. To take an example, pink is red which has been desaturated by adding white to it. So, if the camera scans a pink section of the scene, you'll get an output from the red tube corresponding to the amount of red hue, plus an output from all three tubes corresponding to the amount of white in the colour. At the receiving end you'll then have your original red, this being watered down by the white information given by *all* the tubes. And that explains why I referred just now to saturated colours when I was talking about the outputs from single tubes."

"Well, I'm dashed," said Dick, impressed. "All this is very neat, isn't it?"

"What I've described up to now is nothing," commented Smithy, "compared with some of the other niceties of the system. As I said a moment ago, when the camera scans a white part of the scene you get an output from all three tubes. Whereupon we now come to one of the more crafty bits of design work you encounter in colour TV. The human eye does not have similar sensitivities to all the colours of the spectrum. Because green is near the middle of the spectrum, the eye is more sensitive to this colour than it is to red or blue, which are nearer the ends of the spectrum. It doesn't take much thought to appreciate this fact because we know that the eye's sensitivity to light tails off altogether above violet when we go into the ultra-violets, and that it also tails off altogether below red when we go into the infra-reds. Actually, the eye is about twice as sensitive to green as it is to red and nearly six times as sensitive to green as it is to blue. We want a signal from the camera which corresponds to white in the same manner as occurs with human vision, and so we obtain this signal by adding together the signals from the colour tubes in the appropriate proportions. These are, to be accurate, 59% of green, 30% of red and 11% of blue."

The Luminance Signal

Smithy paused for a moment.

"Are you," he asked, "with me?"

"At the moment," confessed Dick, "only just. But keep on with it!"

"All the bits," said Smithy, "will fall very neatly into place in a minute. Let's continue with the camera. First of all it puts out a green signal from the green tube, and we call this the G signal. Secondly, it puts out a red signal from the red tube, and we call this the R signal. Thirdly, it puts out a blue signal from the blue tube, and we call this the B signal. And, fourthly and finally, it puts out a signal consisting of a combination of 59% green, 30% red and 11% blue. (Fig. 3 (*b*).) This last signal is known as the 'luminance signal' and it's given the letter Y. The luminance signal is just the same as you'd get from an ordinary black and white television camera having a single tube and no colour filters at all!"

"Blimey," commented Dick. "Go on, Smithy!"

"What now happens," said Smithy, "with all the three colour systems I've just mentioned, is that this luminance signal is applied to the transmitter, and is sent out in exactly the same way as a black and white signal. It has the full bandwidth that the television system can offer—with the B.B.C.-2 625-line signal this would be 5.5 Mc/s—and it can be picked up on any black and white receiver and reproduced in exactly the same way as a signal originating from a black and white camera."

"That *is* something," said Dick enthusiastically. "Is that where you get the compatible bit?"

"Partly," said Smithy. "But don't forget that for *full* compatibility you also need colour receivers capable of displaying black and white transmissions, and I haven't mentioned colour receivers yet."

"What about the colour signals?"

"Ah," said Smithy. "This is where we come to another bit of crafty design work. The human eye is by no means as sensitive to colour in very small areas as it is to brightness, and so it is quite in order to send the colour information at a much reduced detail level, which means that it can have a transmitted bandwidth considerably lower than that used for the luminance signal. With the N.T.S.C. system, as used on the American 525-line service, the colour information is sent out over a bandwidth which varies, according to hue, between 0.5 and 1.5 Mc/s only, whilst the luminance signal occupies the full 525 line bandwidth of 4.2 Mc/s."

"Why does the colour information bandwidth vary according to hue?"

"Because", explained Smithy, "the eye can perceive some hues in very small areas more readily than others, and these hues are given the greater transmitted bandwidth. However, you don't want to worry your head about that too much because most current American colour receivers use economical circuits which handle all hues at around 0.5 Mc/s bandwidth only, and the wider bandwidth which is available isn't taken advantage of. This works out perfectly well in practice, by the way."

"I see," commented Dick. "Now, I can see that the luminance signal goes out in the same way as a black and white signal, and you've just told me that the colour information is sent out, at reduced bandwidth, as well. How is this colour information transmitted? On a carrier in another channel?"

"It's transmitted", said Smithy, "in the same channel as the luminance signal."

Dick gave an incredulous snort.

"Pull the other one, Smithy," he said indignantly. "This one's got bells on it! You've already got a channel crammed tight with a luminance signal. How on earth can you push a second signal, which you've already said can be one and a half megs wide, into the same space?"

Smithy chuckled.

"It can be done quite easily," he grinned, "although I must admit that it's a bit of a tight squeeze! It's done by a process called 'frequency interleaving'. If you examine the output from a black and white television camera which is scanning a stationary scene, you'll find that almost all the information appears in clusters around the harmonics of line frequency. The transmitted sidebands therefore carry this information in clusters spaced at harmonics of line frequency away from the carrier. (Fig. 4 (*a*).) The same applies to the transmitted sidebands for the luminance signal obtained from a colour television camera, because this signal is, as we've seen, just the same as that given by a black and white camera. There are quite large gaps between these clusters of information and they could readily be used to take the sidebands of another signal. The colour information is also given by a camera scanning the scene, and because of this the information in this signal will also appear mainly in clusters around the harmonics of line frequency, and result in similar sidebands spaced away from the carrier. (Fig. 4 (*b*).) So what you finally do is to put the colour information on a subcarrier and pop this mid-way between two of the luminance signal harmonic clusters, whereupon the sidebands of both sets of signals become perfectly interleaved with each other!" (Fig. 4 (*c*).)

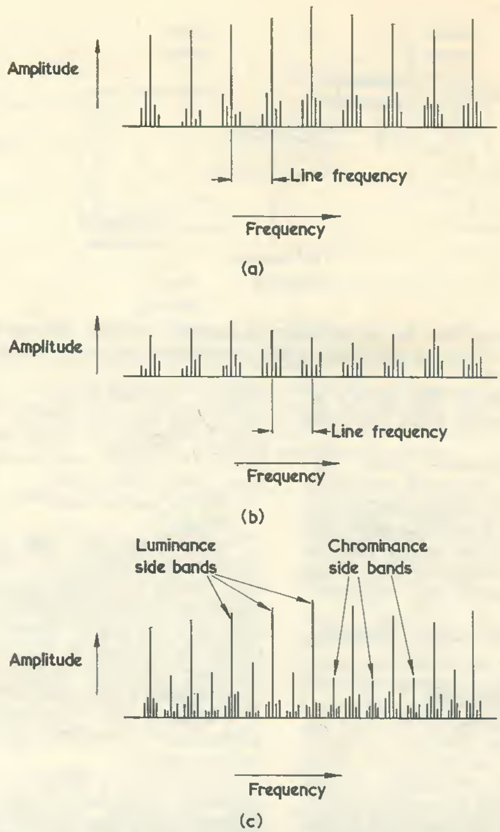


Fig. 4 (a). The information in the output of a television camera is contained mainly in clusters around the harmonics of line frequency. The transmitted sidebands, in consequence, similarly contain clusters of information spaced away from the carrier at harmonics of line frequency
(b). The sidebands of the chrominance subcarrier also consist of clusters of information spaced away from the subcarrier at harmonics of line frequency
(c). Interleaving the sidebands of the luminance and chrominance signals so that these may be transmitted within a single television channel

"Well, I'm dashed," exclaimed Dick. "And this is actually done in practice?"

"Definitely," confirmed Smithy, "and it works very well, too. In the American N.T.S.C. 525-line system the colour subcarrier is inserted, between the 227th and 228th line harmonics, 3.58 Mc/s away from the vision carrier. (Fig. 5.) This subcarrier then modulates the mains vision carrier. With the 625-line system the subcarrier will be about 4.43 Mc/s away from the vision carrier. Incidentally, I'd better start using the proper term here, and call it the *chrominance* subcarrier."

"Are you sure", said Dick, still

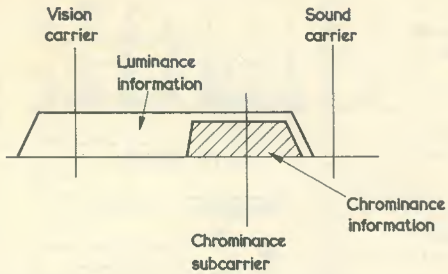


Fig. 5. Showing how the chrominance subcarrier and its sidebands may appear within the pass-band of the transmitted luminance signal

somewhat sceptical, "that there's *no* interference between these two sets of signals?"

"What interference there is," replied Smithy, "is pretty negligible in practice, this being partly for reasons which I'll have to give you later on. Anyway, we're now coming to a somewhat indigestible bit of the process, so you must pay very strict attention!"

"I am", replied Dick obligingly, "all ears."

Chrominance Subcarrier

"A most commendable state of affairs," observed Smithy. "Now, we want the chrominance subcarrier to carry information about hue and saturation, because these are the two factors we need to be able to place any particular colour. So, in the N.T.S.C. system, we first of all *phase*-modulate the subcarrier for hue, and we *amplitude*-modulate it for saturation. I'll repeat that so that you can get these two important facts fully entrenched in your noddle. It's *phase*-modulation for hue, and *amplitude*-modulation for saturation. The phase of the signal can vary through an entire 360°, and the amplitude modulation is such that amplitude increases as saturation increases."

Smithy paused.

"Next", he continued, "we come, as the musician said, to another hard bit. The manner in which the subcarrier is modulated in phase and amplitude is quite complex. But it can be described, without indulging in over-simplification, by saying that the basic modulation signals are R–Y signals and B–Y signals, and that it is possible for the receiver demodulation circuits to reclaim these R–Y and B–Y signals from the transmitted signal and apply them to the colour cathode ray tube."

"Whoa up!" interrupted Dick. "You've jumped a step!"

"Have I? Where?"

"With these R–Y and B–Y signals," replied Dick. "Up to now we've just had R signals, B signals and Y signals on their own. We haven't started subtracting them from each other yet!"

"We've *added* them."

"When?"

"When we got the luminance signal", said Smithy. "We added 59% of the G signal, 30% of the R signal and 11% of the B signal. And this gave us the Y signal. If you think about them in terms of signal *voltages*, it's quite easy to see how these signals can be added together."

"Perhaps so," conceded Dick grudgingly. "But that's not the same as *subtracting*."

"Subtracting is given by a reversal of phase," explained Smithy. "If you reverse the phase of the Y signal then add it to the R signal, you get R minus Y. Got it?".

"Oh, I see," said Dick. "Incidentally, what's happened to the G signal?"

"You can forget about that for the time being," replied Smithy. "I'll be bringing it in later. Let's get back to the chrominance subcarrier. The next thing I want to tell you is that it doesn't exist!"

"Hey?"

"I thought that would shake you!" chuckled Smithy. "Actually, it's a suppressed subcarrier which has to be reinserted at the receiver. Also, it allows me to introduce the reason for having the basic modulation provided by R–Y and B–Y signals. As we saw earlier, when we present a white scene to the colour television camera, we get a G signal, an R signal, a B signal and a Y signal. We know that white light contains all the spectrum colours at equal strength so, for white, the three colour tubes all offer equal output signals. Let's say that they all give an output signal of 1 volt, and that the letters G, R and B correspond to signal voltages. Then,

$$G=R=B=1.$$

At the same time we get a Y signal given by 59% of G, 30% of R and 11% of B. Using decimals instead of percentages, this gives us

$$Y=0.59G+0.30R+0.11B.$$

Perhaps you could scribble that equation down on your pad."

"Okeydoke," said Dick, picking up his pen, "what's the next step?"

"Work it out," replied Smithy, "for the case where G, R and B are all equal to 1."

"That's easy enough," commented Dick. "You then get

$$Y=0.59+0.30+0.11.$$

Well, blow me! That's equal to 1, too!"

"Exactly," said Smithy. "So, when we present a white scene to the television camera, we have

$$G=R=B=Y.$$

You'll still get this relationship if the luminance of the white section of the scene changes, because the proportion of green, red and blue will still remain the same. This relationship holds true, therefore, for all white luminance levels ranging from bright white down through the greys until you get to black where, of course, all signals are zero. This relationship also explains why R–Y and B–Y signals are used to modulate the subcarrier. If the scene presented to the camera is white, grey or black, R is equal to Y and R–Y becomes zero. Similarly B is equal to Y and B–Y becomes zero. The final result is that, if the camera scans a scene which has no colour —apart from white—in it, there is no transmitted chrominance signal at all. It drops out completely, first of all because the subcarrier is suppressed and, secondly, because the R–Y and B–Y signals which modulate it are zero!"

"Well, I'm darned," said Dick. "So far as I can see, that makes the transmitted signal exactly the same as that given out by a black and white transmitter fed by a black and white camera. All that's left is the luminance signal."

"You've got it," confirmed Smithy. "From what I've just described, it follows that the intensity of the chrominance signal increases as the saturation of the colours presented to the camera increases. You'll get a strong chrominance signal for heavily saturated colours, this decreasing as saturation decreases until, for a purely black and white scene, you get no transmitted chrominance signal at all. In practice, most of the colours scanned by the television camera will only be lightly saturated, which means that the chrominance signal becomes relatively weak and less liable to interfere with the luminance signal with which it is interleaved. It is only heavily saturated colours which result in a strong chrominance signal, and which offer the greatest risk of interference with the luminance signal."

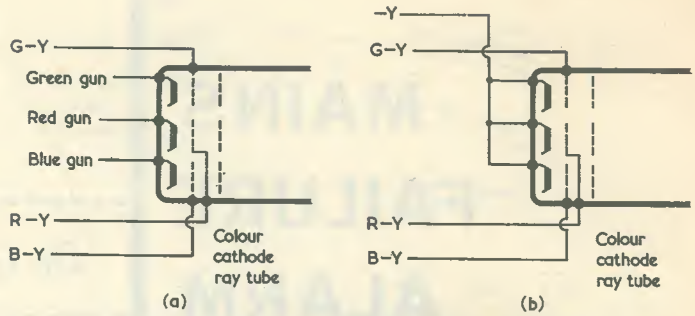


Fig. 6 (a). In a practical colour television receiver the G-Y, R-Y and B-Y signals are applied to the grids of the cathode ray tube
(b). By feeding a -Y signal to the cathodes of the tube, the -Y term in the grid signals is cancelled out, whereupon the electron beams are modulated by the G, R and B signals on their own

Reclaiming the Colours

"Talk about ingenuity," said Dick enthusiastically. "That's *really* something! How do you get the colours back again at the receiver?"

"There are", said Smithy, "quite a few ways of doing this. One method would consist of firstly getting the R–Y and B–Y signals from the chrominance signal. You could then add Y to these. If Y is added to R–Y you get (R–Y)+Y, which is of course equal to R. Similarly, (B–Y)+Y is equal to B. So you've got your R and B signals back again. You know also that:

$$Y=0.59G+0.30R+0.11B,$$

whereupon you could then say that:

$$0.59G=Y-0.30R-0.11B,$$

so that

$$G=\frac{1}{0.59}(Y-0.30R-0.11B).$$

"However, this last bit represents rather a theoretical approach, and I quoted that last equation merely to demonstrate that, if you have Y, R and B in the right proportions and phase, you can reclaim G by combining them together. A G signal doesn't, therefore, have to be transmitted. In practice, colour receivers have sophisticated circuits which combine several operations in a small number of valves and components, and which can't be described in simple terms. These receiver circuits handle the received chrominance signal in such a manner that they obtain R–Y, B–Y *and* G–Y signals. The G–Y, R–Y and B–Y signals are then applied to the grids of the colour tube." (Fig. 6 (*a*).)

"This," interrupted Dick despairingly, "is too much! How on earth can a colour tube reproduce G–Y, R–Y or B–Y? There's no such colours!"

"If", said Smithy severely, "you'd let me finish what I was saying, I'd have been able to tell you that you also apply a −Y signal to the cathodes of the tube. (Fig. 6 (*b*).) Because a cathode going positive is equivalent to a grid going negative, the −Y signal on the cathode is equivalent to a +Y signal on the grid. So the G–Y, R–Y and B–Y signals all have +Y added to them in the cathode ray tube itself, and the beams from the three guns are then modulated by G, R and B signals."

"Phew," said Dick. "We've got there in the end! Would the cathode ray tube be a shadow-mask type?"

"Oh, definitely," replied Smithy. "Up to the moment, the shadow-mask tube is the only one which has been developed sufficiently well to be good enough for domestic use. I hardly need to add that it has three guns, one for green, one for red, and one for blue."

"With", chimed in Dick, "the bean from each gun going through the shadow-mask holes to hit phosphor dots of its own colour. That bit's easy. Indeed, the shadow-mask tube seems to get fully described in everything which has been written about colour TV at popular-science level. What the popular-science writers always seem to avoid are the electronics which cause the signals to get to the shadow-mask tube in the first place!"

Back to Black and White

Smithy chuckled.

"They're probably very wise," he commented. "Colour TV isn't an easy subject to put over at popular-science level. Anyway, I've just remembered that I should be catching up on my paperwork just now, so I'd better get back to it."

"But that's not fair," protested Dick. "We've only *started* on this colour TV business, and I've got stacks more questions I want to ask. How, for instance, do you reinsert the chrominance subcarrier at the receiver?"

But Smithy had already pulled his papers towards him, and was obviously intending to devote his full attention to them.

"And what", wailed Dick, "about SECAM and PAL?"

"We'll have a go at those", replied Smithy, "at our next little session together. In the meantime I hear sounds which seem to indicate that our vanman cometh. Loaded, I should guess, with a great pile of sets for you to get your teeth into!"

To Smithy's delight and Dick's intense disgust, a squeal of brakes outside the Workshop door confirmed the Serviceman's statement.

"So far as I can see," continued Smithy, as a sudden happy thought occurred to him, "because colour television doesn't lead the industry in this country at the moment, we have to put black and white receivers in the van!"

Dick looked puzzled.

"I don't get that," he said eventually. "What has colour TV got to do with our van?"

"Let it pass," sighed Smithy resignedly. "Let it pass. At any event you don't seem to be looking upon colour TV with quite the same foreboding that you showed earlier on."

"I'm not," replied Dick confidently. "It looks as though colour TV will be something which is *really* worth looking forward to."

"For once," commented Smithy, as the Workshop door burst open to reveal an ancient a.m. sound radio followed by a perspiring van driver, "you have said something with which I am in complete and utter agreement."

NEXT MONTH . . . AN ELECTRONIC TACHOMETER

MAINS FAILURE ALARM

By C. P. Finn

THIS ALARM WAS ORIGINALLY DESIGNED AS A cheap, simple and effective means of warning of the failure of the mains electricity supply, and was required by the owner of a large number of tropical fish which are kept warm and aerated by mains power. It could find use in other circumstances: for instance, where trace-heating is employed to prevent water pipes freezing, or where electric pumps are employed in small bore central-heating systems. Other uses will no doubt suggest themselves to readers.

The Circuit

The circuit consists of a transformer and rectifier which supply power to a relay. A pair of normally-closed contacts on the relay are connected to a battery and bell. The bell thus rings when the relay opens, i.e. when the mains supply fails.

The transformer can be any continuously rated type giving a suitable output, and the author used a bell transformer. Such transformers are designed for continuous connection to the mains with intermittent loading, and a good quality component will give a small current continuously without overheating.

The rectifier calls for a little comment, and the prototype used a 12V 1A bridge rectifier taken from a model railway controller.* The 200μF capacitor shown in dotted line may be of help in some cases to eliminate relay chatter. The relay itself should be a low resistance type with at least one pair of normally-closed contacts.

A battery is, of course, needed in the bell circuit, since the bell is required to ring when the mains is off. The prototype uses a 4.5V flat torch battery. Since the battery only supplies current when the bell sounds, its life will be nearly equal to its shelf life.

The unit is operated by connecting to the mains and switching on the bell circuit by S_2. Connection at the point of supply where it is used will give an indication of fuse failure as well as mains failure. However, if fuse failure is deemed unlikely then it is possible to make the unit portable and move it to any part of the house, e.g. to the bedroom at night.

In the event of mains failure, the bell will be switched off by the operator. Extra relay contacts could also be used to connect the mains-driven equipment to a suitable alternative supply, such as accumulators or stand-by generators.

Construction

Construction is simple. Any suitable case may be employed, provided easy access is left for battery replacement. For maximum economy the appropriate transformer tap should be used (3, 5 or 8V for most bell transformers), whilst R further limits the current to reduce the consumption of the unit. The circuit is economical and consumes only one or two watts—electricity costs are therefore only a few shillings a year. To this must be added the cost of replacement batteries.

The user should form a habit of regularly checking the battery. This can be done by pressing the button S_1 (or by unplugging the unit from the mains) and thus de-energising the relay. This also checks that the relay is operating correctly and that its contacts are clean.

* Suitable 12V 1A bridge rectifiers are available from most suppliers, including Henry's Radio Ltd., 303 Edgware Road, London, W.2.—EDITOR.

THE PHOTRAN

by M. J. DARBY

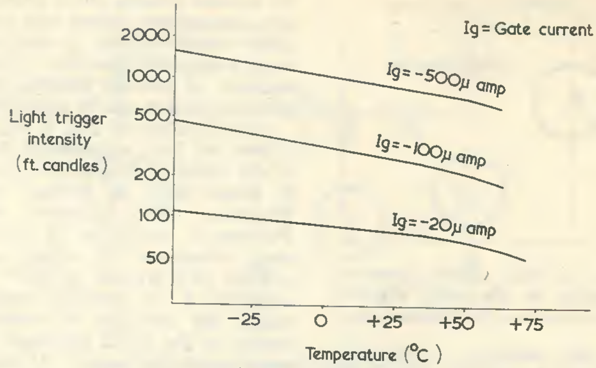


Fig. 2. Variation of triggering light intensity with junction temperature. The values of gate current are plotted as a parameter

THE PHOTRAN IS A NEW TYPE OF device produced by Messrs. Solid State Products, Inc., which can be switched into the conducting state by a beam of light. In appearance it is similar to a very small transistor, with the exception that it has a transparent window at the end remote from the lead-out wires. In some ways the Photran resembles the photo-transistor but, unlike the latter device, the Photran does not stop conducting when the illumination ceases. The Photran is a bistable switching device. Once the illumination has increased to a value above the triggering level, the current passing through the device is independent of the light intensity.

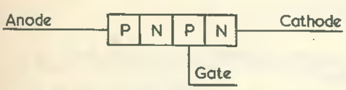


Fig. 1. The structure of the Photran

Construction

The Photran is a p.n.p.n. device with a p-type gate electrode as shown in Fig. 1. The theory of operation of p.n.p.n. devices will not be discussed, since it has already been covered in previous articles in this magazine.[1] In most p.n.p.n. devices, switching is initiated by a change in the gate electrode current or by a change in the applied voltage but, in the Photran, light falling on the junction creates a current which is amplified and causes the device to be triggered.

When a suitable potential difference is applied across a Photran in darkness, the device behaves as a high resistance having a value of more than 10MΩ. This is the "off" state. An impulse of light will switch the device to the conducting state, in which its resistance is less than 10Ω. This is the "on" state. The light pulse can be very short indeed. After the device has switched, the current passing through it must be reduced below a certain value in order to return the device to the high resistance state.

Circuit Simplicity

The Photran can be used to switch a power as high as 40 watts (200 volts at 200mA) with an efficiency of about 99%. The device is very small, the active element being only 0.06in square, but it can nevertheless pass transient currents of up to 5 amps if its average power rating is not exceeded. The low forward resistance of the Photran results in a very high switching efficiency and a very small dissipation of heat inside the device. The potential across a Photran in its conducting state is less than 1.5 volts for currents of up to 200mA. Photrans are the only photosensitive devices which can directly control an appreciable amount of power. The amplifiers which must be used with photocells and phototransistors are not required when a Photran is employed. The Photran can, of course, operate a relay, but even the relay can often be dispensed with. Thus the use of Photrans will result in very great circuit simplification in various applications.

High Speed

The time required for a Photran to switch to its conducting state depends somewhat on the light intensity used to cause the triggering.

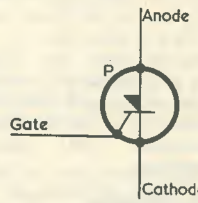


Fig. 3. The theoretical symbol for the Photran

At the minimum light intensity required for triggering the current rise time in a Photran is of the order of 30μs, but this can be reduced to less than 1μs by a sufficient increase

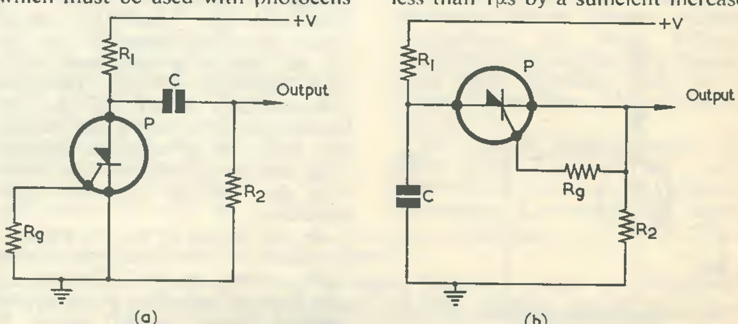


Fig. 4. Light-actuated pulse generators which provide pulses of opposite polarity. In (a) the pulse is positive-going when the light to the Photran is interrupted, and in (b) it is negative-going

[1] See "The Silicon Controlled Rectifier" by M. J. Darby in the September 1962 issue and "The Silicon P-N-P-N Diode Switch" by M. Farnsworth in the November 1962 issue.

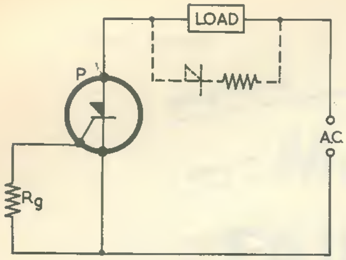


Fig. 5. In this circuit power is applied to the load when light shines on the Photran

in the light intensity. The time required to return to the non-conducting state is of the order of 30μs.

Triggering Level

The light intensity required to trigger a Photran can be set electrically by variation of the gate current. It also depends somewhat on the ambient temperature, as shown in Fig. 2. The operating temperature range is −65°C to +125°C. Variations of about ±75% of the nominal triggering light intensity may occur from Photran to Photran, but this can be absorbed by a suitable choice of gate current. The device has a maximum sensitivity to light of a wavelength of about 0.95 microns (infra-red), but is sensitive over the range 0.4 to 1.1 microns.

The device can be triggered electrically at a constant illumination by variation of the gate bias current. This enables it to be employed in electrical-optical "OR" gates for logic operations.

Typical Applications

(a) Pulse Generators

The symbol for the Photran is shown in Fig. 3. The two circuits of Fig. 4 show how the device may be used to provide an output pulse each time a beam of light is interrupted. If the beam is interrupted by articles coming off a production line, the output pulses can be used (after amplification) to operate an electro-magnetic counter.[2] Thus the number of articles coming off the production line can be counted.

In the circuit of Fig. 4 (*a*), R_1 is chosen so that a quiescent current of the order of 100μA flows through it when light is falling on the Photran. The resistance of the Photran is negligible in this state and therefore R_1=the applied voltage (V) divided by 10^{-4}. The capacitor C is virtually uncharged when the Photran is conducting owing to the small potential difference across the device. If the light beam is momentarily interrupted, the current flowing through R_1 no longer passes through the Photran but is used to charge the capacitor C and hence to provide an output pulse. When the light is cut off, the Photran discharges C through R_2.

The circuit of Fig. 4 (*b*) provides pulses of opposite polarity to those of Fig. 4 (*a*).

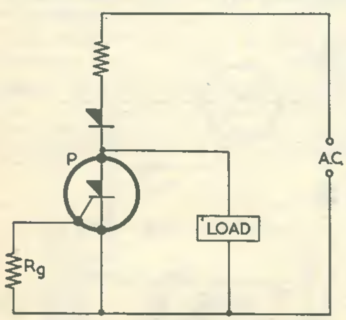


Fig. 6. In this instance, power is applied to the load when no light falls on the Photran

(b) Power Control

If the Photran is fed from an alternating supply, it will be sensitive to light during each half-cycle in which the anode of the device is positive with respect to the cathode. During the other half-cycles the device will remain in its non-conducting state no matter what the light intensity may be. If the device is triggered during one half-cycle it will, therefore, automatically revert to its non-conducting state during the succeeding half-cycle of opposite polarity. The alternating potential thus carries out the resetting operation automatically.

In the circuit of Fig. 5, power is applied to the load only when light shines on the Photran. If the load is inductive, a diode and resistor (shown dotted) should be connected across the load to avoid the build-up of high voltages when the current passing through the load ceases to flow. The diode also allows the energy stored in the inductive load to flow as a current through the load during the half-cycles when the Photran is non-conducting.

The circuit of Fig. 6 can be used if power must be applied to the load when no light falls on the Photran.

The circuit of Fig. 7 may be used when the power supply to the load must be full-wave rectified. The power is applied to the load when light falls on the Photran.

If it is necessary to control a large amount of power by means of a beam of light, the Photran may be used in a circuit which contains large silicon controlled rectifiers. Such circuits can switch tens of kilowatts at perhaps 70 amps.

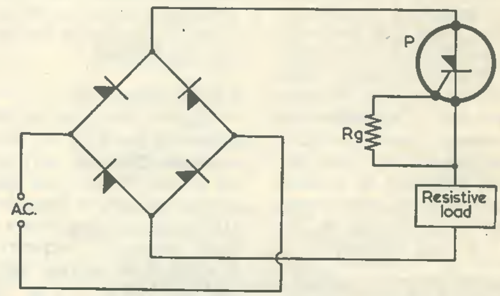


Fig. 7. Here, the load is supplied with a direct current when light falls on the Photran

(c) Light-Actuated Time Delay Circuits

The circuit of a light-actuated interval timer is shown in Fig. 8. When light is applied to the Photran, the capacitor C commences to charge via R_2 and R_3. After a predetermined time interval the potential across the capacitor becomes great enough to fire the silicon controlled p.n.p.n. switch, CS, which conducts and allows power to be applied to the load. The load current passes through the Photran. The circuit is reset by opening a switch in the power supply circuit.

Another type of light-actuated interval timer is shown in Fig. 9. In this circuit the Photran P is used to provide a pulse to the gate circuit of the p.n.p.n. silicon controlled rectifier SCR_1. This gate pulse causes the silicon controlled rectifier to conduct and current passes through it and through the load.

[2] See "Electromagnetic Counters" by J. B. Dance, *The Radio Constructor*, October 1963.

After a predetermined time interval the silicon controlled switch CS_1 (which is also a p.n.p.n. device) will fire. The current passing through R_3 causes a voltage drop across this resistor. A negative pulse is therefore applied from the anode of the silicon controlled switch CS_1 to the anode of the silicon controlled rectifier SCR_1 via the capacitor C_2. This pulse momentarily reduces the anode voltage of SCR_1 to such an extent that the device is switched to the non-conducting state and current will no longer flow through the load. The Photran circuit itself is made to automatically return to the non-conducting state at the end of the light flash.

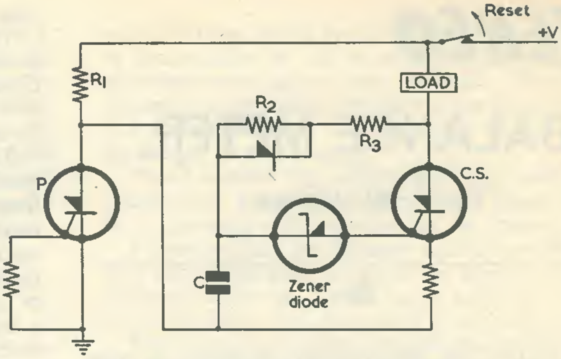


Fig. 8. A light-actuated interval timer

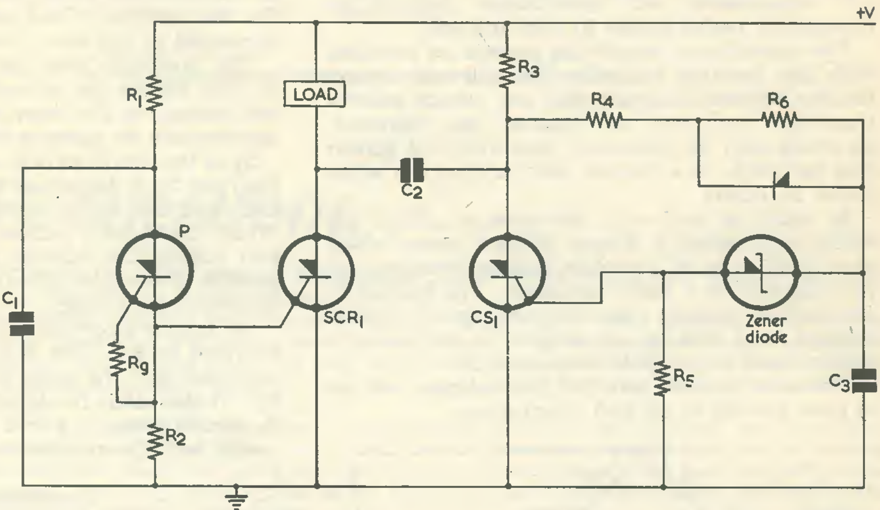


Fig. 9. A light-actuated timer which applies power to a load for a short time

(*d*) *Logic Circuits*

A simple light actuated "AND" logic circuit can be constructed by connecting the desired number of Photrans in series with a load resistor across a power supply. A gate resistor is connected from each Photran gate electrode to the cathode of the same Photran. A current will flow through the load resistor in this circuit only when light falls on all of the Photrans simultaneously.

Many other types of logic circuit can be constructed using Photrans, but will not be discussed here, since they are not likely to be of great interest to the average amateur constructor. They are, however, of great interest to the manufacturers of computers.

Conclusion

The future for the Photran in power control circuitry seems to be very bright, but time alone will tell to what extent these devices will be applied to simplify the circuitry of modern electronic equipment. They do not carry out any functions which cannot be carried out with other devices; their use merely assists in the simplification and miniaturisation of circuits. They will never be used as amplifying devices for audio or radio frequencies, since they are essentially switches which are on-off devices.

Acknowledgement

The circuits described in this article have been designed by the manufacturers of the Photran. They first appeared, together with other circuits, in the booklet *A Survey of Basic Photran Circuit Applications*, this being Bulletin D430-01 (3-62), published by Messrs. Solid State Products, Inc., of 1, Pingree Street, Salem, Massachusetts, U.S.A.

The British representatives for Solid State Products, Inc., are: Dage (Gt. Britain) Ltd., "La Casita", Heronsgate, Rickmansworth, Herts.

LONDON SHOWROOM FOR SONY

Sony—the giants in miniature electronics—whose working and selling slogan "Research makes the Difference" gave the world its first pocket transistor radio and first portable transistors TV sets, recently opened its London showroom at 70–71 Welbeck Street, W.1.

Yet another world's first is on its way—a truly portable transistorised video tape recorder—details of which are expected to be made available later this year.

Sole Sony U.K. agents are Debenhams Electrical & Radio Distribution Co. Ltd.

STEREO

BALANCE METER

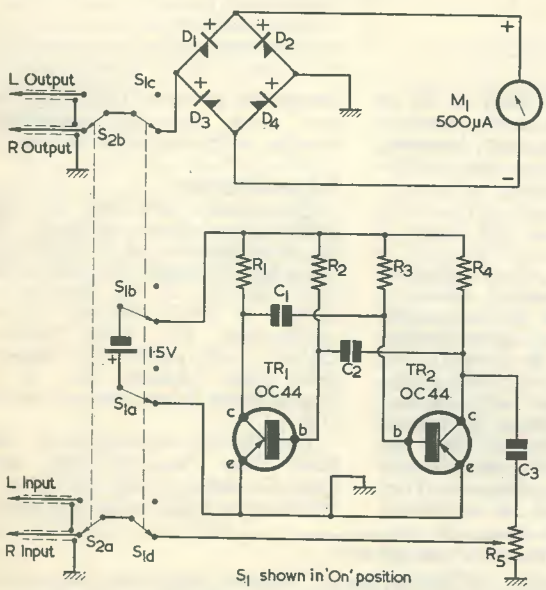
By T. W. Hannen

NO CLAIM FOR ORIGINALITY IS MADE BY THE author for this piece of apparatus, but the constructor will nevertheless find it an exceedingly useful gadget to own and use.

Few stereophonic amplifying systems are provided with any positive indication for showing correct balance between channels, and one cannot entirely trust one's own ears. A "balance" can, therefore, be struck only by guesswork, and what one person may believe to be a balance may be quite out when heard by others.

In order to deal with this state of affairs the writer constructed a simple balance meter which gives indication of complete balance between the two channels of a stereo amplifier. The balance is obtained by visually measuring the output of each channel, and making adjustment to the balance control until the outputs were identical.

The writer is quite sure that this indicator will be of great interest to all hi-fi constructors.



The circuit of the balance indicator unit. The two-transistor multivibrator connects, via $S_{2(a)}$ to the inputs of the stereo amplifier, and the meter circuit, via $S_{2(b)}$ to the outputs

The Unit

The unit can be made quite small in size, and it is cheap to build. It may, also, be permanently fitted as part of an existing stereo set-up. There are two sections interconnected by switches, as shown in the accompanying circuit diagram.

The first section consists of a small transistorised oscillator, producing a square waveform at a fixed frequency around 2,500 c/s, this representing a comfortably audible note. The second section incorporates a rectifying diode bridge circuit which passes the note to a microammeter via the outputs of the amplifier.

By use of the switching arrangement shown, the note is injected first into one channel input of the amplifier, the output of this channel being connected at the same time to the microammeter. By reversing S_2, the oscillator and output meter circuit are connected to the other channel.

The prototype employed a P.O. key switch for S_2, this having the advantage that changing from one channel to the other could be carried out very conveniently by pressing the key.

S_1 is the on-off switch, and it will be noted that $S_{1(c)}$ and $S_{1(d)}$ disconnect both the oscillator output and the meter circuit when the unit is switched off. When the balance indicator is permanently wired into circuit, this ensures that no additional components are coupled into the amplifier circuits when the unit is out of use.

An output amplitude control for the oscillator is provided by R_5. This is needed to prevent possible overloading of the input stages of the stereo amplifier. It also caters for different amplifier sensitivities. R_5 should be set to a level which offers satisfactory results with the amplifier employed.

Components List

Resistors
(All fixed resistors are ¼ watt 20%)

R_1	22kΩ
R_2	150kΩ
R_3	270kΩ
R_4	22kΩ
R_5	10kΩ potentiometer, log track

Capacitors

C_1	0.001μF, paper
$C_{2,3}$	0.01μF, paper

Semiconductors

$TR_{1,2}$	OC44
$D_{1,2,3,4}$	GEX34 (see text)

Meter

M_1 Moving coil, 0–500μA (see text)

Switches

S_1	4-pole, 2-way
S_2	2-pole, 2-way

Battery

1.5 volt cell

The bridge rectifier, D_1 to D_4, incorporates four germanium diodes. The writer fitted GEX34 diodes here, but the type used is not critical. Inexpensive "surplus" diodes will probably be satisfactory. The meter has an f.s.d. of 500μA, that employed by the writer being obtained, at low cost, on the surplus market. It should be pointed out that, if the stereo amplifier has a low output level, it may be necessary to use a meter having an f.s.d. of 200μA.

Operation

Switch the function switch of the amplifier or preamplifier, or otherwise couple the leads from the unit to the amplifier, and switch the unit on.

If everything is in order, a note will be heard from one of the amplifier channel loudspeakers and, upon turning up the volume control of the amplifier or preamplifier, it will be seen that the needle of the microammeter moves over its scale. Turn up the volume control until the microammeter is close to full scale deflection. (Adjustments in R_5 may also be needed at this stage.)

Next, operate S_2, whereupon the note will be heard from the other loudspeaker. There will also be a corresponding reading on the meter.

Finally, adjust the balance control on the amplifier, whilst operating S_2, until the meter readings are identical when the switch is in either position. A perfect balance has then been produced.

The bass and treble controls should be in their normal positions before the balance adjustment is made, as these controls have a slight influence on balancing.

Recent Publications . . .

AN ELECTRONIC ORGAN FOR THE HOME CONSTRUCTOR. By Alan Douglas, M.I.R.E., M.A.I.E.E. 112 pages, 5½ x 8½in. Published by Sir Isaac Pitman and Sons Ltd. Price 20s.

This is the second edition of Alan Douglas's book, the first edition having been published in 1958, and it incorporates a number of additional points including a new arrangement for continuous tuning of cathode note-forming circuits. The organ itself is a valve design incorporating Great and Pedal Generators, a monophonic Solo Generator, amplifier, vibrato, power supplies (including a stabilised supply for the generators) and all the other features required for a comprehensive electronic organ.

The book commences with an introduction to the organ, its techniques and the terms associated with its various facilities. Eight chapters then carry on to give full constructional details. These are followed by a chapter offering suggestions for loudspeakers, a further chapter on tuning and regulating, and a final chapter which gives new information on a polyphonic swell generator. Two very useful appendices list the materials and component parts required for the organ, together with the names and addresses of suppliers.

The complete organ is housed in a handsome case, for which constructional details are also given.

101 MORE WAYS TO USE YOUR VOM AND VTVM. By Robert G. Middleton. 128 pages, 5½ x 8½in. Published by W. Foulsham & Co. Ltd. Price 20s.

101 More Ways To Use Your VOM and VTVM is another title in the Foulsham-Sams Technical Book series, which comprise American texts with short introductions for British readers. These introductions cover differences in British and American terminology, mains voltages and frequencies, and similar matters. For instance, "VOM" in the title of the present book stands for "volt-ohm-milliammeter" or multi-range testmeter, and "VTVM" for "vacuum-tube voltmeter". The book under review is a sequel to an earlier "101 Ways" volume on the VOM and VTVM.

The 101 methods described in the book are published in sequence, each occupying, on average, about a page each. The approach is admirably concise and straightforward, and the text is profusely illustrated with clearly drawn diagrams.

Typical subjects are: the checking of a centrifugal starting switch, the measurement of the input capacitance of a VTVM, the measurement of the negative resistance of a crystal diode, and finding the crest and trough values of a pulsating d.c. voltage. Some of the tests are for household electrical appliances, the remainder being concerned with circuits and components in the radio category.

This is a most interesting book, and it is full of practical and useful information. There is, also, an excellent index.

PRACTICAL TRANSISTOR SERVICING. By William C. Caldwell. 191 pages, 5½ x 8½in. Published by W. Foulsham & Co. Ltd. Price 24s.

This book is also in the Foulsham-Sams Technical Book series. It commences with a description of transistor operation, carries on to transistor circuits (bias, stabilisation, a typical amplifier and oscillator feedback), after which the remaining chapters are devoted to servicing proper. These chapters provide the bulk of the book and cover, amongst other things, faulty stage isolation, the interpretation of voltage readings, the in-circuit and out-of-circuit testing of transistors, and the troubleshooting of automobile radios. There is also a chapter which gives case histories of the clearing of actual faults.

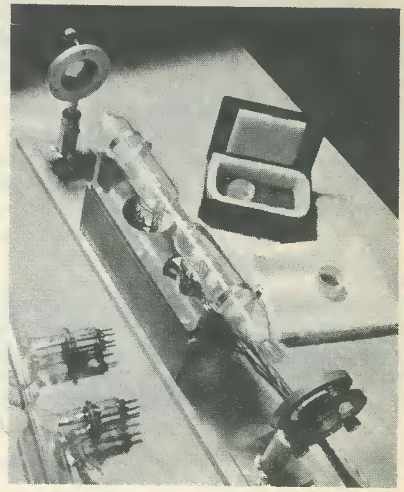
The book provides considerable detail which is patently backed by experience on the part of the author. The transistors and transistor receivers referred to are American types but this, in the reviewer's opinion, represents no disadvantage since the circuits and techniques involved are similar to European practice.

LASERS

Part 1

The Principles of Laser Operation

By J. B. Dance, M.Sc.



Since the inception of the laser much has been written about the performance and operation of this important new device. However, practically all the technical information currently published assumes a working understanding of quantum mechanics and cannot, in consequence, be fully appreciated by the layman or technician who does not possess the requisite knowledge. In this specially commissioned series of three articles, our contributor intentionally assumes that readers may not be familiar with the quantum mechanics involved, and explains the phenomenon of stimulated emission in carefully detailed terms which may be readily followed by anyone who has a basic knowledge of electricity and the structure of the atom

This first article deals with the principles of laser operation. The second article in the series will carry on to describe the types of laser at present available and their functioning. The third, concluding, article will deal with laser applications including, in particular, the use of the laser in communications and by the amateur

THE LASER IS ONE OF THE MOST IMPORTANT devices which have been developed by physicists in recent years. Although it is a device which generates light rather than radio waves, it is nevertheless of great interest to the electronic engineer, since it is expected to play a great part in future communication networks. In addition, as we shall show in detail later in this series, the laser has a very wide variety of other applications including extremely accurate measurement, delicate surgery and the verification of a basic postulate of the relativity theory. Lasers will almost certainly have some military applications, but these are not likely to be of the science fiction "death ray" type.

Why should there be such great excitement over a device which produces light? How, for example, does the output light from a laser differ from the output of a powerful searchlight? These questions cannot be fully answered in a brief sentence, but basically the laser is important because it produces a powerful beam of light which has a very narrow bandwidth and in which all the waves are in phase and have the same polarisation. The light output can be focused on to a minute area so that the power dissipation in this area is quite fantastic. These points will be elaborated.

Brief History

The laser functions on very similar principles to the maser. The word maser is an acronym or abbreviation for "Microwave Amplification by Stimulated Emission of Radiation". Masers are used as very low noise amplifiers which are usually operated at extremely low temperatures. They are complicated equipment and are employed at the centre of aerials (such as the Jodrell Bank aerial) which are used for work in Radio Astronomy and for tracking artificial satellites. Masers operate at microwave frequencies as opposed to the laser (or optical maser) which operates at the much higher frequencies of visible light or of the infra-red region of the spectrum. The word laser stands for "Light Amplification by Stimulated Emission of Radiation"; the exact meaning of this will be seen later in this article.

The possibility of designing a laser was first suggested in 1958[1]. The first type of practical laser employed a ruby crystal as the active device[2]. In

HEADING ILLUSTRATION

A small Ferranti gas laser powered by a d.c. supply. Note the Brewster end windows and the three adjusting screws for the end mirror. (Ferranti, Ltd.)

1961 a totally different form of laser was described in which the laser action took place in a gas discharge tube containing a mixture of helium and neon[3]. In 1962 the first semiconductor laser was described by a number of American workers. More recently still a form of liquid laser has been evolved[4], but this operates rather indirectly because it is used in conjunction with another laser. Thus the active region of a laser may be a solid, a liquid or a gas, or a solid in the form of a semiconductor.

Basic Theory

Radio waves are generated by electronic oscillators. Microwaves are generated by oscillations in small cavities. The light of lasers is a much higher frequency still and is generated by something much smaller, namely atoms themselves. Ordinary electronics deals mainly with electrons which are free to move in a vacuum or in a semiconductor material, but the electrons used to provide amplification in lasers are bound inside atoms. In order to understand the basic principles by which lasers function, it is thus necessary to develop a simple understanding of the basic quantum theory governing the emission and absorption of energy from the atoms of a substance. This theory is essentially mathematical in nature. For this reason many amateur physicists have not bothered to attempt to understand the operation of lasers. It is hoped, however, that readers will spare the time required to read the following basic theory, since the fundamental ideas can be expressed in a simplified and non-mathematical way. Although a few simple equations are included in this article, they are not essential to the explanation of the basic action of the laser and can be omitted by the less mathematical reader.

Electron Energy Levels in Atom

If an electron approaches a positive charge, it will be attracted and will increase in speed as it gets nearer to the charge. When it is moving at a velocity v, it has an energy of $\frac{1}{2}mv^2$ where m is its mass. The increasing kinetic energy of the electron as it approaches the positive charge can only come from the energy of the electric field. An electron situated some distance from a positive charge (at point 1 in Fig. 1) is said to possess electrostatic potential energy since, if the electron is free to move, it will be accelerated towards the positive charge and obtain kinetic energy. Thus although the total energy remains constant (as required by the Law of Conservation of Energy), the initial electrostatic potential energy has been partly converted into the kinetic energy of the electron. The electrostatic potential energy of the electron at point 1 in Fig. 1, where the electron is at some distance from the positive charge, is thus greater than the electrostatic

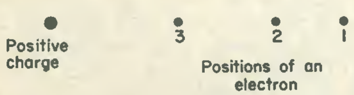


Fig. 1. The distance of an electron from a positive charge governs its electrostatic potential energy

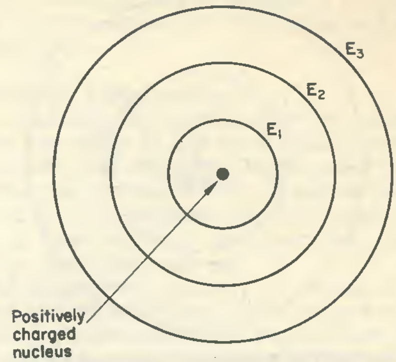


Fig. 2. Electron energy levels in an atom

potential energy at point 2 which, in turn, is greater than that at point 3. Thus the farther the electron is away from the positive charge, the greater the electrostatic potential energy.

For the purposes of this discussion, an atom may be thought of as a positively charged nucleus surrounded by a number of electrons. In a neutral atom the number of electrons must equal the number of positive charges in the nucleus. The diameter of the whole atom (about 10^{-8} cm.) is about 100,000 times larger than the diameter of the nucleus; thus the atom is largely empty space. The electrons which are farthest from the positively charged nucleus have a greater electrostatic potential energy than those which are nearer to the nucleus. Thus the energy of an electron, E_3, which is travelling in the outermost orbit of the atom represented in Fig. 2 is greater than that of the electron which has the energy E_2; which is, in turn, greater than the energy E_1 of the electron in the innermost orbit.

In a stable atom electrons cannot travel in orbits of any radius; only certain orbits and therefore certain electron energy levels are possible. The possible energy levels may be represented by those shown in Fig. 2, for example, although actual atoms contain more stable levels than three. The reasons for the existence of a limited number of stable levels is one of the problems of quantum mechanics which need not concern us here. The electrons in any one of the main energy levels shown in Fig. 2 will not usually all have exactly the same energy, but these sub-divisions of the main energy levels will not be discussed in detail.

The Interaction of Electromagnetic Radiation with Matter

Atoms may emit or absorb electromagnetic radiation or, in certain circumstances, electromagnetic radiation striking an atom may stimulate the atom to emit further radiation.

(1) Emission

All natural systems tend to assume a state of minimum potential energy. In the same way that an apple tends to fall and so to assume a state of minimum gravitational potential energy, electrons

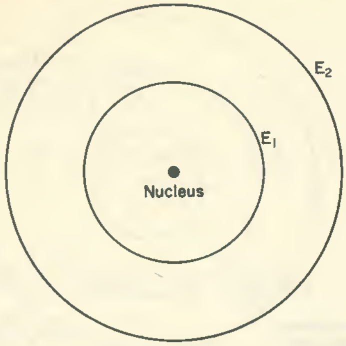


Fig. 3. Two energy levels are assumed here

in an atom tend to pass into the levels of minimum potential energy (which are those closest to the nucleus). When all of the electrons in an atom occupy the lowest possible energy levels, the atom is said to be in the ground state. This does not mean that each electron has the energy E_1 (see Fig. 2), since in any atom the number of electrons which can occupy the minimum energy level is limited (according to the Pauli Exclusion Principle). If an atom is in the ground state, the available electron orbitals of lowest energy are filled. If one or more electrons are moved to a state of higher energy, the atom is said to be in an excited state.

Let us suppose that the energy level E_1 in Fig. 3 is not fully occupied by electrons; that is, the atom is in an excited state. An electron from the energy level E_2 will tend to fall into the level E_1 and the surplus energy (E_2–E_1) is given out as electromagnetic radiation. (Visible light, infra-red radiation and radio waves are all forms of electromagnetic radiation.) The important point is that the frequency of the light given out in such a change is directly proportional to the energy change E_2–E_1. When an electron in an atom of, say, hydrogen moves between two specified energy levels, the light given out is always of one particular frequency; in the case of visible light this corresponds to light of one particular colour.

If there are three energy levels in an atom, as in the atom represented in Fig. 2, the possible energy changes are (E_3–E_2), (E_2–E_1) and (E_3–E_1). This would give three colours. More complex systems with many energy levels give more colours as bright lines in the spectrum of the element. For example, some street lamps give a bright yellow light because electrons in the sodium vapour in the lamp jump between two levels which have a difference in energy corresponding to yellow light. Mercury vapour lamps give a blue light and neon lamps a red light. If the light from such lamps is examined by means of a spectroscope, the wave- length of the lines may be determined. These wavelengths are characteristic of the emitting atoms; thus the line spectrum is a very useful way of determining the elements present in an unknown mixture.

In the case of solids, the interaction of each atom with its neighbours generates so many new energy levels that light of any visible frequency can be emitted. Thus a hot solid, such as the filament of a tungsten filament lamp, emits light over a very wide range of frequencies (including the infra red), no lines being present in the spectrum. Such light is said to have a continuous spectrum.

It has been stated that the frequency, f, of the light produced by an atom is proportional to the difference in energy between the two electron energy levels, that is

$$E_2-E_1 \propto f$$

Thus $$(E_2-E_1)=hf \qquad \text{equation (1)}$$

where h is a constant known as Planck's constant. The radiation is emitted from atoms in little packets, each of energy hf. These packets of energy are known as photons, which may be considered to be particles of light. No fraction of a photon can exist. The minimum amount of light of frequency f which can exist has an energy hf. If an electron moves nearer to the nucleus and the resulting energy change is equal to half the energy of a photon of, say, blue light, no blue light can be emitted. A photon of half the frequency of the blue light will appear and will carry just the right amount of energy.

The Greek symbol ν (pronounced "nu") is normally used for the frequency of light in spectroscopical work, but f will be used here, since readers are probably more familiar with this symbol.

The energy change in any one atom (E_2–E_1) is very small indeed. The frequency, f, of the light emitted by the atom is very large. Thus the constant h is extremely small (actually $h=6.624 \times 10^{-27}$ erg-sec). A photon is sometimes referred to as a quantum of light.

Although one can have a photon of low energy (for example, a photon of a radio wave), the concept of the photon is most important when considering electromagnetic radiation of higher frequencies. At radio frequencies an individual photon contains such a small amount of energy that it cannot be detected. Very high energy photons are emitted from many radioactive nuclei and are known as gamma rays; in this case the energy levels inside the nucleus change in much the same way as do the changes in the electron energy levels of an atom which cause visible light to be emitted. Individual gamma ray photons can easily be counted by a Geiger tube and this helps many people to think of electromagnetic radiation as individual packets of energy (photons). In some cases it is best to think of light as waves, but when light is interacting with matter, it is best thought of as a number of photons.

An atom which is not in the ground state usually emits its excess energy within a millimicrosecond or perhaps within less than a micromicrosecond. However, some atoms cannot get rid of their excess energy nearly so easily and they have the comparatively long life of some milliseconds. Such atoms, which are of great importance in laser operation, are said to be in a metastable state. A change in the electron levels which does not occur very easily may be referred to as a forbidden transition.

(2) Absorption

If light strikes an atom in a gas, there is a certain probability that the light will be absorbed and its energy used to raise an electron in the atom to an excited state. This probability is high if and only if the energy of the photon of light is just adequate to raise the electron in the atom to a stable higher energy level. For example, if an electron has an energy E_1 and is to be raised to the level E_2, the photon must have an energy of (E_2-E_1) units and its frequency must be $(E_2-E_1)/h$ cycles per second. Photons of other energies are not absorbed unless they happen to have just the amount of energy required to bring about another change between two stable levels; for example, E_2 to E_3 or E_1 to E_3. One may think of a photon of energy E_2-E_1 as being "in tune" with an atom which will absorb it easily.

It is most important to note that each gaseous element absorbs light of the same frequencies as it will emit when an electric discharge is passed through it. If one examines the spectrum of the sun, one finds that it contains many dark lines known as the Fraunhofer lines. These dark lines arise because light of certain frequencies proceeding outwards from the centre of the sun is absorbed by gaseous elements in the outer regions of the sun. Only those photons which have the correct amount of energy to cause an electron in an atom to jump to a higher energy level are absorbed. Thus the amount of light of these frequencies reaching the earth is less than that of the intermediate neighbouring frequencies which are not absorbed. Although the absorbing atoms give out the light which they have absorbed, this light is given out in all directions and much of it is absorbed in the sun. Thus its intensity is not sufficient to compensate for the absorption. The dark lines in the spectrum of the sun correspond in frequency to the bright lines in the spectrum of a gas containing the same elements as the outer layers of the sun.

(3) Stimulated Emission

If a photon of energy E_2-E_1 strikes an excited atom in which the E_1 level contains a vacancy for an electron, it may stimulate an electron to fall from the E_2 energy level to the E_1 level, in which case an additional photon of the same energy as the incident photon will be emitted. It is most important to note that the additional photon is emitted in an extremely short time and is exactly similar to the incident photon. It has the same frequency, the same plane of polarisation and is in phase with the incident photon. In addition it travels in the same direction. Thus the two photons travel away from the atom together.

This process is one of light amplification. The two photons thus formed may each be used to stimulate two other atoms to emit photons, thus making a total of four photons. These photons can undergo further amplification if they encounter other excited atoms with suitable energy levels. It is this principle that is used in the operation of the laser and from which the laser has derived its name. As stated previously, the word laser is an abbreviation for "Light Amplification by Stimulated Emission of Radiation".

Conditions for Laser Action

The principle of amplification by stimulated emission may seem at first to provide a method of amplification with negligible input power; but we know that this cannot be true—in nature one never gets something for nothing. Excited atoms must be present if laser action is to occur and energy is needed to excite these atoms.

If one considers a mixture of atoms in which some are excited and others are in the ground state, an incident photon which has the required amount of energy to produce stimulated emission in the excited atoms will also have just the right amount of energy to be absorbed by an atom in the ground state. No laser action will occur unless stimulated emission is more probable than absorption. This condition will be fulfilled only if there are more atoms in the excited state than there are in the ground state, since a photon is then more likely to meet an excited atom than an atom in the ground state. The atoms are said to "populate" the states.

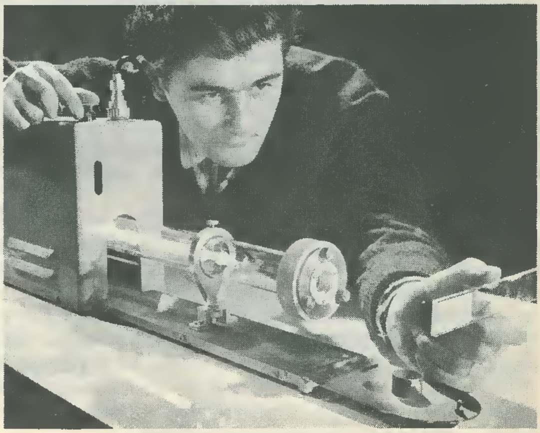
It might be thought that if the material containing the atoms were heated, the energy given to the atoms would produce more excited atoms than those left in the ground state. Actually this is not so. The Maxwell-Boltzmann theory of the partition of energy between the various energy levels states that at equilibrium

$$\frac{N_2}{N_1} = e^{\frac{-(E_2-E_1)}{kT}} \qquad \text{Equation (2)}$$

where N_1 and N_2 are the numbers of atoms in the respective energy states E_1 and E_2, and where

e is the base of natural logarithms
k is Boltzmann's constant
and T is the absolute temperature.

If E_2 exceeds E_1, the index $-(E_2-E_1)/kT$ is negative and therefore N_2/N_1 is less than unity. Thus at



Adjusting the Ferranti Mark I r.f. gas laser. The glowing inner tube contains the gas, the end mirrors being fixed in the outer tube. (Ferranti Ltd.)

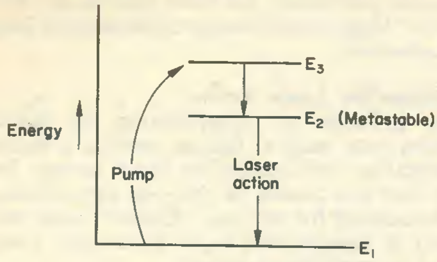


Fig. 4. Energy levels in a three level laser

equilibrium there are always more atoms in the state of lower energy.

In order to achieve laser action it is necessary to "invert the population" (that is, make N_2 exceed N_1). This can only be done by a process known as "pumping" which destroys the natural equilibrium. The pumping raises the energy of atoms to the excited state.

Pumping

Let us consider how laser action can be achieved with a material in which the atoms have three energy levels, as shown in Fig. 4. In this diagram the vertical axis represents increasing energy, but the horizontal axis has no particular significance; it is therefore a type of one-dimentional graph. The energy levels are represented as straight lines, since this is more convenient than the circles of Figs. 2 and 3.

Incident radiation of a frequency $(E_3–E_1)/h$ is directed at the atoms in the laser material. Some of this radiation is absorbed and a proportion of the atoms will be lifted from the level E_1 to the level E_3. Almost immediately these excited atoms will lose a part of their additional energy equal to $(E_3–E_2)$ and thus fall to the level E_2. This level E_2 is a metastable one and atoms with this amount of energy do not easily lose it. Thus when an atom reaches the level E_2, it tends to remain in this level for a relatively long time (some milliseconds). If the pumping action is sufficiently rapid, the number of atoms in the level E_2 can be made to exceed the number of atoms in the level E_1. Thus the natural population of these states has been inverted and amplification of light of a frequency $(E_2–E_1)/h$ becomes possible. The power put into the pumping action may be compared to the h.t. supply of an electronic oscillator.

The pumping action is very similar to that of ordinary fluorescence. Light of a fairly high frequency falling on a fluorescent material is absorbed; the material loses its additional energy in more than one stage so that the emitted light is of longer wavelength. Eosin (red ink) shows this phenomenon. Sometimes chemicals which absorb ultra-violet light and change it to visible light are added to washing powders to give a "whiter than white" effect; this is also fluorescence.

Pumping Efficiency

The pumping process is not a particularly efficient one. Only a fraction of the incident pumping radiation will be absorbed, since it is not normally convenient to produce light of the required pumping frequency $(E_3–E_1)/h$ without simultaneously producing light of other frequencies—which represents wasted energy. An amount of energy $(E_3–E_1)$ must be supplied to each atom which is pumped to the level E_3, but the energy of the photon produced by this atom in stimulated emission is only $(E_2–E_1)$. Some of the atoms pumped to the level E_3 will lose their energy in a way which does not assist the laser action.

The material used in a practical laser must be very carefully chosen to achieve reasonable efficiency. The level E_2 of Fig. 4 should be a metastable one of long life. It is often possible to choose a substance which has a group of energy levels close together instead of the single energy level E_3. In this case photons of several energies can be absorbed and used for the pumping process.

The efficiency of a laser may also be improved by employing a four level system (as shown in Fig. 5) instead of the three level system of Fig. 4. The incident photons pump the atoms from the ground state to the level E_4, after which they lose energy and fall to the level E_3. The laser action takes place between E_3 and E_2 and therefore E_3 must be more densely populated by atoms than E_2. In this system the level E_2 is less densely populated at equilibrium than the level E_1 (see equation 2) and it is thus easier to raise the population density of the level E_3 above that of E_2 than above that of the ground state E_1. The conditions required for laser action can therefore be achieved somewhat more easily in a four level system than in a three level material. Neodymium in glass is an example of a four level laser.

If the temperature of a laser material is reduced, it can be seen from equation 2 that the population density of the excited states will be reduced. In a four level laser the population of the E_3 energy level of Fig. 5 is maintained by the pumping process, but that of E_2 falls at very low temperatures and this assists in generating the conditions needed for laser action.

The energy level diagrams which have been discussed apply to isolated atoms, the electrons of which cannot easily exchange energy with those of neighbouring atoms. Thus the material used in a

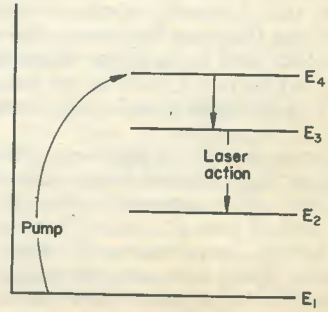


Fig. 5. Energy levels in a four level laser

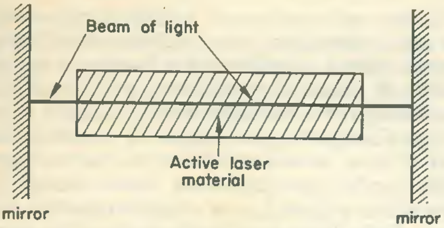


Fig. 6. The basic construction of a laser

laser may be in the form of a monatomic gas at low pressure where there is little interaction between atoms. Alternatively the active atoms may be present at a low concentration in a host crystal. For example, the ruby crystals used for laser work contain about 0.05% of chromium atoms in the aluminium oxide material of the crystal. There are certain elements known as "rare earths" or "lanthanides" (since the first of these elements is lanthanum) which can be used as laser materials at much higher concentrations (about 5%) in an amorphous material such as glass. Perhaps the most commonly used rare earth element is neodymium. The electrons of these atoms which take part in the laser action are in an inner orbital which is well screened from the effects of the neighbouring atoms by the electrons in the outer orbitals. A similar effect occurs in the actinide elements, but all of these (except uranium) are too dangerously radioactive to be of great interest for laser work at the present time. In addition many of the actinide elements are short lived (owing to their radioactive decay) and are expensive.

Oscillation by Reflection

The laser systems discussed so far are amplifiers. Lasers are required to produce light in the way that a radio transmitter produces radio waves. Positive feedback must therefore be applied to the laser amplifier system to convert the amplifier into an oscillator.

In an electronic system the feedback signals are conducted by wires from the output to the input, but light can be fed back into a material by the use of a mirror. The feedback is obtained in a laser by means of the simple mirror system shown in Fig. 6 which is known as a Fabry-Perot resonator. This type of system was first suggested in 1958[1] before a practical laser had been made. The two mirrors must be parallel to each other and must face each other. The active laser material is placed between the mirrors; it is often in the form of a cylinder.

The light passes to and fro along the central axis of the system as shown in Fig. 6 and is amplified somewhat each time it passes through the laser material. As in an electronic oscillator, the power builds up until a maximum intensity is reached when the energy lost per cycle is equal to the energy gained per cycle. Any rays not returned to the laser material by the mirrors and any photons which are absorbed by the laser material represent energy lost from the beam. Lasers have a "Q" factor similar to the quality factor of an electronic tuned circuit. The greater the energy lost when the light undergoes one complete cycle in the system and returns to its starting place, the lower the Q.

If a photon is formed at point A in Fig. 7 and travels at an angle slightly inclined to the axis of the system, it will be quickly reflected out of the system by a path such as that shown. If a photon moves in a path which is more inclined than AB to the axis of the laser, it will pass out of the system even more quickly. Any amplification of the light by stimulated emission between A and B or between B and C will not affect the direction of propagation of the ray. Only those photons which pass along the axis of the system, as in Fig. 6, will be amplified to any great extent. Thus the divergence of a laser beam is extremely small, often a fraction of a degree. The laser therefore behaves as if it were a light transmitter with an aerial of extreme directivity. (Compare the divergence of a laser beam with the polar diagram of an H aerial!)

One of the mirrors of the laser may be only partially silvered so that the output beam may be taken from it. In some lasers one of the mirrors has a small unsilvered area through which the laser output beam can pass.

Laser Tuning

In order that the feedback in a laser shall be positive, it is necessary that the waves which have undergone two reflections shall be returned in phase with the original waves. If a trough of one wave arrives at a certain point at the same time as the crest of another wave, the two will tend to cancel each other. In practice this condition means that the path length between the two mirrors must be an integral number of half wavelengths of the light which is undergoing amplification in the system or the laser will not be "in tune".

If the distance between the two mirrors has the fairly typical value of one million wavelengths, the system will be able to resonate at many different frequencies, each resonant frequency being separated from the adjacent ones by one part in two million. A number of these frequencies may be close enough to the laser material frequency $(E_2-E_1)/h$ (E_2 and E_1 are shown in Fig. 4) to give rise to stimulated emission. Thus although the approximate frequency of operation of the laser is controlled by the properties of the atoms used, the exact frequency of the

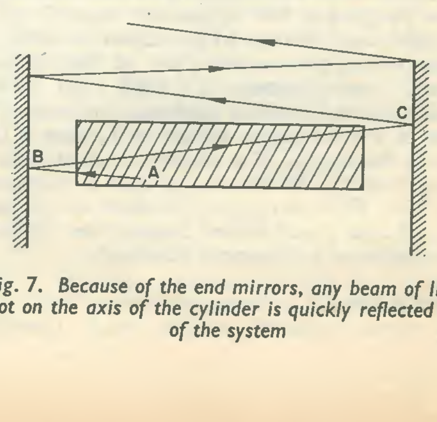
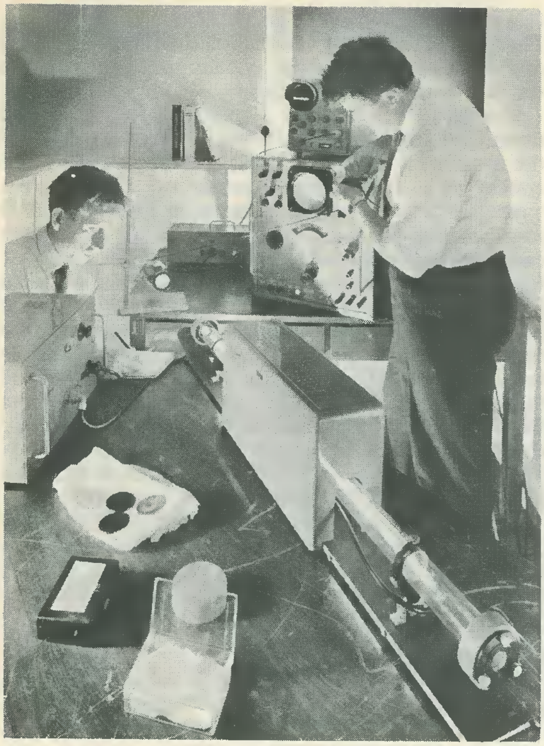


Fig. 7. Because of the end mirrors, any beam of light not on the axis of the cylinder is quickly reflected out of the system



In this photograph, the output from a Ferranti Mark I gas laser is striking a photosensitive detector which is connected to the oscilloscope. Note the r.f. power unit to the left. (Ferranti Ltd.)

light output is determined by the spacing between the mirrors of the resonant system. Simultaneous oscillation may occur at more than one frequency, especially if the rate of pumping (and hence the Q of the sytesm) is relatively large. For some applications this must be prevented.

If a gas laser is considered, the active material may be able to resonate over a frequency band of some hundreds of megacycles and the mirror system may be able to resonate over a band of perhaps one megacycle. Nevertheless the laser can be so designed that the spread in the output frequency is less than one cycle per second. This is most remarkable when one considers that the frequency of the light emitted may be about 4×10^{14} cycles per second. If the laser light were stable to one part in 10^{14}, its stability would far exceed that of the standard frequency transmissions of MSF and WWV; unfortunately the slightest movement of one of the mirrors in the resonator system will cause a large change in frequency. For example, a change in the distance between the mirrors of half a wavelength (about 4×10^{-5} cm.) can produce a frequency change of over one hundred megacycles. Thus the laser is useless as a frequency standard.

Coherent Light

The word "cohere" means "stick together". (Old time radio amateurs will certainly remember the coherer detector[5], the particles of which stuck together when a suitable radio frequency signal was applied. A direct current from a battery could then pass through the particles and operate a relay or a bell.) Coherent light is light in which all of the peaks of the waveform reinforce each other and "stick together" as the wave moves along. Thus truly coherent light has a single frequency, all the waves of the light are in phase and the plane of polarisation of all of the waves is the same.

This appears fairly straightforward, but things are not quite so simple when one tries to put these ideas on coherency into practice. Unfortunately, almost all Sixth Form physics courses tend to merely mention coherency without actually explaining how the theory is connected with practical aspects of the subject. Many of the G.C.E. "A" level textbooks seem to conspire to be rather incoherent about the subject of coherency. Possibly it is because coherence appears to be so relatively simple at first sight that it is often not adequately treated. However, the invention of the laser has stimulated interest in coherency and at least two good articles have recently been published on this subject[6 7].

The difficulty most people meet in understanding the practical aspects of coherence can be expressed in the question "How coherent is coherent light?". For example, it is often stated that laser light is coherent. The gas laser provides light with the narrowest frequency spread (or spectral line width) of about 1 c/s, but the light from other types of laser has a much larger frequency spread; for example, the light from a gallium arsenide semiconductor laser may spread over a bandwidth of 100,000 Mc/s[8] at a frequency of 355.4 million megacycles. How can this be reconciled with the fact that coherent light must be of a single frequency?

Interference

In order to answer this question, a property of all wave motion (including light) known as interference will be discussed. We shall meet interference again when we discuss the use of lasers for accurate measurement in the final article of this series. Interference occurs when two sets of waves meet; two crests of the waves will form a large crest, whilst a crest and a trough will cancel each other out. This effect may, to some extent, be observed when two stones are thrown into a river and the resulting waves interfere.

In Fig. 8 a beam of light is separated into two parts which are brought together again at the screen. The light travelling by the direct path 1 will cover a shorter distance than that travelling by reflection from the mirror (path 2). A crest of Wave 1 will meet a crest of Wave 2 at point A. if the difference in the path lengths is a whole number of wavelengths of the light being used. A bright line is formed on the screen at A. A dark line is formed at the nearby position B where the crest of one wave meets the trough of the other wave. A similar effect occurs at other positions so that a series of alternate bright and dark lines is formed on the screen. These are known as interference fringes or collectively as an interference pattern.

If the two sets of waves arriving at the screen are not coherent, the necessary phase relationship between them is not maintained for more than a very short time. If at one instant of time two crests meet at A, whilst an instant later a crest and a trough meet there, the screen will be uniformly illuminated and no interference pattern will be seen.

If two waves from different sources of light (other than lasers) meet, their phase relationship varies considerably over even very small time intervals and no interference fringes can be obtained. Even if the light is taken from two separate points on the same source, no interference pattern will be obtainable. This is only to be expected, since the atoms of a substance emit photons at random times (except in the laser). Light from two independent laser beams can, however, produce an interference pattern, since all of the photons in each beam are in phase with one another.

Although the light from any source, even from a laser, shows some spread of frequency, the light from a laser behaves as if it were coherent over short time intervals during which the light travels quite large distances. Any difference in frequency between two parts of a waveform can only be detected by observation of the wave for a time exceeding this short time interval.

The time for which a beam of light remains effectively coherent is approximately equal to the reciprocal of the spectral width of the beam. For example, if the frequency spread of the beam from a ruby laser is 20 Mc/s, the light remains effectively coherent for $\frac{1}{20,000,000}$ second, which equals 5×10^{-8} second. This is a very short time indeed, but light travelling at 30,000 million cm. per second covers a distance of 1,500 cm. in this time. If an interference experiment is tried with this light, it will not be successful unless the path difference is less than about 1,500 cm. Light from a gas laser can be made to have a frequency spread of only one cycle per second and therefore remains effectively coherent for a maximum time of one second. Thus the maximum path difference in interference experiments using this type of light can, at least in theory, be of the order of 186,000 miles. (Light travels at 186,000 miles per second.)

Before the invention of the laser, one of the most coherent sources of light available had a frequency spread of about 1,000 Mc/s. Thus the time of effective coherence was 10^{-9} second and the maximum path difference in interference experiments about 30 cm. This is what is meant by "coherent light" in pre-1960 textbooks. Ordinary white light is, of course, incoherent, since it has a bandwidth of rather less than 500 million megacycles (ignoring ultra-violet and infra-red components). It remains effectively coherent for about 2×10^{-15} second and, for the white light as a whole to be used in interference experiments, the path difference must be less than about 6×10^{-5} cm. Interference occurs when oil or petrol is spilled on a wet road. The white light as a whole is not usually coherent enough to produce an interference pattern, but each of the colours in the white light shows interference and the well known coloured patterns are produced. This also occurs in thin soap films.

For most path differences which are likely to be used in laboratory experiments, laser light behaves as if it were perfectly coherent. White light shows incoherent behaviour except when extremely thin films (such as petrol on a wet road) are being considered. It should be remembered that the difference in the path length is usually very much smaller than the actual path length of either ray.

From the preceding discussion about stimulated emission, it would be expected that the light emitted by a laser would be of a single frequency, the value of which would be determined by the energy levels in the atoms of the laser material employed. Nevertheless it has already been stated that even laser light has a small spectral line width. One of the reasons for this is that light behaves as if it were discrete particles (that is, photons) and arrives at its destination in short bursts of energy rather than continuously. This is effectively a form of random modulation and contributes to the sidebands in the spectrum of laser light. It also acts as noise in the same way that electrons arriving at a valve anode contribute to "shot effect" hoise. At radio frequencies the effect also exists in theory, but each photon has such a small energy that the amount of random modulation due to this cause is negligible; at radio frequencies each photon is as difficult to detect as each atom in a large jet of water which is, for all practical purposes, a continuous stream of water.

Perhaps the Doppler effect is the major cause of frequency spread, at least in gas lasers. The Doppler effect is noticed in sound by a stationary observer when an express train rushes past the observer with its whistle sounding. As the train passes, the observer notices a fall in the frequency of the sound. When the train is moving towards the observer, the apparent frequency of the whistle is greater than when the train is stationary which, in turn, is greater than when it is moving away from the observer. The molecules of the laser material are moving in random directions at an enormous speed; this motion is the energy of heat. As in the case of the sound waves emitted by the whistle of the express train, the apparent frequency of the light seen by an observer will be greater when the light is emitted from an atom moving towards the observer than from a stationary atom. Similarly the frequency of the light emitted from a stationary

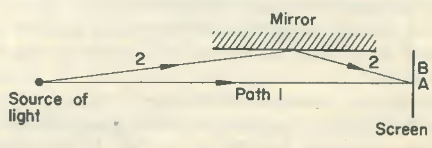


Fig. 8. An interference experiment ("Lloyd's Mirror")

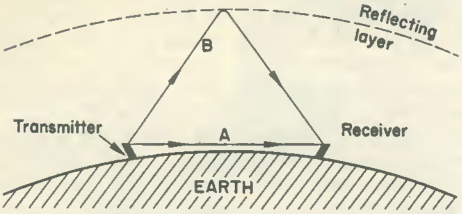


Fig. 9. Interference can cause fading of radio signals

atom is somewhat greater than that emitted from a receding atom. Thus the frequency spread will increase with the speed of the atoms, that is, with the temperature of the laser material.

Further effects cause broadening of the spectral lines in certain types of laser. For example, the interaction of the emitting atoms with neighbouring atoms ("pressure broadening").

Noise

Coherency becomes a very important consideration when the possibility of modulating light for communication purposes arises, since incoherent light is essentially a carrier modulated with noise from the point of view of the radio engineer. In order to understand why this is so, it is necessary to appreciate that when a radio frequency carrier wave is modulated, sidebands are developed on either side of the original carrier. Incoherent light contains a number of frequencies and these act as noise (or random modulation) of the carrier. If one could obtain perfectly coherent light, it would have a pure sine waveform. Its coherency would be destroyed if it were modulated.

Although it is possible to send signals by means of incoherent light, the amount of information which can be carried per unit time is relatively very small, so the system becomes very inefficient. An example of the use of incoherent light for signalling occurs when a car driver operates his "flashers" when he wishes to turn. Incoherent light may be compared with the incoherent radio signals produced by the old spark type transmitters (as used by Hertz in his early experiments). The use of spark transmitters is no longer permitted, since they generate signals which occupy a very large frequency band and which cause a very great deal of interference to other users. Spark transmitters produce a succession of oscillatory discharges due to intermittent breakdown of the spark gap. The waveform is more or less randomly modulated and cannot be used to transmit much more complex signals than the on/off type such as morse. (Compare this with car "flashers".)

Probably the first coherent radio frequency source was the Duddell arc transmitter which was developed by Poulsen for use at 100 kc/s. By 1936 coherent radiation at frequencies up to about 50,000 megacycles was obtainable. The invention of the laser has raised this uppermost coherent frequency by a factor of about 2,000 to 500 million megacycles, although an ultra-violet laser has now been developed[9]. Coherent light of many different frequencies extending into the far infra-red can now be produced by the use of various laser materials, but it is not yet possible to cover all of the frequency bands. In addition it is not yet possible to produce coherent radiation in the gap between the highest microwave frequency and the lowest frequency at which a laser can produce infra-red light [10]. A constant search is being made for new laser materials which will enable new frequency bands to be covered.

Ordinary radio transmissions consist of coherent radio waves. Interference occurs between the wave A in Fig. 9 which travels directly from the transmitter to the receiver and the wave B which is reflected from the layers in the upper atmosphere back to earth. As the height of the reflecting layer changes slightly, the positions of the point at which the two waves reinforce one another and the point at which the waves cancel out change. This results in the phenomenon of "fading" which is so prevalent on the medium and short wavehands. It is usually completely absent on v.h.f. and u.h.f. bands, since radio waves of these frequencies are not normally reflected from the upper atmosphere back to earth. In the short wave bands interference can also occur between waves which have been reflected a different number of times from the upper atmosphere or between waves which have travelled around the earth in opposite direction; this again leads to fading.

This concludes our theoretical discussion about the functioning of lasers and the nature of the light they emit. Next month the construction and properties of the various types of lasers will be covered in detail. In the third and final article of this series some of the vast variety of practical applications of lasers will be discussed; the article concluding with a review of the practical possibilities offered by lasers to the serious amateur experimenter who is willing to go to some trouble to investigate these new devices.

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The 1965 International Audio Fair

THE 1965 INTERNATIONAL AUDIO FESTIVAL AND Fair was the tenth to be held in London, and it demonstrated very clearly that this exhibition has now settled comfortably into its quarters at the Hotel Russell. Those who remember the very first London Audio Fair at the Hotel Washington (where Press tickets were so difficult to get hold of that the late "Free Grid" of *Wireless World* had to get in by way of the kitchen quarters, and where the present writer had to wave the first official-looking card he could find in his wallet and push past the queue calling out the magic word "Press") can appreciate that the hotel method of presentation, with stands downstairs and demonstrations in the hotel rooms, has developed into as efficient a system as the economics can allow. There are still those who congregate in tight bunches at the doorways to the demonstration rooms and prevent other people from getting in or out, but this appears to be a hazard which will be with us always.

This year's Fair, held over the period 22nd to 25th April, had 85 exhibitors, of which nearly one-quarter were from overseas.

Loudspeakers

After a long period of what might almost be looked upon as semi-retirement, the Ionophone reappeared on the scene this year, taking the form of a high frequency unit known as the Ionofane Model 601 in two complete reproducers marked by Fane Acoustics, Ltd. The first of these is the Ionofane Model 602, a medium and high frequency reproducer whose range is quoted as 800 c/s to 50 kc/s and which is designed to work with an existing bass unit. The second is the Ionofane Model 603 full range reproducer, quoted as covering 20 c/s to 50 kc/s. The 602 has the Ionofane Model 601 and a mid-range moving-coil speaker, whilst the 603 has the Ionofane Model 601, a moving-coil mid-range unit and a 15in moving-coil bass unit. Both the 602 and 603 have cross-over networks, of course, and in each case the Ionofane 601 comes in at about 3.5 kc/s. The Ionophone principle consists of ionising a small volume of air in a quartz cell by means of a high voltage r.f. signal. When the r.f. signal is amplitude modulated at an audio frequency, the degree of ionisation varies correspondingly, and pressure waves are formed which produce sound. These pressure waves have to be coupled to the outside air by way of a horn. The system is completely aperiodic and is affected only by the characteristics of the horn itself. Present development prevents the use of the Ionophone at anything except the higher audio frequencies, where it is free from resonances and can handle transients without distortion. The Fane version of the Ionophone—the Ionofane Model 601 just referred to—uses a single pentode r.f. oscillator running at 27 Mc/s to ionise the air, this pentode being screen-grid modulated. The unit is quite small, the rectangular mouth of the horn measuring 6 x 1¼in, with the larger dimension vertical. A wide angle (160°) of horizontal dispersion is given. The writer was soon able to locate the Ionofane Model 601 in the full range 603 reproducer demonstrated at the Fair by looking carefully through the front of the cabinet. The 601 gives a blue glow at the neck of its horn which is quite visible through the front grille!

Another new development is the addition of an "acoustic lens" to the Kelly Ribbon Speaker. This offers considerable improvement in high frequency diffusion, and the model is backed by Decca Radio and Television, who market Kelly loudspeakers. (Decca, incidentally, have also introduced a magnetic bias compensator for pick-up arms—i.e. to compensate for the small force towards the centre of the record—as an alternative to the pulleys, weights and threads which have hitherto been the order of the day for this particular function.)

Making its appearance during the last 12 months, and representing another change in loudspeaker outlook, is the "Maxim" reproducer manufactured by Goodmans Industries Ltd. Although measuring only 10½ x 5½ x 7¼in deep, this offers a response from 45 to 20,000 c/s and is capable of handling 8 watts. Incorporated are a special bass and treble unit, the whole being enclosed in a thick timber cabinet with heavy internal acoustic damping to provide an infinite baffle. Another newcomer to the small high fidelity range is the "Ditton 10", this being exhibited, for the first time, by Celestion Ltd. The "Ditton 10" measures 12¾ x 6¾ x 8¼in, and has an overall frequency range of 35 to 15,000 c/s with a power handling capacity of 10 watts r.m.s. This also employs separate bass and high frequency units in a totally enclosed and heavily damped cabinet. At the Fair, Celestion took advantage of the hotel room décor to mount a homely-looking assembly of shelves, complete with vases and a set of Dickens, against one wall. This showed very effectively the small amount of space taken up by the "Ditton 10" loudspeaker in typical domestic surroundings. The two units being demonstrated reproduced stereo at a level which was more than adequate for home listening.

Modular Design

Also capable of working in a small enclosure but, otherwise, showing a complete breakaway from traditional loudspeaker construction is the Jordon-Watts Modular high fidelity loudspeaker, which is distributed by Boosey & Hawkes (Sales) Ltd. This unit was introduced at last year's Fair, and a number of complete reproducers incorporating one or more of the Modular speakers are now in production. A 12 watt speaker system incorporates 1 speaker, a 25 watt system 2 speakers, a 50 watt system 4 speakers, and a 100 watt system 8 speakers. The speakers are simply added to suit the power required and the enclosure designed accordingly. The Jordon-Watts 12 watt "Mini-12" unit has an infinite baffle cabinet measuring 16½ x 8 x 3½in deep, but 12, 25, 50 and 100 watt reproducers are also available in reflex cabinets. The important feature of the Jordon-Watts module speaker is that it breaks away completely from the rigid mass-less piston concept and employs a cone whose shape and material deliberately allow flexure and provide, in consequence, an effective cone area that automatically adjusts to the frequency being reproduced. A 4in metal cone is employed with considerable axial movement to provide the necessary bass response, and the coil is centred by three silvered beryllium copper cantilevers, two of which carry the voice-coil current. The absence of conventional materials was aptly demonstrated by the fact that one unit at the Fair was operating completely immersed in water! Completely new was the Jordon-Watts stereo reproducer model DPS100. This has four Modular speakers per channel, these being progressively phase-delayed to cause the wave-front of sound directed at the listener to be tilted inwards. The listening position is, in consequence, considerably less critical than occurs with the more conventional set-up.

Transistors

Although transistors are overtaking valves in most audio equipment, notably tape recorders and tuners, the valve is still by no means entirely dismissed from the field. Acoustical Manufacturing Co., for instance, continue with their "Quad" valve equipment without change, apart from the fact that their f.m. tuner now incorporates a switch on the chassis which enables the addition of a multiplex decoder to be carried out without modifying the wiring or components of the tuner. Acoustical maintain that a transistor amplifier of the same performance in the 15 watt class compares very unfavourably as to price with their valve amplifier. Nevertheless, transistor high fidelity amplifiers were well in evidence, including the "Stereo 30" transistor integrated amplifier manufactured by H. J. Leak & Co.

Mullard were well in evidence and exhibited their "Harmonious Range of Audio Transistors". The range consists of complementary n.p.n./p.n.p. types for use in transformerless output stages with output powers from 40mW to 40W. Typical of the transistors in the range is the LFK4 package consisting of AC127 pre-amplifier, OC81D driver and a complementary pair of OC81 and AC127. This package offers 700mW from a 9 volt supply, or 1 watt from a 12 volt supply. There is also the AD161/AD162 complementary pair which requires only small heat sinks but can offer 3 to 6 watts output. As always, Mullard looked after the interests of home-constructors and had a number of transistor designs available, these including a 10 watt pi-mode amplifier, a 5 watt Class-A amplifier and a v.h.f. tuner unit.

Similarly of interest to the home-constructor was the introduction this year of the Model AA-22U all-transistor "20+20 Watt Stereo Amplifier" by Daystrom Ltd. This amplifier (shown during the Fair period at the nearby Grand Hotel and not at the Hotel Russell) is available as a kit in the Heathkit range and incorporates 20 transistors and 10 diodes. There is a very comprehensive specification including a frequency response which is flat within ±1dB from 15 to 30,000 c/s and within ±3dB from 10 to 60,000 c/s. Output impedances are 4Ω, 8Ω and 16Ω, and distortion is 0.3% or less at 1,000 c/s. The amplifier has a sensitivity of 6mV on gram and 250mV on tuner, tape recorder and two auxiliary inputs, and it is housed in a fully finished walnut veneered cabinet with a gold anodised front panel.

Cover Feature

Variable H.T. Supply

By J. Thornton Lawrence

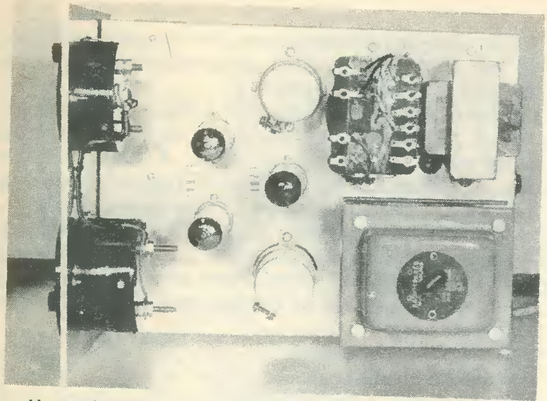
A power unit which offers variable h.t. voltage with good regulation, together with a 6.3 volt a.c. output at 3 amps. Despite its relatively low cost, the power supply employs new components which are run well within their ratings

THE DESIGN OF THE POWER SUPPLY TO BE DESCRIBED resulted from the need for a variable source of direct voltage suitable for feeding experimental valve circuits in a school or technical college laboratory. The components required needed to be both inexpensive and readily available.

The main requirements were a continuously variable d.c. output of 0–250 volts at 0–75mA, the source having reasonably low output impedance, and a 6.3 volt a.c. supply suitable for feeding valve heaters. It is impractical to use a potential divider or potentiometer to provide a variable d.c. supply due to the relatively high output resistance, so a simple cathode follower circuit was chosen using two EL84 pentode valves strapped as triodes and connected in parallel. The output impedance of a cathode follower stage (see Fig. 1) is given by the expression:

$$Z_{out} = \frac{1}{gm}$$

For two EL84 valves triode-connected and paralleled, the output impedance is approximately 50Ω.



Above-chassis view, showing the clean, uncluttered layout

However this only holds good providing the grid, anode and screen voltages do not vary with the current drawn from the cathodes.[1]

Due to the internal resistance of the mains transformer, rectifier and smoothing circuits supplying the cathode follower stage, the anode and screen supply voltage does vary with the current drawn, and this results in an increase in the effective output impedance.

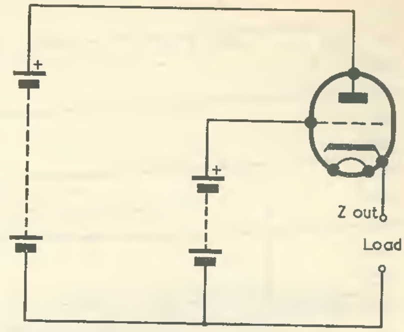


Fig. 1. Basic cathode follower

Circuit Description

The complete circuit of the power supply is shown in Fig. 2. The control grid voltage for V_2 and V_3 is fed from a variable potentiometer VR_1. In order that the voltage across this potentiometer be main-

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[1] The equation $Z_{out}=\frac{1}{gm}$ is approximate, but is quite adequate for practical work. The output impedance of a cathode follower may be expressed as $Z_{out}=\frac{m}{gm}$ where m is gain (and is, normally, close to unity).—EDITOR.

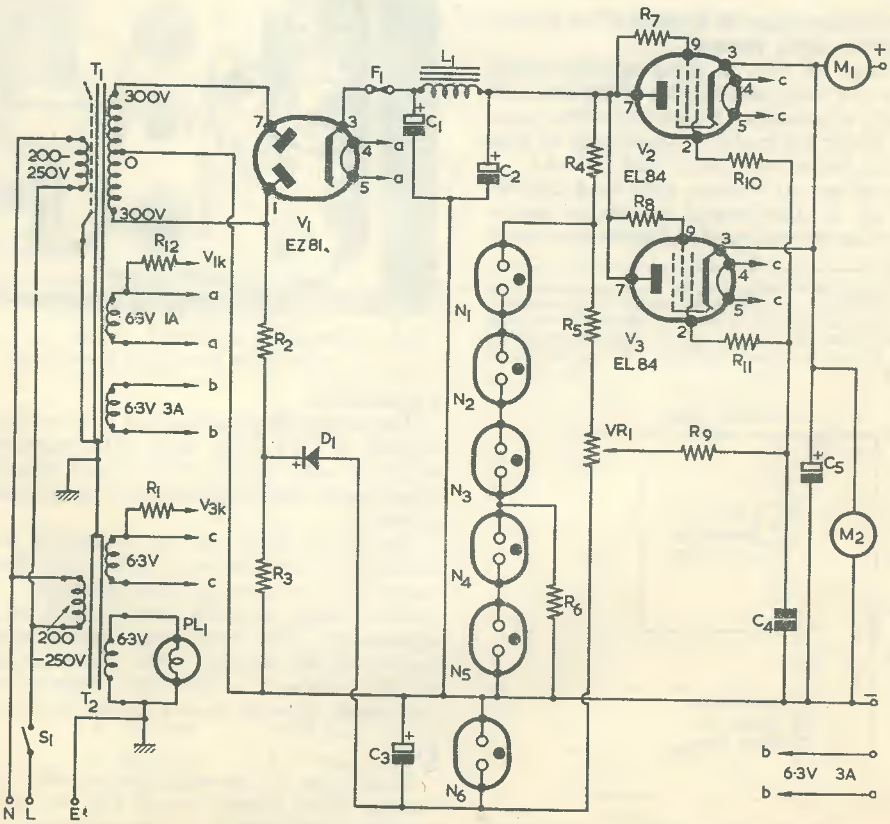


Fig. 2. The circuit of the power supply. R_{12} connects to pin 3 of V_1 and R_1 to pin 3 of V_3

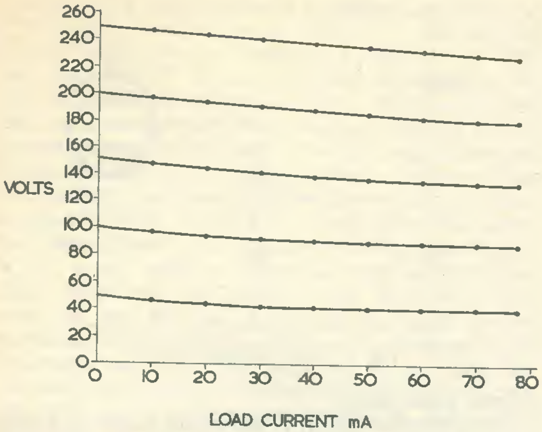


Fig. 3. Output voltage/current curves, illustrating the regulation provided

tained as constant as possible, the negative supply to the lower end of VR_1 is shunt stabilised by a neon tube N_6, whilst the positive supply to the junction of R_4, R_5 is stabilised by neon tubes N_1–N_5. As no current is drawn by the grids of V_2 and V_3 the grid voltage is determined purely by the setting of VR_1.[2]

This voltage is decoupled by R_9 and C_4 to ensure there is negligible ripple present.

The total range of VR_1 is from approximately −50 volts to +260 volts with respect to the negative output terminal; this enables V_2 and V_3 to be completely cut off under no-load conditions and to give 250 volts output under maximum load (75mA).

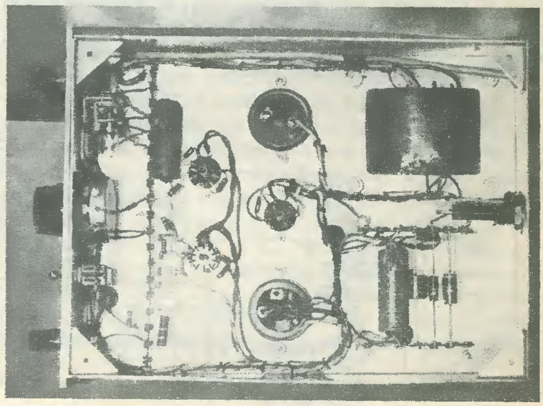
The change of output voltage with load current is shown in Fig. 3. The output impedance represented by the slope of the graph indicates that, even under the worst conditions, the output impedance is less than 250Ω. This is considered quite satisfactory for most purposes.

The output is shunted with a 16μF capacitor, C_5, which provides a low dynamic output impedance from audio frequencies upwards. A 10MΩ resistor, R_6, is connected across two of the neon tubes to reduce the striking voltage of the whole chain.

The h.t. circuits and l.t. supply are completely floating and are not connected to chassis in any way, but the mains transformer screen is connected to chassis and this is earthed through the mains lead and plug.

Two separate meters are used to indicate output voltage and current, but this is not absolutely necessary and a suitably scaled milliammeter could be switched to perform as a volt or current meter as shown in Fig. 4. In this case it would be advisable to fit a 220kΩ ½ watt resistor to discharge C_5 when the unit is switched off.

The testing of the unit was carried out by connecting various values of high wattage wirewound resistors across the output terminals and noting the change of output voltage for various load currents.



The wiring below the chassis. Lacing the connecting wires gives a very neat overall finish

[2] It might appear that, on striking, neon N_6 could pass a relatively high current until the voltage across C_3 was brought down to burning level. This point has been checked in practice, however, and it has been found that the value and duration of the initial current in N_6 after switching on is such as to have negligible effect on the life of this neon.—EDITOR.

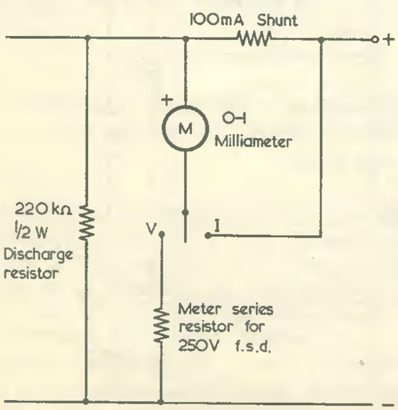


Fig. 4. Using a single meter instead of the two shown in Fig. 2

Construction

The power supply is built on a 16 s.w.g. aluminium chassis 10 x 7½ x 2in deep. The valveholder holes were cut with the aid of a chassis punch, and the transformer and meter cut-outs were made using an Abrafile.

The front panel of the prototype was of ⅛in aluminium, but 16 s.w.g. with a ¼in lip all round would have been quite strong enough.

The chassis normally has a cover of perforated aluminium. The component layout is not critical and could be changed from that shown in Fig. 5 to suit a cabinet of different dimensions. Chassis and panel dimensions are shown in Figs. 6 and 7.

Cost

Using new components throughout purchased at normal retail prices, except for the meters which were ex-Government surplus, the total cost of the prototype amounted to £12.

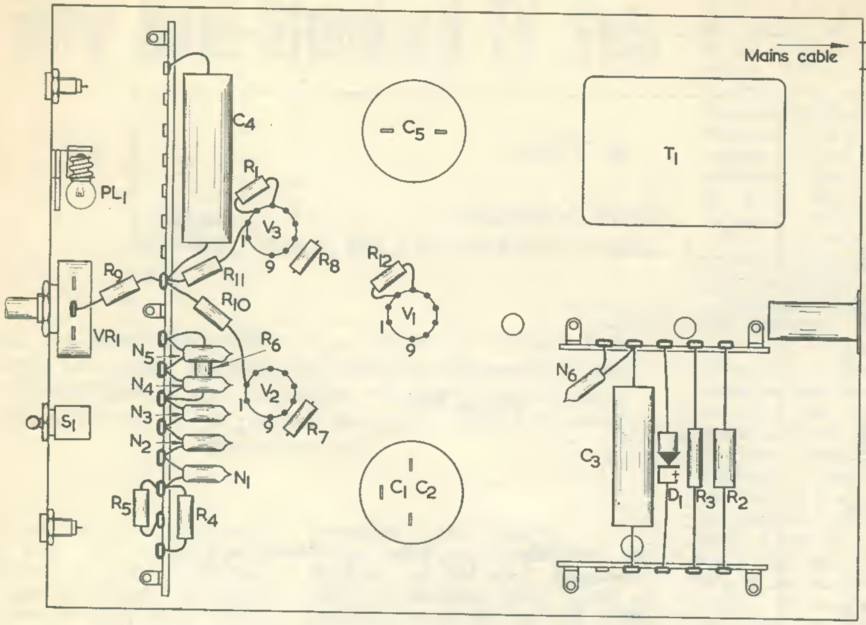


Fig. 5. Component positioning below the chassis

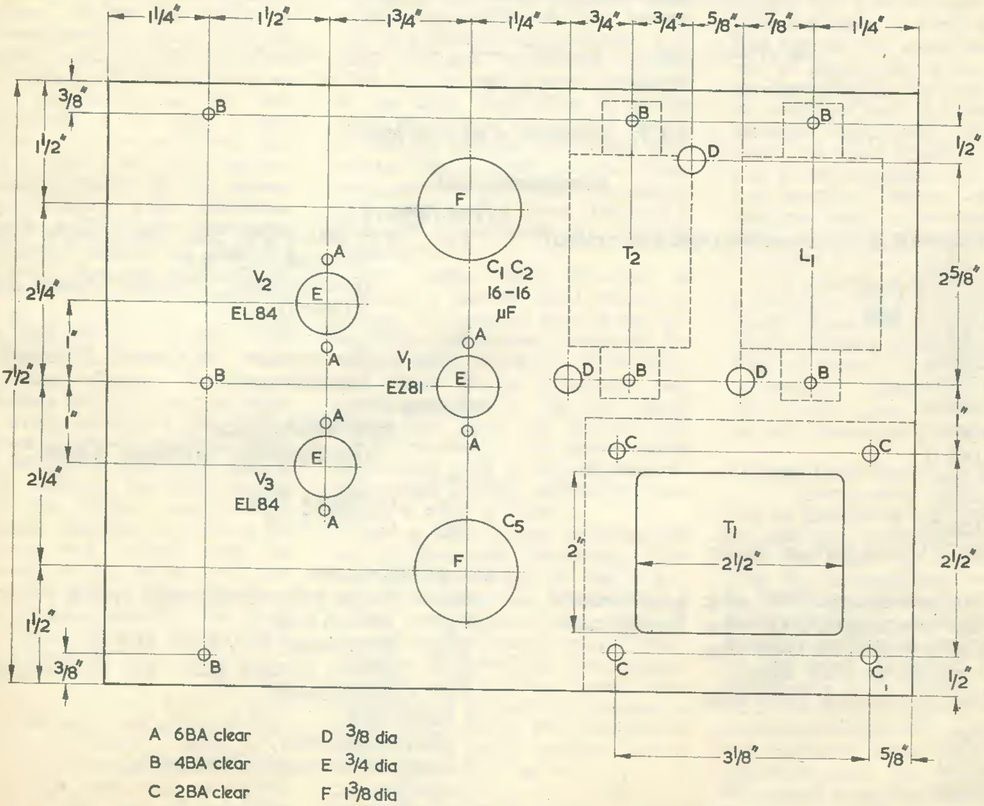


Fig. 6. Top view of the chassis, showing drilling dimensions. Holes D are for grommets. Holes F may require different diameters for some electrolytic capacitors

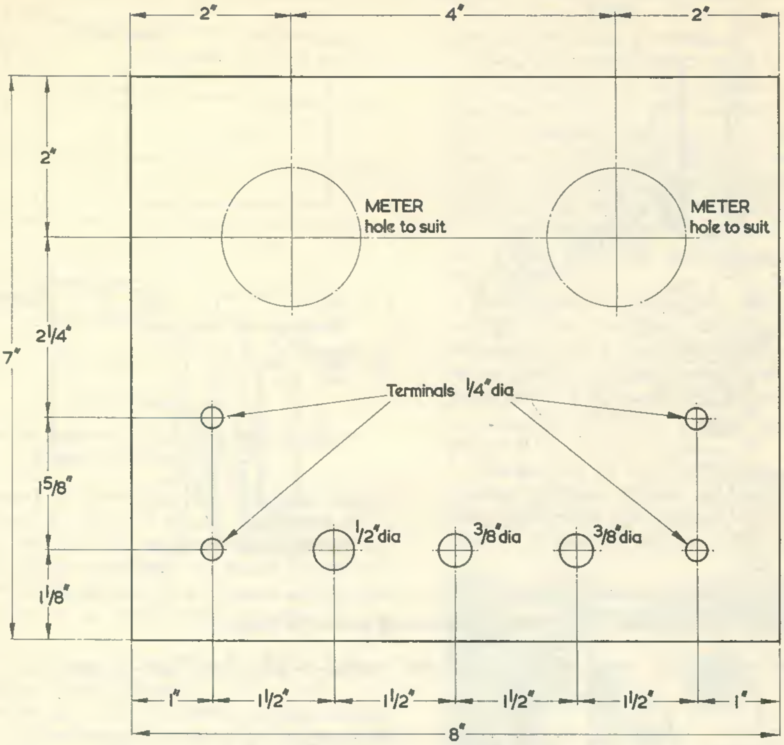


Fig. 7. Dimensions of the front panel

Components List

Resistors

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

R_1	100kΩ
R_2	47kΩ 2 watt
R_3	15kΩ 1 watt
R_4	100kΩ
R_5	220kΩ
R_6	10MΩ
R_7	100Ω
R_8	100Ω
R_9	100kΩ
R_{10}	4.7kΩ
R_{11}	4.7kΩ
R_{12}	100kΩ
VR_1	2MΩ 1 watt carbon, linear

Capacitors

C_1	16μF electrolytic 500V wkg. } combined in single can
C_2	16μF electrolytic 500V wkg. } combined in single can
C_3	40μF electrolytic 150V wkg.
C_4	0.5μF paper 350V wkg.
C_5	16μF electrolytic 350V wkg.

Valves

V_1	EZ81
V_2	EL84
V_3	EL84

Neons

N_1–N_6 Miniature neons—wire ended (Radiospares)*

Transformers

T_1	Pri. 200–250V; Sec. 300–0–300V 120mA; 6.3V 3A; 6.3V 1A (Radiospares "Hygrade" Mains Transformer*)
T_2	Pri. 200–250V; Sec. 6.3V 1.8A; 6.3V 1.8A (Radiospares "Hygrade" Filament Transformer*)

Inductors

L_1 10H 90mA choke (Radiospares "Hygrade" Choke*)

Meters

M_1	0–100mA f.s.d.
M_2	0–250V f.s.d.

Other Components

S_1	Single pole on/off toggle switch
F_1	150mA fuse
PL_1	Pilot lamp, 6.3V 0.3A M.E.S.
D_1	Silicon rectifier REC 50A (Radiospares*)

3 B9A valveholders
1 fuseholder
1 pilot lampholder
4 heavy-duty insulated terminals.
Tagstrips, etc.

*Radiospares components are available only through retailers.

The New Dual-Standard TV Sets

PART 13

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

In this, the concluding article in our series on 405-625 line receivers, the author discusses the latest developments in the field of transistorised u.h.f. half-wave and quarter-wave tuners. Also described are hybrid receiver principles and u.h.f. aerial signal boosters

In part 3 of this series, published in the July, 1964 issue, details were given of both v.h.f. and u.h.f. tuners as found in dual-standard sets of that date. Since that item there has been considerable development in the field of u.h.f. transistors. Before the advent of u.h.f. television in Great Britain, transistors were sometimes found in the tuners of 405-line-only receivers, particularly in the "all-transistor" set of this type. Indeed, transistor v.h.f. tuners were described in Part 1 of "Transistorised Television Circuits," by the present author, published in the November, 1963 issue of *The Radio Constructor*.

Transistors suitable for operation up to 1,000 Mc/s are comparatively recent additions to the semiconductor lists and it is this type of device that is now in use in many u.h.f. front-ends. Moreover, the v.h.f. all-transistor teletuner has undergone a face lift, and circuits somewhat more advanced than that described in the November, 1963, article referred to above are now in use. In addition, the trend is now towards the hybrid dual-standard set which features a mixture of transistors and valves, with the transistors in the tuners and low-level signal stages and the valves in the power circuits. We shall have more to say about these receivers later on.

Firstly, let us look at the new transistor v.h.f. and u.h.f. tuners. Circuits of these are given in Fig. 41. These are from a design of a hybrid dual-standard receiver by Mullard Ltd., and they are shown along with the first i.f. amplifier stage, so that the switching and filter circuits can be appreciated.

Transistor U.H.F. Tuner

The u.h.f. tuner employs two Mullard AF186 u.h.f. transistors. The first of these, TR_1, is the r.f. amplifier and the second, TR_2, the self-oscillating mixer (frequency changer). This tuner employs tuned or resonant half-wave lines instead of the more conventional coil used in low frequency tuners. This kind of tuning was introduced in the July, 1964 (Part 3) article with reference to valve u.h.f. tuners. It may be recalled that short rods located in troughs in the tuner case serve as half-wave resonators, and that tuning over the u.h.f. channels is achieved by variable capacitors.

The same basic principle is adopted in the new u.h.f. transistor tuners, but here the lines or resonators are sometimes designed for quarter-wave working. The rods and their tuning capacitors are clearly revealed in Fig. 42, which shows the inside of the R.G.D. u.h.f. teletuner. The quarter-wave versions of u.h.f. tuners are remarkably small in size, measuring only about 4 x $2\frac{1}{4}$ x $1\frac{1}{2}$in.

Let us now further examine the use of lines and resonators. The rod in the trough in the u.h.f. tuners possesses the characteristics of a transmission line, such as coaxial cable. Indeed, coaxial cable could be employed for the resonant elements, but this is never done because it is so easy to produce a much more stable and convenient line in the tuner proper, as is demonstrated by Fig. 42.

Transmission Lines

A transmission line which is adjusted in length to suit the frequency it is required to tune can be made to appear electrically to the circuit as an ordinary parallel tuned circuit, comprising an inductor and capacitor. With the line open-circuit at one end it is resonant at $\frac{1}{2}$, $\frac{3}{2}$, $\frac{5}{2}$, and so on, wavelength. When one end is short-circuited, then it is resonant at $\frac{1}{4}$, $\frac{3}{4}$, $\frac{5}{4}$, and so on, wavelength. Thus, in half-wave tuners of the valve or transistor type, the line is open-circuit, while in quarter-wave transistor tuners it is short-circuited.

Now, on Channel 33, for example, the physical halfwave length is in the order of 28 cm. (about 11in). Obviously, a line this length could never be used in a tuner. Fortunately, the line can be shortened a great deal to exhibit an electrical halfwave length. This is possible because a length of open-circuit line which is less than one-quarter wavelength is equivalent to a capacitor. Thus, if a length is cut off each end of a physical halfwave line it can be made up by a capacitance. Of course, the end bits cut off *must* be less than one-quarter wavelength, since the whole line is only half a wavelength!

This is what is done in resonant-line tuners. The capacitance at one end of the cut-down line is formed by the variable capacitor and that at the other end is formed by the collector capacitance of the transistor (or valve anode capacitance), plus a trimming capacitor. Although the electrical length of the line remains half a wavelength, the physical length is reduced to something like 5 cm.

This method of line loading makes it easily possible to vary the electrical length of the line simply by making the end loading capacitance variable. This, of course, is what is done in commercial tuners, each section of the tuning gang representing the far end loading of the line.

Quarter-Wave Resonant Line

A quarter-wave resonant line can be handled in a similar manner. In this case, however, one end of the line must be short-circuited. This is accomplished in practice by the inner conductor of the line being electrically connected to the trough, or effective outer conductor of the line. In effect, then, the "hot" end of the line is cut down and replaced by capacitance. The capacitance here is composed of the collector capacitance of the transistor, plus the capacitance of the tuning gang and trimmer capacitance (along, of course, with circuit strays).

In a practical quarter-wave tran-

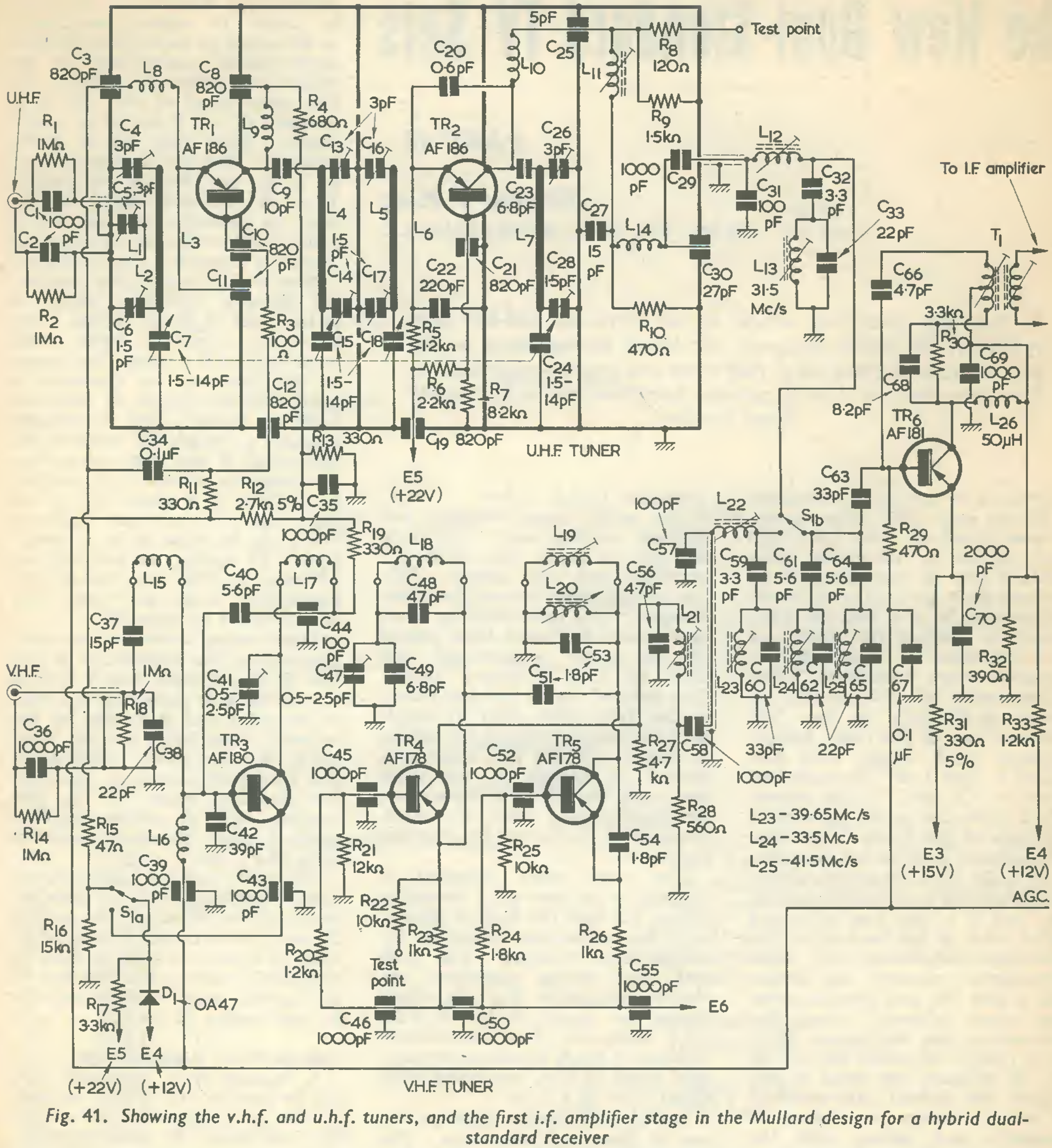


Fig. 41. Showing the v.h.f. and u.h.f. tuners, and the first i.f. amplifier stage in the Mullard design for a hybrid dual-standard receiver

sistor tuner the physical length of the lines is reduced to something like 3 cm. It should now be made clear that although transistor u.h.f. tuners are designed around both half-wave and quarter-wave lines, the counterpart using valves is always designed around the half-wave line.

It is not feasible with valve circuits to adopt the quarter-wave line principle because the line must include the lead in the valve connecting to the anode electrode, and the substantial length here generally means that the line proper is too short! The much smaller dimension of the transistor electrode and the fact that the collector connecting lead can be made very short means that the actual line section in quarter-wave transistor tuners predominates. The quarter-wave design thus becomes possible.

The u.h.f. tuner in Fig. 41 is of the half-wave type. Here it will be seen that the four main lines are tuned by four sections of a ganged tuning capacitor. The gang sections load the far ends of the lines, while the ends nearer to the collector circuits are loaded mainly by trimming capacitances.

Both transistors in Fig. 41 are arranged in the common-base configuration, with the signal applied to the emitter circuit and taken from the collector circuit. The bases are earthed for r.f. by C_{10}

and C_{21}. From the signal point of view, this tuner is equivalent to the valve half-wave tuner described in Part 3 of this series (July, 1964, issue) and illustrated in Fig. 11 on page 844. It is interesting to compare the two circuits and see how the transistors are used to replace the valves. Indeed, one early experimental transistor half-wave tuner was based on an existing valve tuner, the valves simply being replaced by transistors and the component values altered accordingly. Thus, the functioning of the signal path and coupling arrangements can be gleaned from the earlier article, it not being intended here to describe the whole process all over again. Further information can be obtained from the "In Your Workshop" article in the December, 1964 issue of *The Radio Constructor*, pages 327 to 333.

For the sake of completeness, the circuit of a quarter-wave transistor tuner is shown in Fig, 43. This is a tuner designed by the German R. E. Hopt Company and incorporating Siemen AF139 u.h.f. transistors. It will be seen that the lines are short-circuited at one end and that, at the other end, they are loaded by the tuning capacitors and trimmers.

Image Rejection

A difference between the quarter-wave and the half-wave tuner is that in the latter a four-gang tuning capacitor is employed, while only three tuned sections are used in the quarter-wave tuner. Some quarter-wave tuners however do employ four-gang tuning. Half-wave valve tuners started off with three tuned sections, but in view of possible second channel (image) interference problems, the design was changed to four tuned sections to give an image rejection ratio in the order of 53dB minimum. With half-wave tuners it was found necessary to use four tuned circuits, as with three the image rejection ratio was below the recommended minimum value.

With quarter-wave transistor tuners, however, it was found that the minimum 53dB rejection ratio could be achieved with three tuned circuits only. In the u.h.f. bands image rejection is an important consideration, as was explained in Part 3 of this series, on page 844.

A typical laboratory specification for a quarter-wave u.h.f. transistor tuner is as follows. Power supply 12V and 6mA, coverage Channels 21 to 68 inclusive (470 to 854 Mc/s) for 180° spindle rotation, power gain 19.5dB at 470 Mc/s and 21dB at 854 Mc/s, average voltage gain 34dB, average noise 7.5dB at 470 Mc/s and 11dB at 854 Mc/s, rejection i.f. and image respectively 50dB and 55dB, and oscillator radiation (i.e., oscillator signal at aerial terminals) 45μV at 470 Mc/s and 200μV at 854 Mc/s.

In the circuit of Fig. 43 the transistors are arranged in the common-base mode, with C_{14} and C_7 "earthing" the bases. The aerial signal is applied to the emitter of the r.f. amplifier, TR_1, and the collector of this transistor is loaded by the first tuned line. A second tuned line is bandpass-coupled to the first and, from this, the signal is coupled to the flatly tuned loop in the emitter circuit of the frequency changer transistor, TR_2. The third tuned line is associated with the local oscillator.

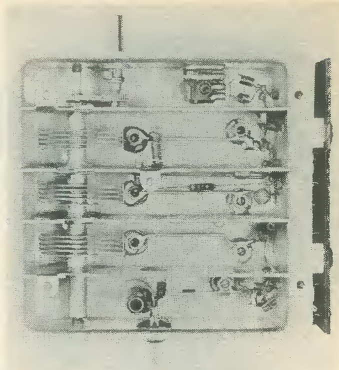


Fig. 42. Inside view of the transistor u.h.f. tuner used in R.G.D. receivers. Note the tuned lines located in troughs

Signal at i.f. is extracted from the collector of the frequency changer via L_7, and is tuned by L_6, at

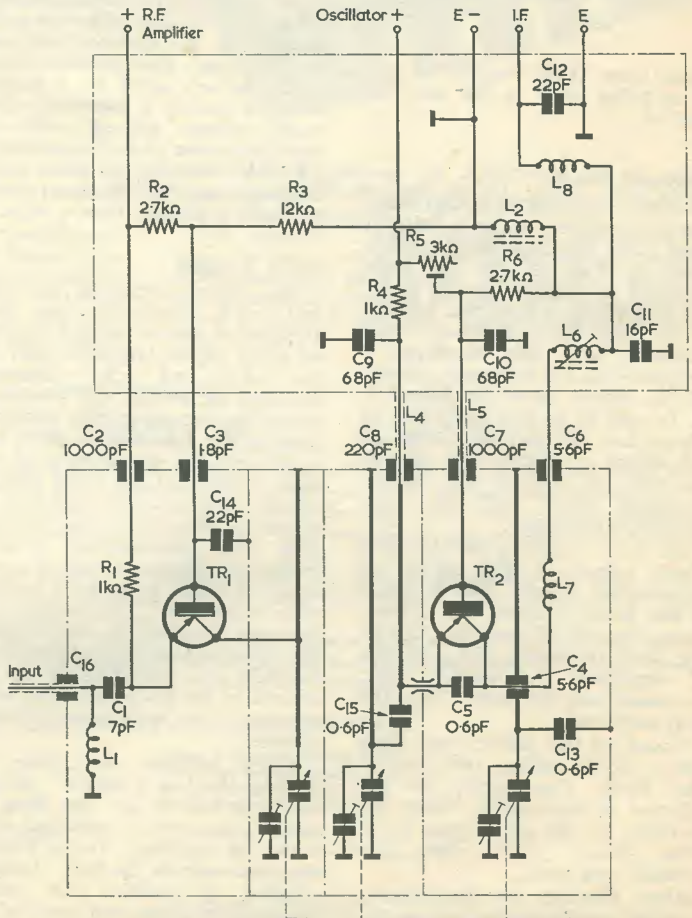


Fig. 43. Circuit diagram of the quarter-wave tuner by R. E. Hopt of West Germany. This firm also produces a composite v.h.f. u.h.f. transistor tuner

Fig. 44. The 625-line "Telebooster" by Gordon J. King, This uses a totally enclosed cavity in which is loaded a quarter-wave resonator. The model shown is for set-top mounting and is complete with battery. Consumption is about 1.5mA

which point it is coupled to the i.f. amplifier strip in the set, via filter L_8.

Composite Tuners

Tuners employed in British dual-standard receivers differ a little in detail from the continental version shown in Fig. 43, but the basic principles as outlined are the same. It is interesting to note that Messrs. R. E. Hopt (KG, Rottweil, West Germany) have now developed a composite v.h.f./u.h.f. tuner, Model 260-50, which embraces Bands I, III, IV and V; so it is likely that at a later date we may see tuners of this nature in British sets, for at the time of writing the British composite tuner has not been officially announced.

The v.h.f. tuner in the Mullard hybrid circuit of Fig. 41 is of conventional design. Use is made of the latest Mullard v.h.f. transistors, the AF180 and the AF178. The first transistor, TR_3, is the r.f. amplifier, the second, TR_4, the mixer and the third, TR_5, the local oscillator.

Tuners of this nature were dealt with in the November, 1963 issue of *The Radio Constructor*, in the reference already given. They can be either of the switch-type or of turret design. Both types are currently employed.

After filtering, in the manner described earlier in this series, the tuners of Fig. 41 are terminated at changeover switch section S_{1b}, the selected tuner being then coupled to the base of the first i.f. amplifier, which employs fixed neutralisation. The various tuned circuits here have their resonant frequencies indicated alongside them. They can thus be related to the response characteristics detailed in Part 4 of this series (August, 1964, issue).

While a number of sets at the time of writing employ the hybrid principle to the extent of using a transistorised u.h.f. tuner, the true TV hybrid is not yet in the shops.

Before concluding this series, mention must be made of the desirability of using transistors in the first stages of the receiver. A well designed transistor front-end, particularly on the u.h.f. channels, has a noise figure several decibels below that of a valve tuner. From the practical aspect, this means that, for a given noise level on the picture, a set with a transistor tuner will work on about 20 to 30% reduced signal level. This is highly desirable on the u.h.f. channels where the signal can be greatly attenuated by buildings, trees and so forth, even relatively close to a station. In other words, a transistor u.h.f. tuner endows the set with an improved value of *usable sensitivity*. All this, because a good u.h.f. transistor in a well designed circuit produces less noise than a valve.

Signal Boosters

The noise advantage of v.h.f. and u.h.f. transistors has been exploited in recent months in terms of aerial signal boosters, both for the v.h.f. and u.h.f. channels. Boosters for set-top and mast-head mounting are commercially available. The author has had a great deal to do with the development of this type of unit, and one of his designs, which may interest readers, is shown in Fig. 44. This differs a little from conventional boosters in that it employs a fully-enclosed cavity in which is loaded a quarter-wave resonator. The booster can be mounted either at the masthead (for which special clips and powering facilities are available) or at the set-end of the downlead. The boost is around 12 to 14dB on any required channel.

Other boosters are made by Belling & Lee Limited. Indeed, this was one of the first firms to make a commercial masthead v.h.f. transistor amplifier. Teleng Limited was also early in the field. Labgear Limited is another firm manufacturing boosters, and most of the firms originally specialising in valve amplifiers (and others) are now marketing transistor boosters of one kind or another.

The i.f. channel of the Mullard design for a hybrid receiver uses two Mullard AF181 and one Mullard AF179 transistor. The first AF181 is, in fact, TR_6 in Fig. 41. This has a negative-going a.g.c. potential applied to its base. The final transistor in this channel operates into a switched (405/625) vision detector circuit.

The sound i.f. channel (switchable to 6 Mc/s intercarrier, or the 38.15 Mc/s 405-line i.f.) also uses transistors—a pair of AF115's. This section is switched into a ratio detector (for 625 lines) or an ordinary a.m. diode and noise limiter (for 405 lines). The sound amplifier also uses transistors. There are four in a transformerless complementary output stage, using two p-n-p type and two n-p-n type. This follows conventional design and feeds into a 25Ω speaker.

A transistor is also used in the a.g.c. circuit, and to ensure that the sound comes on immediately the set is switched on, the a.g.c. control potential is derived from a point preceding the video amplifier. If it were derived after the video amplifier, the sound channel would be overloaded until the video valve warmed up.

The output from the final i.f. stage is rectified by a semiconductor diode and the mean level of the resulting positive-going output is coupled to the base of the a.g.c. amplifier. Under zero signal conditions this transistor is bottomed. On signal, however, the transistor swings from its bottomed state and thus provides a suitable output for the controlled stages.

The receiver circuit uses valves in the video amplifier (as already intimated), the black-level correction circuit, the sync pulse detector circuit, the phase detector for the line sync, line oscillator, the line output, the booster diode, the e.h.t. rectifier, the vertical oscillator and the vertical output stages. Silicon diodes are employed for valve and transistor power supplies.

By using valves and transistors in a hybrid circuit, the total power consumption of the receiver is reduced from an all-valve typical value of about 160 watts to about 95 watts. Instead of a mains dropper, the heaters are fed from tappings on an autotransformer, from which source suitable voltages are derived for the transistors.

(Conclusion)

TRADE REVIEW . . .

The Goldenair "Thirty" High Fidelity Amplifier

The Goldenair range of amplifiers marketed by Sona Electronics Company of Briggate House, 13/14 Albion Place, Leeds, 1, includes the "Thirty" high fidelity amplifier shown herewith. This particular equipment has been specially designed for use in large halls, theatres, schools and clubs, and for public address work or home hi-fi applications.

Independent bass and treble controls provide adequate lift and cut, making the unit suitable for long-playing records. Negative feedback is employed with 20dB feedback in the main loop.

Six Mullard valves are employed in the circuit, these being two EF86 low noise a.f. voltage amplifying pentodes, one ECC83 double-triode phase splitter, two EL34 output pentodes and a GZ34 full-wave rectifier.

A specially wound output transformer is used with the two EL34 push-pull output pentodes.

A heavy duty double-wound mains transformer is employed with the GZ34 rectifier, this giving complete isolation from the a.c. mains supply. A very high level of smoothing is given, the output of the power supply being virtually ripple-free.

A well ventilated protective cover can be provided for the unit if required, this being available at 21s. The approximate size of the amplifier is 12 x 9 x 8in.

A polished black control panel is fitted to the amplifier, the panel being distinctively marked with control indications set in gold relief.

The performance figures given by the manufacturers are as follows: frequency response ±2dB from 25 to 20,000 c/s; bass control ±12dB at 50 c/s; treble control ±12dB to ±6dB at 12,000 c/s; hum and noise level 70dB down; sensitivity 12 millivolts for full output, thus making the amplifier suitable for use with any type of

microphone or pick-up. It is intended for a.c. mains operation at 200-230-250V, 50 c/s, power consumption being 150 watts approx.

The Goldenair "Thirty" amplifier is covered by the usual Goldenair full guarantee for 12 months. Suitable loudspeakers can be provided. The amplifier, less cover and speaker, is priced at 16 gns., hire purchase terms being available if required. Carriage anywhere in the U.K. is 15s.

THE FRIENDLY BAND

Our heading refers not only to a well known aspect of the 160 metre amateur band but also to the many bands (nets) of amateur transmitting stations which habitually transmit over these frequencies. Many of these nets operate to time schedules known to the local listeners who include SWL's, local club members, the Dads, the Mums, the Aunts, the Uncles (including Naughty Uncle!), the relatives, the friends and the elderly. Additionally, of course, there are the lonely and the sick always, alas, amongst us.

Many of the transmitting fraternity, when joining the net, often refer by name or implication to such people, proffering cheerful advice or comfort and thereby bringing in, as it were, the "outsiders" into the contact—often making their day and their lot just that much easier to bear.

One of the many groups currently operating is that in the Medway area of Kent and, during a recent listening session, our General Editor heard G5VZ (W. Birchall) read out an ode sent to him by an unknown SWL. We thought it so typical of the atmosphere surrounding Top Band that we reproduce it herewith.

ODE TO THE AMATEUR TRANSMITTERS

Each morn at ten you'll find 'em,
Calling on Top Band,
They are a jolly bunch of lads,
The best that's in the land.

"The Bills", there's Six, Five, Four and Zero,
All with time to spare,
To think of all the listeners,
You wouldn't think they'd care.

But no! Each day they read a list,
As long as any arm,
Of cheery greetings to all and sundry,
It can't do any harm.

In fact it does a power of good,
To all the sick and lonely,
So carry on—you Bills,
Don't think its all baloney.

There's L.U.G. and R.Z.U. and T.X.S. and "you know who",
There's George's clock that goes tick-tock,
But never goes cuckoo.

We also hear from Basil and Alan T.C.I.,
There's S.K.E. and Dot and Vernon and Ray that's T.S.I.,
There's "Reggie-Boy"—old E.G.J. of Little Thurrock Fair,
And lots of others you will find,
If you just listen on the air.

RADIO TOPICS . . .

by Recorder

IT WAS IN 1948 THAT THE BELL Telephone Laboratories in America announced the appearance of the first point-contact transistor. And what fantastic changes have occurred in the world of electronics since that now-ubiquitous little device first saw the light of day!

Some years were to pass, after 1948, before transistors came to be generally used by home-constructors in this country, and it wasn't until 1953 or so that the first amateur designs began to filter through into the pages of the technical press. Including, notably, this journal.

Early Days

An early transistor loudspeaker receiver featured by *The Radio Constructor* was the "Transistorette". This was designed by the redoubtable G. A. French of Suggested Circuit fame (and who, at that time, had only reached Suggested Circuit No. 63!) and it was described in the February 1956 and subsequent issues. This receiver employed three early S.T.C. junction transistors, two type TJ2 and one type TJ3, and even these were superseded by types TS2 and TS3 as the articles went through the process of preparation for the printer. The prototype of the receiver was just finished in time for the 1955 Radio Show at Earl's Court and it was exhibited on the Standard Telephones and Cables stand. It was the only transistor loudspeaker receiver at the Show!

For those of us who cut our teeth on 2-volt filament valves like the HL2 and PM2, the first transistors opened up fantastic new visions. To obtain one of these tiny little devices and get it to amplify or oscillate without even thinking about a heater or filament supply was, to us, an amazing experience. Transistors are, of course, completely commonplace these days but they were like little bits of magic when we first got our hands on to them. I remember my own very first experiments, these being also with some of those early S.T.C. transistors. To get the "feel" of the manner in which they operated I inserted a meter and series resistor in the collector circuit and watched, almost disbelievingly, the collector current increase as the base current went up. It sounds a trifling enough effect now, but at the time it had me completely absorbed.

Nowadays, like most other people in the radio game, my outlook has shifted through 180° and I look upon the transistor as the first choice for any job that requires doing, and the valve as second choice. Whenever I have to knock up an electronic gadget my immediate reaction is to see what transistors I have in stock or can buy cheaply, and to check with the manufacturer's information to see if they'll cope at the voltages and currents involved. If they do, all well and good, and that's another job sorted out. If they don't and I *have* to use valves, I give a mental groan as I visualise the business of having to hack out chassis holes for the valveholders, wire up all the heaters, think about 200-volt h.t. supplies instead of a nice convenient PP9 battery, and finally end up with a bit of gear which needs great bulky valves all dissipating heat like miniature electric fires.

I'm beginning to feel that we should stop employing the term "transistorised" to describe equipment which uses transistors instead of valves. Instead, it should be "valvised" to define equipment which differs from the norm by *not* using transistors. On second thoughts, though, it may be better to leave the term in circulation if only for those people who, like myself, have become fully converted from valves to transistors. It's *us* who are transistorised!

The Vitavox Multi-Zed M100 microphone complete with its flexible stem. An in-built transformer provides four output impedances

Multi-Impedance Microphone

One way of overcoming microphone matching problems is solved very neatly in the new Vitavox multi-impedance microphone which appears in the accompanying photograph. This incorporates its own line matching transformer, and a simple screw adjustment enables one of four output impedances to be selected. These are 25Ω, 200Ω, 10kΩ and "High", and this wide range provides accurate matching with any normal valve or transistor input circuit.

The microphone, which is known as the Multi-Zed model M100, is a dynamic (i.e. moving-coil) unit, and is finished in black satin with a flexible stem in chromium plate. The complete weight is 17 oz. A frequency response of 50 to 15,000 c/s$\pm$3dB is claimed, and the microphone is supplied with 9ft of screened cable in a container which offers full protection.

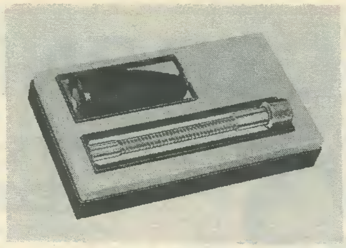
The Multi-Zed M100 is manufactured by Vitavox Ltd., Westmoreland Road, London, N.W.9 (COLindale 8671), from whom any further information may be obtained.

Political Colour

It's a pity that the choice of European colour television systems went political. France and the U.S.S.R. have, of course, agreed to use the French SECAM system, their decision being taken in advance of the Vienna meeting of the International Radio Consultative Committee (C.C.I.R.) which was called to discuss the question of which colour system should be adopted as a standard in Europe.

It is ironical that two of the three competing systems, SECAM and PAL, are developments of the original American N.T.S.C. system. Since the N.T.S.C. system sends out hue information by phase modulating the chrominance sub-carrier, shifts in phase throughout the system from studio camera to receiver can result in a change in hue in the reproduced picture. To overcome this problem phase shifts at the transmitting end, including long distance links for network operation, have by now been reduced to very low proportions, but it is still necessary for an N.T.S.C. receiver to have a hue control to take up any remanent phase shifts which may occur in the system. This control shifts the phase of the colour burst frequency fed to the receiver phase discriminators and, therefore, counteracts any phase shift which may occur in the signal after it leaves the studio. The hue control in current American N.T.S.C. receivers appears to offer a fairly wide range. It is most convenient to adjust it so that flesh colours (peoples' faces) appear natural, and present-day hue controls have a range which can cause flesh tones to have a greenish shade at one extreme and a purplish shade at the other. It is possible that a change in transmitter networking, or a change in receiver channel, may necessitate a readjustment of this hue control.

With SECAM the colour information is sent sequentially, one line carrying one set of information (actually the R–Y red colour-difference signal) and the other carrying the complementary set of information (the B–Y blue colour-difference signal). Errors in hue presentation due to phase shift in the transmission and reception system cannot therefore occur, and a SECAM receiver does not require a



Full protection for the Multi-Zed microphone is provided by a carefully designed container

hue control. Nor, also, does a PAL receiver. The PAL system is rather similar to the N.T.S.C. system except that the phase of the colour signal is reversed on alternate lines. In consequence, errors in phase move in opposite directions on alternate lines, and may be averaged out at the receiver.

Great play has been made of the advantages incurred by the lack of a hue control in SECAM and PAL receivers, and it certainly has to be admitted that this is a most important point. However, quite a little bitterness has crept into the controversy recently, as was exemplified by a series of SECAM advertisements in *New Scientist* showing, in grossly exaggerated form, a frantic colour television viewer with hands gyrating frenziedly. The inference is that this is a result of continual adjustments of the hue control of his N.T.S.C. receiver. It does seem a shame that what should be an objective approach to the colour TV problem is beset with extravagances of this nature.

One has to have a wry chuckle, nevertheless, over the sarcastic interpretations which have been going the rounds for the initials which make up the system names. (Such interpretations always seem to arise when letter-initial names are coined, and it was only the other day that I was told that LASER stands for "Lolly Acquisition Scheme for Expensive Research"!) The meaning of PAL is (somewhat cornily) "Pray And Learn", whilst that of N.T.S.C. (bashing away once more at that hue control) is "Never the Same Colour" or "Never Twice the Same Colour". The one for SECAM is, I think the wittiest. SECAM stands for "*Suprême Effort Contre les Américains*" i.e. "Supreme endeavour against the Americans".

At the time of writing I don't know the final outcome of the colour battle. But I still think it's a pity that the politics crept in.

NEW PLUMBICON/VIDICON TV CAMERA

A new all-transistor television camera which uses a Plumbicon or a vidicon pick-up tube is announced by EMI Electronics Ltd.

Weighing only 40lb (18kg), camera type 208 is fitted with an integrated 10:1 zoom lens and produces broadcast quality television signals on 405, 525 and 625 line standards. The standard in use can be changed simply by pressing a switch on the control panel A 7in electronic viewfinder is fitted. Camera type 208/1 is an alternative version designed for fully remote operation.

Maintenance and accessibility are facilitated by the extensive use of plug-in printed circuit sub-units.

One version of the camera control unit is mounted in a standard 19in rack for studio use. Another is fitted into a portable case for outside broadcasts.

Production.—Letterpress/contact litho.

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SERVICE SHEETS, 1925–1965. From 1s. Catalogue 6,000 models, 1s. 6d. S.A.E. enquiries.—Hamilton Radio, 13 Western Road, St. Leonards, Sussex.

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MULLARD TRANSISTORS & DIODES. OC45, OC71, OC76, OC81, OC81D, OC84, 3s. OC75, 3s. 6d. OC81, OC84 pairs, 6s. OC35, 7s. 6d. OA70, OA79, OA81, OA96, 1s. 3d. Texas 2G344a, 3s. MA393, 3s. 6d. 1S100, 2s. 3d. G75D, 2s. 3d. ZR31C, ZR31CR, 15s. All post paid.—Radio Constructor's Centre, 363 Westborough Road, Westcliff-on-Sea, Essex.

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FOR SALE. AF186, 27s. 6d. each and other components for B.B.C.2 pre-amplifier. 3d. stamp for details.—John Williams Electronics Ltd., 176 Hagley Road, Halesowen, Birmingham.

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FOR SALE. Cossor double beam oscilloscope, model 1049 Mk. IIIA with intensity modulation. Also instruction book and service manual. Excellent condition. £30—Everest, 61 Oliver Crescent, Farningham, Nr. Dartford, Kent.

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SMALL ADVERTISEMENTS

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INTERESTED IN AMATEUR RADIO TELEPRINTING? Then join the British Amateur Radio Teleprinter Group. Details from Hon. Sec., G3LLV, 15 Havelock Square, Broomhill, Sheffield 10.

THE INTERNATIONAL HAM HOP CLUB is a non-profit-making organisation open to RADIO AMATEURS AND SHORT WAVE LISTENERS. OBJECT: to improve international relationships through an organised system of hospitality. MEMBERS offer overnight hospitality to visiting members, subscription 10s. per annum. ASSOCIATE MEMBERS invite radio amateurs to visit their stations. Associate membership 5s. per annum. FAMILY EXCHANGE holidays arranged, also FRIENDSHIP LINKS between radio clubs. The Club's official journal is free to both Full and Associate Members.—Hon. Gen. Secretary: G. A. Partridge, G3CED, 17 Ethel Road, Broadstairs, Kent.

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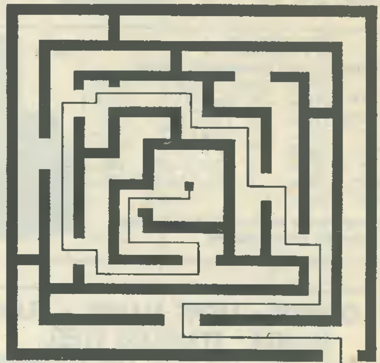

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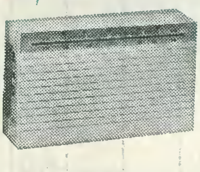

TOTAL COST TO BUILD
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★ All parts sold separately.

★ 6-Transistor design. Push-pull output.
★ 2¼" Cleartone speaker. Printed circuit.
★ Attractive moulded cabinet.
★ Slow motion tuning.
★ Full medium and long waves.
★ Size: 5" x 3" x 1¼".
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★ Pre-built units sold separately.

TOTAL COST TO BUILD
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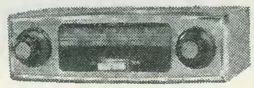
P.P. 3/6



(7" x 4" speaker with car fixing kit and baffle board **20/–** extra.)

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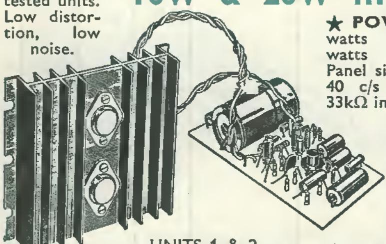

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PREAMPLIFIERS. Mono and stereo versions, 8 inputs, 1½ to 300mV at 1k to 500k. Response 30 c/s to 20 kc/s. Complete range of controls. Mains unit or battery operated. For pick-ups, tuners, tape, microphones, etc.
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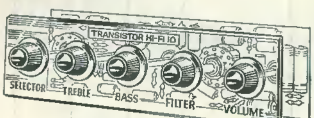
PRICE BUILT **£10.19.6** P.P. 3/6
(Front panel plate **12/6**)

UNIT 5



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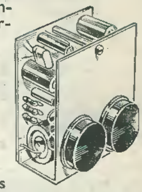

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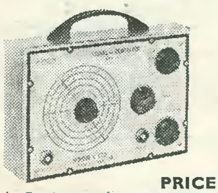

All units size 6⅝" x 4⅝" x 2¾".
★ RF generator, 150 kc/s to 350 mc/s in 8 ranges. RF, Mod. RF, AF outputs.
PRICE £9.10.0 P.P. 2/6
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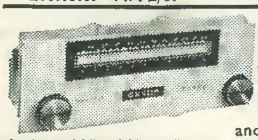

★ Two pre-built plus metal work and front panel.
★ Size: 9½" x 3½" x 4"
★ 88 to 108 mc/s tuning.
★ 100mV to 100kΩ cut-out
★ 6-Transistor printed cct. superhet design
Total Cost **£12.17.6** P.P. 2/6

TWO WAVE BAND PUSH-BUTTON TRANSISTOR PORTABLE TO BUILD

TOTAL COST
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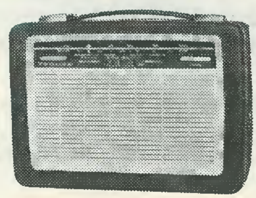
P.P. 3/6
(Batteries 6/–)



★ 5" speaker.
★ 6-Transistor push-pull design
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VHF/FM TRANSISTOR TUNER TO BUILD

TOTAL COST
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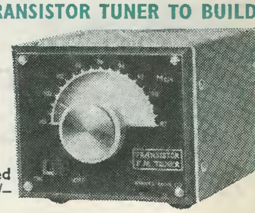
P.P. 2/6
(complete with frontplate)
(Gold sprayed cabinet **20/–** extra).



★ 5-Transistor 4 diodes.
★ Printed circuit superhet.
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