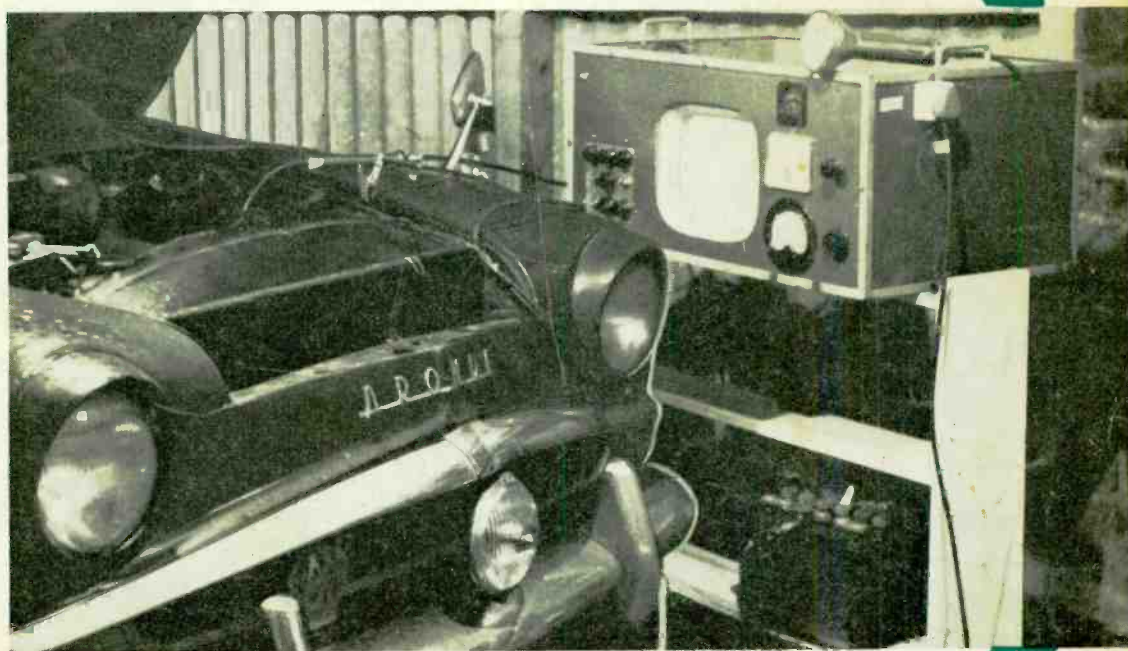


# THE Radio Constructor

RADIO  
TELEVISION  
AUDIO  
ELECTRONICS

VOLUME 19 NUMBER 4  
A DATA PUBLICATION  
TWO SHILLINGS & THREEPENCE

November 1965



**Electronic Car Ignition Analyser**

Top Band  
Push-Pull Modulator



Linear Scale  
Ohmmeter



Electronic Counting  
with Dekatrons



3-Transistor  
Reflex Receiver

# Scottish Insurance Corporation Ltd

38 EASTCHEAP · LONDON · EC3



## TELEVISION SETS, RECEIVERS AND TRANSMITTERS

Television Sets, Receivers and Short Wave Transmitters are expensive to acquire and you no doubt highly prize your installation. Apart from the value of your Set, you might be held responsible should injury be caused by a fault in the Set, or injury or damage by your Aerial collapsing.

A "Scottish" special policy for Television Sets, Receivers and Short Wave Transmitters provides the following cover:

- (a) Loss or damage to installation (including in the case of Television Sets the Cathode Ray Tube) by Fire, Explosion, Lightning, Theft or Accidental External Means at any private dwelling-house.
- (b) (i) Legal Liability for bodily injury to Third Parties or damage to their property arising out of the breakage or collapse of the Aerial Fittings or Mast, or through any defect in the Set. Indemnity £10,000 any one accident.
- (ii) Damage to your property or that of your landlord arising out of the breakage or collapse of the Aerial Fittings or Mast, but not exceeding £500.

The cost of Cover (a) is 5/- a year for Sets worth £50 or less, and for Sets valued at more than £50 the cost is in proportion. Cover (b) (i) and (ii) costs only 2/6 a year if taken with Cover (a), or 5/- if taken alone.

Why not BE PRUDENT AND INSURE your installation—it is well worth while AT THE VERY LOW COST INVOLVED. If you write to the Corporation's Office a proposal will be submitted for completion.

---

Write for full details, quoting reference J/B, to:—

**THE MANAGER**  
**SCOTTISH INSURANCE CORPORATION LTD.,**  
**38 EASTCHEAP, LONDON E.C.3**

J/B

## 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 11 1/2" x 4", chassis size 11 1/2" x 4" x 5 1/2". A recommended Fidelity Unit for use with Mullard "3-3" or "5-10" Amplifiers.

**Bargain Price**, aligned, tested & ready for use, **£12.10.0**. Carr. & Ins. 7/6. Complete kit of parts, inc. Power Pack, **£10.19.6** as illustrated. Ditto less Power Pack, **£9.19.6**. Carr. 7/6. Circuit and constr's details, 4/6 free with kit.



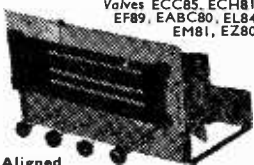
## 7 VALVE AM/FM RADIOGRAM CHASSIS

New 1965 Model Now Available.

**Three Waveband & Switched Gram positions.** Med. 200-550mc, 86 Mc/s, 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 13 1/2" x 6 1/2". Height 7 1/2". Edge illuminated glass dial 11 1/2" x 3 1/2". Vert. pointer Horiz. station names. Gold on brown background. A.C. 200/250V operation. Magic-eye tuning. Circuit diag. now available.

Comp. with Tape, O/P socket, ext. spkr's and P/U sockets and indoor F.M. aerial, and 4kΩ—walmart or ivory to choice. 3Ω P.M. Speaker only required. Recommended Quality Speakers 10" Rola, 2/7.6. 13 1/2" x 8" E.M.I. Fidelity, 3/7.6. 12" R.A. with conc. Tweeter, 4/2.6. Carr. 2/6.

**Jack Plugs.** Standard 2 1/2" Igranite Type, 2/6. Screened Ditto, 3/3. Miniature scr. 1 1/2", 2/3. Sub-min. 1/3. **Coax Sockets.** Open Igranite Mounted Type, 3/6. Closed Ditto, 4/-. Miniature Closed Type, 1/6. Sub-min. (leaf 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 25W Inst., 24/6. Spare Elements, 5/6. Bits, 1/3. 65W, 29/6, 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.



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

## ANOTHER TAPE RECORDER BARGAIN

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

A 24 gns. Tape Recorder offered at the fabulous bargain price of only 15 gns. + 10/- Carr. Supplied in 3 Units already wired and tested—only simple inter-Unit connections necessary. A modern Circuit for quality recording from Mike, Gram or Radio, incorporating the latest BSR Twin Track Monardeck Type TD2. Housed in attractive two-tone Cabinet of contemporary design, size 14" x 13 1/2" x 7 1/2" complete with Tape and Mike storage pockets. Valve line up—EF86, ECL82, EM84, EZ80 and Silicon Diode.



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

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

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

**COAX 80 OHM CABLE**  
High grade low loss Cellular air spaced Polythene—1/2" diameter. Stranded cond. Famous mfrs. Now only 6d. per yard.

**Bargain Prices—Special lengths:**  
20 yds. 9/-. P. & P. 1/6.  
40 yds. 17/6. P. & P. 2/-.  
60 yds. 25/-. P. & P. 3/-.  
Coax Plugs 1/-. Sockets 1/-.  
Couplers 1/3. Outlet Boxes 4/6.

**Close Tol. S/Micas**—10% 5pF-500pF 8d. 600-5,000pF 1/-. 1% 2pF-100pF 9d. 100pF-500pF 11d. 575pF-5,000pF 1/6. **Resistors**—Full Range 10 ohms-10 megohms 20% 1/2 and 1/4V 3d., ditto 10% 4d., 1/4V 5d. (Midget type modern rating) 1W 6d., 2W 9d. Hi-Scab 5% 1/4W 100 ohms 1 megohm 6d. Other values 9d. 1% 1/4W 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** Free—Expanded gile anodized metal 3" x 4" 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**—15 reels, 14g-20g, 3/-, 22g-28g, 3/6; 36g-38g, 4/9; 39-40g, 5/-. etc.

**TINNED COPPER WIRE**—14-22g, 4/- ± lb.

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

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

### TRANSISTOR COMPONENTS

**Midget I.F.s**—465 kc/s 1/2" diam., 5/6 first, second or third.  
**Occ. coil M. & L.W.** 1/2" diam. 5/6  
**Midget Driver Trans.** 9/1 6/0  
**Ditto O/P Push-pull** 3 ohms 6/0  
**Elect. Condensers**—Midget Type 15V 1mf-50mf, ea. 1/9. 100mf. 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.** 1.5. "00" 208 + 176pF, 8/6. Ditto with trimmers, 9/6. 365pF single, 7/6. Sub-min. 1/2" DILEMIN 100pF, 300pF, 500pF, 7/-.  
**Midget Vol. Control** with edge control knob, 5kΩ with switch, 4/9, ditto less switch, 3/9.

### JASON FM TUNER UNITS

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

## L.P. RECORDING TAPE

BARGAIN OFFER!

By leading British manufacturers—

**PROFESSIONAL GRADE—DOUBLE-SIDED**

(each side coated) 5 1/2" reels only

**Special Price Offer** 1,450 feet (2 reels) **20/-** post free

Ideal for the experimenter who wants to record both sides, and a good L.P. Tape for the enthusiast who wishes to record single side only.

New Boxed	VALVES	Reduced Bargain Prices	Electrolytics All Types	New Stock
174	3/6	EF80 7/6	PCF80 8/-	25/25V
1RS	6/-	EF86 8/6	PCL83 10/6	50/12V
155	6/-	EL33 12/6	PCL84 10/-	50/50V
354	7/-	EL34 12/6	PCL85 11/6	100/25V
3V4	7/-	EL84 7/-	PL36 10/6	8/450V
ECC81	9/6	EL81 9/6	PL81 9/6	4/150V
ECC82	7/-	EY86 9/-	PL83 8/-	16+16/450V
ECC83	7/-	EZ80 7/-	PY33 10/6	32+32/450V
ECL80	9/-	EZ81 7/-	PY82 7/-	1000/25V
ECL82	10/-	GZ32 9/6	U25 10/6	Ersin Multicores
ECL86	10/6	PCC84 8/-	UL84 9/-	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 wax 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: 17 1/2" x 16" x 8".

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

Ready wired, 30/- extra.

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

## STANDARD RECORD PLAYER KIT

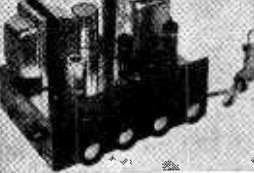
Using BSR UA14 Unit, complete kit **£11.10.0**, carr. 7/6. Ready wired Amplifier, 7" x 4" quality Speaker and O/P trans. **£3.19.6**, carr. 2/6. BSR UA14 Unit, £6.10.0, carr. & ins. 5/-. Rexine covered cabinet in two-tone maroon and cream, size 15 1/2" x 14 1/2" x 8 1/2" with all accessories plus uncut record player mounting board 14" x 13", 59/6, carr. & ins. 5/-.  
**Condensers**—S/Mica all values 2pF to 1,000pF 6d. Ditto Ceramic 9d. each. .005, .01 and .1, etc., 1/-. Paper Tubular 450V .001 mfd. to .01 mfd and .1/350V 9d., .02-1 mfd 1/-. .25 mfd 1/6, 5 mfd 1/9.



**Speakers P.M.**—2" Plessey 75 ohms, 15/6. 2 1/2" 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.

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

3 OHM & 15 OHM OUTPUT



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

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

**MULLARD "5-10" AMPLIFIER**—5 valves 10W, 3 and 15 ohms output. **£11.10.0**

Mullard's famous circuit with heavy duty ultra-linear quality output tfr. Basic amplifier kit price **£9.19.6**. Carr. 7/6. **Ready built 11 1/2 gns.**

**2-VALVE PRE-AMP. UNIT**  
Based on Mullard's famous 2-valve (2 x EF86) circuit with full equalisation with volume, bass, treble, and 5-position selector switch. Size 9" x 6" x 2 1/2". **Ready built, wired and tested, £7.19.6**. Carr. 3/6.



Send for detailed bargain lists, 3d. stamp. We manufacture all types Radio Mains Transf. Chokes, Quality O/P Trans., etc. Enquiries invited for Specials, Prototypes for small production runs. Quotation by return.  
**RADIO COMPONENT SPECIALISTS**  
70 Brigstock Road, Thornton Heath, Surrey THO 2188. Hours: 9 a.m.-6 p.m., 1 p.m. Even. Terms C.W.O. or C.O.D. Post and Packing up to 1lb. 1/-. 1 lb. 1/9, 3 lb. 3/-. 5 lb. 3/9, 8 lb. 4/6.



# Choose Heathkit models for value and performance

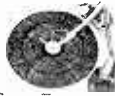
Easy-to-follow instruction manuals tell you how to build any model

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

STEREO  
AMP.  
AA-22U



PLAYER  
AT-60



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

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

**GARRARD AUTO/RECORD PLAYER. Model AT-60.** less cartridge **£13.1.7** With Decca Deram pick-up **£16.15.1** 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**

Many other Garrard models available.

POWER  
AMP.  
MA-12



STEREO  
AMP.  
S-99



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

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

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

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

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

## FOR THE INSTRUMENTALIST

**PA AMPLIFIER, Model PA-1.** 50W amplifier. The ideal, compact unit. Two heavy duty speakers. Variable tremolo. 2 channels. Legs optional extra 17/6 Kit **£54.15.0** Assembled **£74.0.0**

## STARMAKER - 33

**TRANSISTOR PA/GUITAR AMPLIFIER, PA-2.** 20 Watt amplifier. Two heavy duty speakers. Four inputs on two channels. Variable tremolo. Speed and depth controls. Elegant compact cabinet, weight 51lb. 18" high x 29" wide x 10" deep.

Kit **£44.19.0** Assembled **£59.10.0**

Castors or legs available as extras.

## INSTRUMENTS

**DE LUXE LARGE-SCALE VALVE VOLTMETER: Model IM-13U.** Circuit and specification based on the well-known model V-7A but with many worthwhile 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**

**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**

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

**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). Kit **£37.18.0** Kit **£47.10.0** Assembled

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

**2 1/2" PORTABLE SERVICE SCOPE. Model OS-1.** This is a light, compact oscilloscope, ideal for servicing, etc. Dimensions 5" x 8" x 1 1/4" long. Wt. 10 1/2lb. Fitted mu-metal CRT shield. Kit **£22.18.0** Assembled **£30.8.0**

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

**TRANSISTOR POWER SUPPLY. Model IP-20U.** Up to 50V, 1.5A output. Ideal for Laboratory use. Compact size. Kit **£35.8.0** Assembled **£47.8.0**



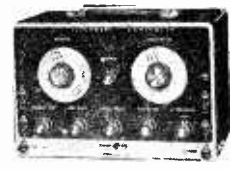
IM-13U



V-7A



RF-1U



IO-12U

## TRANSISTOR RECEIVERS



UXR-2



UXR-1



UJR-1

**"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.

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

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

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

### ARE YOU ON OUR MAILING LIST?

FREE CATALOGUE of full range  
INSTRUMENT BROCHURE  
AMATEUR RADIO BROCHURE or

Full specification of any model gladly sent on request

# Enjoy Yourself and Save Money with these Kits

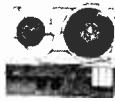
No previous experience required to build any Heathkit model



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



FM  
TUNER  
FM-4U



MAGNAVOX  
NEW  
TAPE  
DECK

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

Total Kit **£16.8.0**

**MAGNAVOX NEW TAPE DECK.** The finest buy in its price range. Operating speeds: 1½, 3½ and 7½" p.s. Two tracks, "wow" and "flutter" not greater than 0.15% at 7½" p.s. **£14.19.6**

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



TRUVOX  
DECK



AM/FM  
TUNER

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

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

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

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

## SPEAKER SYSTEMS



SSU-1

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

**COTSWOLD "MFS" SYSTEM.** Designed to give best possible results where floor space is at a premium. This minimum floor space model is based on standard Cotswold. Size: 36" high x 16½" wide x 14½" deep. Kit **£25.12.0** Assembled **£33.17.0**

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

Kit **£25.12.0** Assembled **£33.17.0**



MFS

## NEW INSTRUMENTS



IM-30U

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

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IM-12U

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DEPT. RC.11  
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**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**

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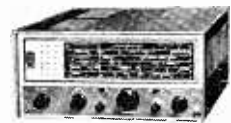
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RA-1



RG-1



HM-11U

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SB-300E

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# Ready for you to build at once THE WORLD'S FIRST POCKET-SIZE F.M. TUNER-RECEIVER

—and there are no alignment problems



SIZE  
2-15/16" x 1-5/8" x 3/4"

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7 TRANSISTORS • 2 DIODES • AFC • 2 OUTPUTS

Sinclair's latest design, the SINCLAIR MICRO FM is a high quality FM tuner designed to be used with hi-fi amplifier or tape recorder. It can also be used independently as a self-contained pocket F.M. receiver for personal listening anywhere. This exciting Sinclair triumph, barely half the size of a packet of 20 cigarettes, is a fully fledged 7 transistor-2 diode superhet circuit incorporating many unique and original design features to achieve fantastically good standards of performance. Pulse counting detection ensures better linearity than conventional detection methods, and therefore better audio quality. Powerful A.F.C. together with unusually good sensitivity make tuning easy, and the set's own telescopic aerial suffices almost everywhere. The two-output arrangement allows the unit to be used both as a tuner and as a self-contained receiver. In styling, this is the most elegant, most professional looking design in miniaturised equipment ever made available to constructors, and is one you will be justifiably proud to possess. **YET WITH ALL THESE WONDERFUL FEATURES, THE SINCLAIR MICRO F.M. COSTS POUNDS LESS AND OFFERS ADVANTAGES NOT FOUND IN ANY OTHER F.M. TUNER.**

*Advance design  
features ensure  
superb performance*

- Pulse counting detector
- A.F.C.
- Unique circuitry
- Professionally styled case
- High sensitivity
- Tunes from 88–108 Mc/s
- Requires no alignment
- A SINCLAIR  
GUARANTEED DESIGN

FULL SERVICE FACILITIES ALWAYS AVAILABLE TO SINCLAIR CUSTOMERS

### USE IT AS A TUNER AND A POCKET F.M. RADIO

#### ★ TECHNICAL DESCRIPTION

Seven transistor, two diode F.M. superhet for use both as a tuner and a self-contained pocket portable receiver. The screw-on telescopic aerial is coupled to an R.F. amplifier followed by a self-oscillating mixer. Use of a low I.F. dispenses with the need for bulky I.F. transformers and alignment. A three stage I.F. amplifier amplifies and limits the signal to produce a square wave of constant voltage which is fed into the pulse counting discriminator. This converts the square wave formation into uniform pulses, the average output from which is directly proportional to the signal frequency, so that the original modulation is reproduced exactly. After equalisation for pre-emphasis, the signal is fed to the audio output socket for use with an amplifier or recorder and also to the receiver's own audio amplifying stage which enables the Micro FM to be used as an independent self-contained receiver. A.F.C. makes tuning simple as each station is automatically "locked" as the dial is turned. THE SINCLAIR MICRO FM is completely self-contained

within a neat black plastic case faced by an elegantly designed front panel of brushed and polished solid aluminium with spun aluminium tuning dial to match. The tuning scale is marked in Mc/s.

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- HIGH LEVEL AUDIO OUTPUT—9V peak
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- SIGNAL TO NOISE RATIO—30dB at 30 microvolts

THE COMPLETE KIT OF PARTS for building the SINCLAIR MICRO FM including extending aerial, 7 transistors, case, tuning dial, aluminium front panel, lightweight earpiece, plugs and sockets and instructions cost only

**£5.19.6**

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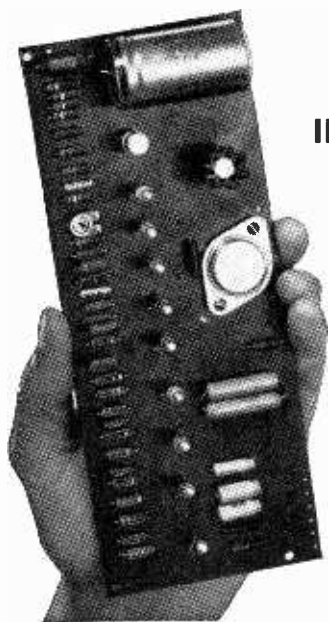
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COMBERTON, CAMBRIDGE Telephone: COMBERTON 682

# FOR HI-FI POWER AND QUALITY

## SINCLAIR X-20

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



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Details in full tone and volume control systems to suit the equipment you use with your X-20. Includes stereo, stereo balance and input switching. FREE with all X-20 amplifiers. Available separately 2/- post free.

By the use of Pulse Width Modulation in circuitry developed exclusively by Sinclair Radionics, the unique X-20 achieves standards never before reached by any audio amplifier in the world. From the input through to the power output stage, this amazing amplifier gives quality and power far ahead of anything in its class to make it the most original and interesting design for years. You use your X-20 like any conventional quality amplifier. It has

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MEASURES 8 1/4" x 3 1/4" x 1" — DELIVERS 20 WATTS R.M.S.

Only the Sinclair X-20 has all these features!

- ★ 12 Transistors including silicone epitaxial planars in output stage.
- ★ Constant square wave amplitude
- ★ 95% conversion efficiency factor at output
- ★ Frequency response—20 to 20,000 c/s 1dB
- ★ Total harmonic distortion—0.1% at 10 watts R.M.S.
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- ★ Signal to noise ratio—better than 70dB
- ★ Output into 7.5 ohms—20 watts R.M.S. music power 15 watts R.M.S. continuous
- ★ Output into 15 ohms—15 watts R.M.S. music value 10 watts R.M.S. continuous

- ★ Also makes an ideal guitar or P.A. amplifier
- ★ Built-in low-pass filter ensures wide tolerance-to-load at output
- ★ Power requirements—36V d.c. at 700mA
- ★ Add tone and volume control systems to choice, mono or stereo, as described in the X-20 manual

Complete kit of parts including X-20 Manual and instructions.

**£7.19.6**

Ready built and tested

**£9.19.6**

X-20 power supply unit to drive up to two X-20s.

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- WEIGHT UNDER 1 OZ
- AMAZING POWER AND SELECTIVITY
- GETS LUXEMBOURG LIKE A LOCAL STATION
- BUILT IN AN EVENING

### SINCLAIR MICRO-6

No transistor set has ever yet compared with the six-stage Micro-6 for size, power, performance and design. No set has ever given such pleasure and satisfaction both in building and using it. Everything except the lightweight earpiece is contained within the tiny, elegant white, gold and black case. Important features include bandspread at the higher frequency end of the tuning for easy reception of Luxembourg, powerful A.G.C. to counteract fading of distant stations, and vernier type tuning. Quality is outstandingly good. Many thousands of Micro-6 receivers have been built all over the world, and it cannot be too highly recommended as an intriguing design to build and a most practical radio to use. When you have built it you will want your Micro-6 with you always—and it plays everywhere!



All parts including the special Micro Alloy Transistors, case, dial, lightweight earpiece, all parts and easy to follow instructions come to

**59/6 COMPLETE**

MALLORY MERCURY CELL ZM312 (2 required) each 1/11 (Pack of 6—10/6)

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 A.C. Voltage: 10V f.s.d. — 1,000 f.s.d. in 5 ranges.  
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As from 1st November, 1965  
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MM/17

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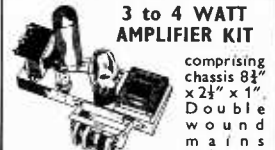
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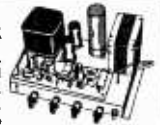
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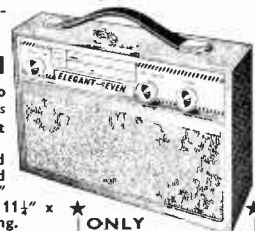
Size: 9" x 6" x 1½" A.C. Mains 200-250V 5 valves. For use with Std. or L.P. records, musical instruments, all makes of pick-ups and mikes. Output 8 watts at 5 per cent total distortion. Separate bass and treble lift controls. Two inputs, with controls, for gram. and mike. Output Transformer tapped for 3 and 15 ohms speech coils. Built and tested. £3.19 6. P. & P. 8/-.

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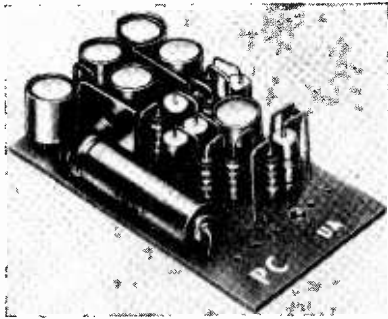
# SURPRISE! SURPRISE!

Here are some interesting items which we stock but are not yet in our catalogue.

## PACKAGED CIRCUITS

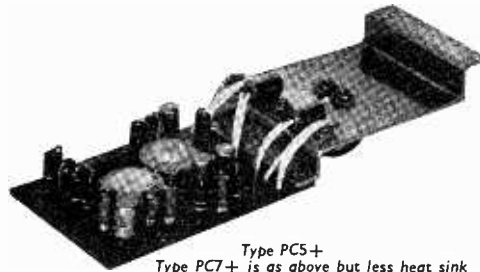
### NEWMARKET PACKAGED CIRCUIT AMPLIFIERS AND PRE-AMPS

The Newmarket Packaged Circuits are small, general purpose amplifiers. Circuits are of transformerless, complementary symmetry type, operating off standard voltages. Can be wire-in or plug-in as required.



Types PC1 to PC4

Type	Sensitivity	Input Impedance	Output Power	Supply Voltage	Dimensions inches			List
					L	W	H	
PC1	100mV	1.5K	150mW	9V	2	1	1	37/6
PC2	2mV	1.0K	400mW	9V	2½	1½	1½	52/6
PC3	10mV	2.5K	400mW	9V	2½	1½	1½	52/6
PC4	200mV	220 K	400mW	9V	2½	1½	1½	52/6
PC5+	5mV	1.5K	3 W	12V	5½	1½	1½	105/-
PC7+	5mV	1.5K	1 W	9V	3	1½	1½	69/3
nominal								



Type PC5+  
Type PC7+ is as above but less heat sink

The Newmarket Transistors packaged circuit type PC9 is an impedance matching AF amplifier intended primarily for use in laboratories to enable a high impedance capacitive source to be fed into relatively low impedance amplifiers such as the PC2, 3, 5+, 7+. The unit features a 1MΩ series input resistor and a single stage emitter follower to provide a 600Ω output. Dimensions: 1½" x 1¼" x ¼". List Price 33/9

### NEWMARKET PACKAGED CIRCUIT MAINS POWER PACKS

Mains Power Packs primarily designed to supply D.C. power for standard Newmarket Packaged Circuits, but also suitable for application in other fields.

The NKT packaged circuit type PC101 is a general purpose 50-60 c/s mains D.C. power supply giving a nominal 9V D.C. output. It is particularly suitable for use with NKT packaged circuit amplifier types PC2, PC3, PC4, PC7+, but will find applications in many other fields. The unit features a full wave bridge rectifier with capacitor smoothing.

D.C. Output:	9V	
Max. Load Current:	150mA	
Input Voltage:	240V A.C.	
Max. Ripple Voltage:	200mV rms.	
Dimensions	2½" wide x 2¼" x 2" high	List Price 37/6

The NKT packaged circuit types PC102 is a general purpose 50-60 c/s mains D.C. power supply giving a nominal 21V D.C. output. It also has separate secondary winding which with external rectification and smoothing can provide an isolated additional 21V D.C. supply. The unit features a full wave bridge rectifier with resistive-capacitance smoothing.

D.C. Output:	21V	
Max. Load Current:	320mA	
Input Voltage:	200-250V A.C. (in two voltage taps).	
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# THE Radio Constructor



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# Top Band Push-Pull Modulator

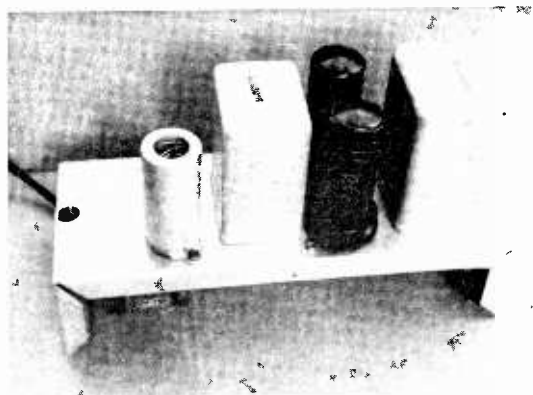
Frederick Sayers

*A simple modulator which may be used with the "V.F.O. Top Band Phone Transmitter" described in last month's issue or with any similar transmitter. Low-cost components are employed, and the use of suitable alternatives is discussed*

THE MODULATOR DESCRIBED HERE WILL BE found very satisfactory for use with most Top Band transmitters, or other transmitters running with an input of about 8-12 watts at about 250 volts h.t. It functions excellently as a modulator for equipment such as the "VFO Top Band Phone Transmitter" described in last month's issue, for which it was originally designed.

From Fig. 1 it will be seen that the circuit is very straightforward, while still having sufficient gain for the popular type of crystal microphone. The driver transformer  $T_1$  and modulation transformer  $T_2$  are ex-SCR522 equipment. The output stage uses a pair of 12A6's, which were also originally employed in the SCR522. With a 250V h.t. supply, these valves provide about 6.5W output. They have 12.6V heaters, and are operated with the 12AT7 from a small 12.6V heater transformer, the total current requirement being 0.45A.

It should be mentioned at this stage that it may be difficult to obtain the two ex-SCR522 transformers direct from surplus suppliers, although the complete SCR522 transmitter/receiver is still



Above-chassis view of the modulator unit

available. However, many ex-SCR522 transformers will be lying idle in amateurs' spares boxes and, as is explained later in this article, it is also possible to employ simple alternatives.\*

For a 6.3V supply, a pair of EL32 valves may be used, the 12AT7 then being wired for this voltage. (Tag 9 to chassis, and tags 4 and 5 joined for 6.3V.) Other similar output valves are also satisfactory. With the 250V supply, the optimum load of the 12A6's is 7.5k $\Omega$ .

## Modulator Chassis

This is 8 x 3 x 2in. deep, as in Fig. 2, and was bent from a 12 x 3in. "Universal Chassis" runner (Home Radio, Mitcham), 90° sections being cut from the flanges at the points of bending. Any similar small chassis should be satisfactory.

Large circular clearance holes were cut for the pins of  $T_1$  and  $T_2$ , which are bolted in position from below. Fig. 3 shows a suitable layout of components and wiring.  $C_2$  may be an 8 $\mu$ F or similar electrolytic capacitor, if to hand, instead of the 0.5 $\mu$ F component specified. A tagstrip is used to support  $R_2$ ,  $R_3$  and  $R_5$ . A further tagstrip, under  $T_2$ , supplies anchor points for the power supply connections. The points marked "MC" indicate earthing tags bolted to the chassis in the usual way.

It was convenient to mount the microphone socket on the equipment panel a little distance away from the modulator, so a length of screened lead was connected as shown. The microphone lead terminates in a coaxial plug to suit.

The pin numbers in Fig. 3 are those on the ex-SCR522 driver and output transformers. Pins 1 and 2 are the driver transformer primary, and pins 3 and 5 the secondary, with centre-tap 4. With  $T_2$  (modulator output transformer) pins 1 and 3 are primary, with centre-tap 2, and pins

\* At the time of writing, from Charles Britain (Radio) Ltd., 11 Upper Saint Martin's Lane, London, W.C.2.

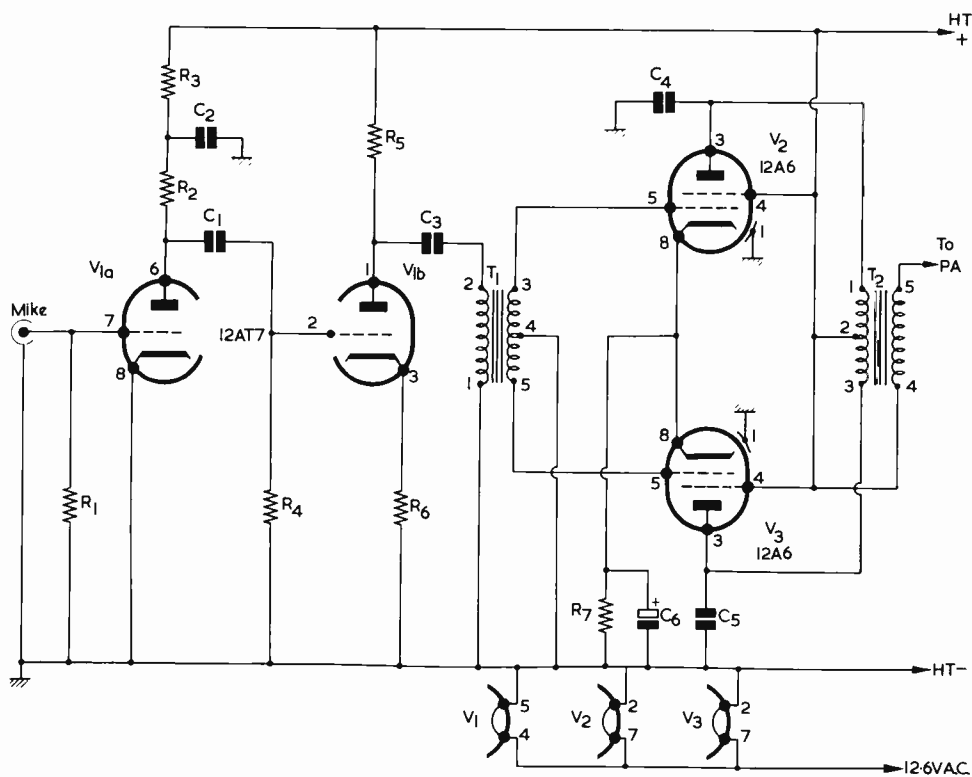


Fig. 1. The circuit of the modulator unit. The number references at  $T_1$  and  $T_2$  apply to ex-SCR522 transformers

### Components List

#### Resistors

(All  $\frac{1}{2}$  watt 10% unless otherwise stated)

$R_1$	2.2M $\Omega$
$R_2$	220k $\Omega$
$R_3$	22k $\Omega$
$R_4$	1M $\Omega$
$R_5$	220k $\Omega$
$R_6$	2.2k $\Omega$
$R_7$	440 $\Omega$ 2 watts

#### Capacitors

$C_1$	0.005 $\mu$ F, paper
$C_2$	0.5 $\mu$ F, paper (see text)
$C_3$	0.1 $\mu$ F, paper
$C_4$	0.005 $\mu$ F, 500V wkg., paper
$C_5$	0.005 $\mu$ F, 500V wkg., paper
$C_6$	50 $\mu$ F, 25V wkg., electrolytic

#### Transformers

$T_1, T_2$  see text

#### Valves

$V_1$	12AT7
$V_2$	12A6
$V_3$	12A6

#### Sockets

- 2 octal valveholders
- 1 B9A valveholder with skirt and screen
- 1 coaxial socket for microphone

#### Chassis

12 x 3in "Universal Chassis" runner (Home Radio (Mitcham) Ltd.)

#### Microphone

Crystal microphone (see text)

4 and 5 are the secondary. Here, pin 4 is connected to the h.t. positive circuit, so that the same h.t. supply is used for both the modulator and the transmitter p.a. If, for any reason, a separate h.t. pack is used for the p.a., then the connection between pins 2 and 4 must be removed.

A skirted holder to take a screening can is recommended for the 12AT7. The 12A6's are metal types, with the shell earthed by pin 1. If glass output valves are employed, no screening is required with them.



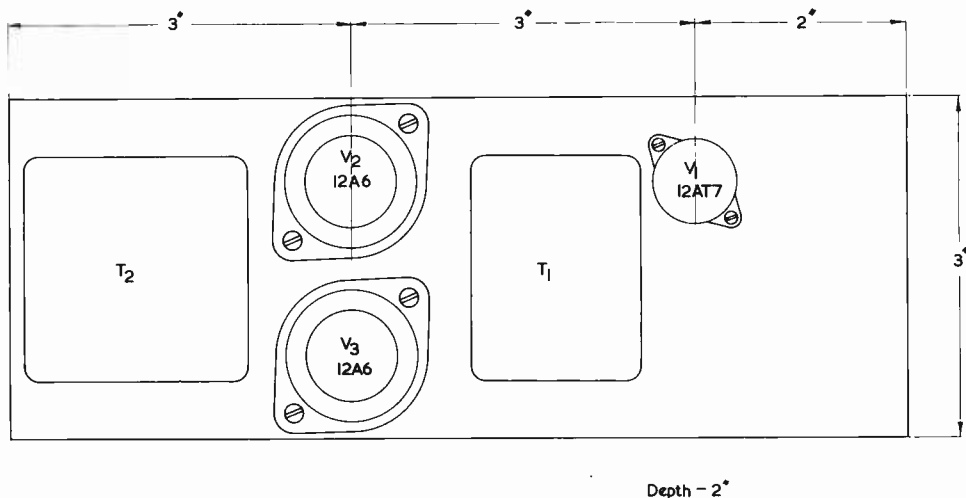


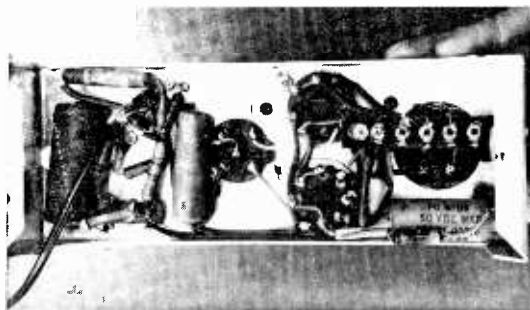
Fig. 2. The above-chassis layout

### External Connections

Four colour coded leads pass from the modulator. Black is used for h.t. negative. This is also the return of the 12.6V or other heater supply, and connects to the chassis of the transmitter. The 12.6V lead is green, and is taken to the secondary of the 12.6V heater transformer (or to the 6.3V supply point, if 6.3V heaters are to be operated). The h.t. positive lead is red, and goes to a suitable circuit point in the transmitter where about 250V h.t. will be available when the equipment is switched to "Transmit." The Power Amplifier (p.a.) lead is pink, and is taken to the positive tag of the anode current meter in the transmitter. This also supplies the screen grid of the p.a. valve, as is usual with anode and screen modulation. Thus, the p.a. anode and screen grid obtain their h.t. supply via the secondary of T<sub>2</sub>.

### Working Conditions

The modulator requires about 50mA from the h.t. supply, this depending somewhat on the valves employed. With the SCR522 transformer in the T<sub>2</sub> position, modulator matching is satisfactory with the p.a. loaded to draw about 40-50mA



Below-chassis view of the modulator unit

at 250-275V or so. Small changes in loading have no significant effect on modulation.

If it is wished to calculate the modulator transformer ratio for a particular pair of output valves and p.a. this is quite easily done.

First take the anode-to-anode optimum load for the pair of output valves from the maker's data or a valve manual. This figure will vary slightly according to the h.t. voltage and other conditions.

The modulating impedance of the p.a. is then found by dividing the anode voltage by the anode current plus screen current. For example, assume the p.a. anode receives 250V, and draws 40mA when loaded to the usual input, and that the screen grid draws 10mA.

$$\text{Impedance} = 250 / 0.05 = 5,000 \text{ ohms.}$$

The transformer ratio is then

$$1: \sqrt{\frac{\text{P.A. Impedance}}{\text{Optimum Load of Modulator}}}$$

Some modulation transformers have tappings, so that a sufficiently accurate match can be arranged between any pair of output valves and p.a.

With the push-pull modulator in use, it will often be possible to overmodulate the transmitter p.a. This can be checked by listening for splatter, or using an oscilloscope. If an oscilloscope is available, it may be noticed that modulation peaks tend to be stronger in one direction. If so, these peaks should be phased to give positive swing to the p.a. (extended peaks on the scope) not negative swing (troughs on the scope). This allows stronger modulation without interrupting the carrier. Phase can be changed by reversing connections to one transformer winding. This asymmetry is liable to occur with speech, and will not normally be observed if an audio oscillator is used to check modulation. The particular phase adopted may be incorrect if the microphone is

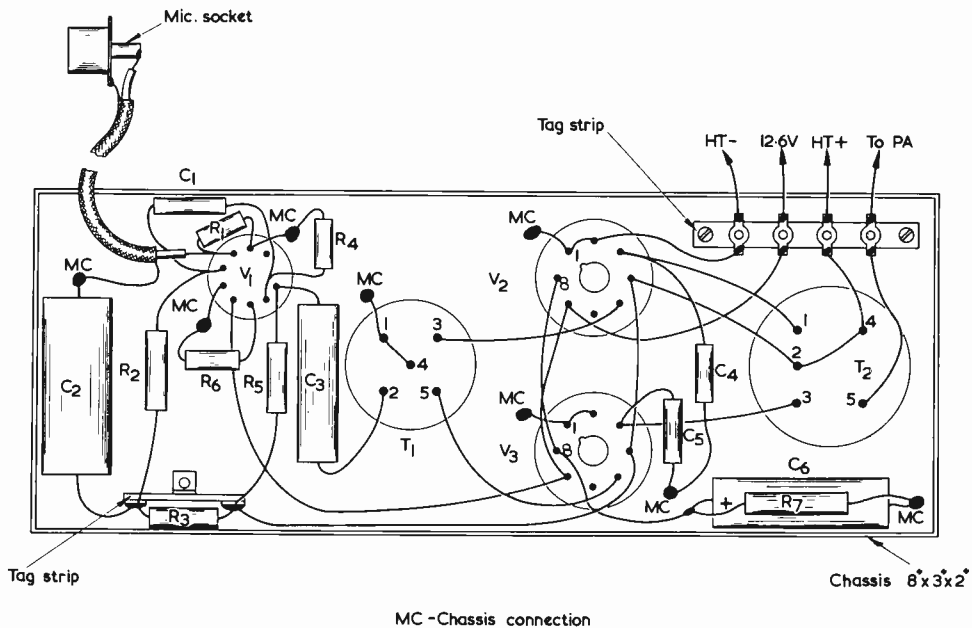


Fig. 3. Wiring and components below the chassis

changed. The effect is small, however, and can be ignored if no oscilloscope is available.

Capacitor values in Fig. 1 were found satisfactory for good communications quality speech. If higher frequencies are to be cut, this can be done by connecting a capacitor of suitable value between  $V_{1(a)}$  anode and chassis or by increasing  $C_4$  and  $C_5$ . On the other hand, if the particular combination of the operator's voice and microphone results in a rather low pitched effect, bass can be cut by reducing  $C_1$ , or  $C_3$ , or both in value, or treble can be lifted a little by reducing  $C_4$  and  $C_5$ .

No gain control was found necessary with the prototype, but one can readily be incorporated by changing  $R_4$  to a  $1M\Omega$  log track potentiometer, the slider connecting to the grid of  $V_{1(b)}$ . The potentiometer should be mounted close to  $V_1$  valveholder.

#### Alternative Transformers

It may be wished, for reasons such as those mentioned earlier, to use transformers other than those from the SCR522 equipment. In a small modulator of this kind, alternatives are easily arranged, and need not consist of components specifically intended for transmitter modulation.

In Fig. 4 (a) a small 1:3 intervalve type transformer is provided with an artificial centre-tap for the secondary by means of two  $470k\Omega$  resistors. The component used was Cat. No. TIV3, available from Home Radio, Mitcham. Any similar transformer to hand should be suitable. The writer has checked the TIV3 transformer in the  $T_1$  position, with complete satisfaction.

Various substitutes and alternatives were also tried in the output position. As expected, it was found that the exact ratio is not important. It will also be found that transformers which would be unsatisfactory for high-fidelity purposes are perfectly satisfactory for speech equipment of this kind.

A push-pull speaker output transformer primary can be used as an auto-transformer, as shown in Fig. 4 (b). This is possible when, as intended with the present design, the modulator and p.a. use the same h.t. supply. The "whole primary" p.a. ratio is 2:1. If the primary has otherappings, one can be used for the p.a. to modify the ratio. The actual transformer checked by the writer for this circuit was the Elstone MR/7, 10-watts,

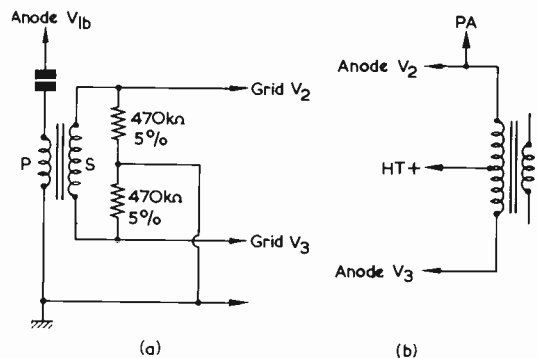


Fig. 4. Employing alternative transformers in the  $T_1$  and  $T_2$  positions

70mA model. Other transformers, rated at 70mA or more, and intended for push-pull mains pentodes, should be equally satisfactory.

Home-wound transformers have also been used, with complete success. The simplest method is to take a speaker transformer of at least 5W size (8-10W is preferred) for push-pull mains pentodes, and with the secondary wound last. The speaker secondary is then removed, whereupon the p.a. winding, of 34 s.w.g. enamelled wire, occupies this space. The number of turns required can be found without disturbing the primary. First, count the secondary turns as they are removed, and multiply by the ratio to find the primary

turns. The ratio is *primary turns: secondary turns*, and the number of turns needed on the new secondary can then be found. This number depends on the core dimensions, etc., but will be several hundred. Small transformers would need many turns, and have insufficient space.

#### Microphone

Any inexpensive crystal microphone should cope satisfactorily with the modulator. That employed by the writer was an Elpico hand-mike unit (as supplied by KW Electronics Ltd., of 1 Heath Street, Dartford, Kent, for use with their transmitters).

---

## 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*

**Saja M40 Tape Recorder.**—E. Slater, 25 Roker Park Avenue, Audenshaw, Manchester—loan or purchase of circuit diagram.

\* \* \*

**Amplion Tape Recorder.**—C. F. Bridgewater, 84 Marie Curie Avenue, Netherton, Bootle 10, Lancs.—circuit diagram, loan or purchase.

\* \* \*

**Champion Receiver Model 719B.**—F. Chadwick Greene, 44 Cliff Road, Leeds 6—circuit diagram or service sheet.

\* \* \*

**Raymond TV F107.**—C. Johnson, 14 Kings Road, Tranent, E. Lothian—purchase of service manual.

**Geloso VFO 4/102.**—D. J. Druhan, Dunkitt, Waterford, Eire—circuit diagram required.

\* \* \*

**PCR2 Receiver.**—B. P. Bradley, 63 The Lowe, Chigwell, Essex—would like to hear from any reader who has successfully replaced the valves by modern miniature types.

\* \* \*

**Halicrafters SX25 Receiver.**—N. P. Spry, 26 Scott House, Hesters Way, Cheltenham, Glos.—handbook or circuit diagram or any information.

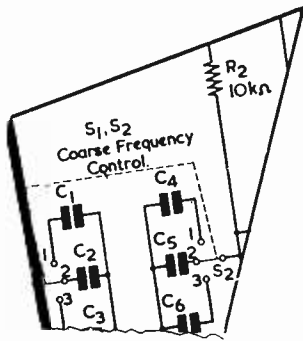
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## New Compact Thyatron

A new metal-bodied deuterium-filled pulse modulator thyatron, type E2830, is now being produced by The M-O Valve Co. Ltd.

Designed specifically for radar applications, this compact tube measures only 4½ in by 2¼ in diameter and has a peak anode voltage of 20kV, forward and reverse, and a mean anode current of 600mA (500A peak). It can also be used as a grid controlled rectifier with ratings of 20kV, forward and reverse, and 1 amp mean current.

The metal body facilitates the cooling of the grid and enables the gas density of the tube to be kept constant so contributing to compactness and well controlled triggering characteristics at high power.



# A Linear Scale Ohmmeter

**SUGGESTED CIRCUIT No. 180**

**By G. A. FRENCH**

DEVICES FOR MEASURING RESISTANCE are in common use in radio and electronic work, the most frequently employed type being the ohmmeter with an energising battery. An instrument of this type is simple, robust and reasonably accurate, but it has the disadvantage that its scale is non-linear and becomes cramped at one end. It then becomes both difficult and time consuming to interpret readings on the scale, this being particularly true over the cramped section.

This month's "Suggested Circuit" describes an ohmmeter which offers a linear scale and with which readings can, in consequence, be taken much more readily. It is not, however, as simple as the conventional ohmmeter, and its range, using the readily available components employed in the prototype, is from zero to 25k $\Omega$  only. Apart from other uses, a particularly attractive application would be given when resistance readings have to be taken by non-technical persons, as on a factory production line, because the linear scale can be followed much more readily by people without previous experience of meters and meter readings. A limitation on the accuracy of the instrument is given by the sensitivity of the meter employed for displaying the resistance readings. As is discussed at the end of this article, greatest accuracy will be given by the use of a transistorised or valve voltmeter having a fairly high input resistance, although perfectly acceptable accuracy can be obtained with a moving-coil meter.

## The Ohmmeter Circuit

The ohmmeter achieves a linear scale by passing what is very nearly a constant current through the resistor to be measured, the voltage across it being indicated by a volt-

meter. Since the current is virtually constant, the voltage across the resistor is directly proportional to its resistance, and the latter may be found from the voltage reading. The voltmeter may be scaled in ohms, or the circuit may be set up such that the figures in an existing meter scale calibration apply also to, say, units in k $\Omega$ .

To check the practicability of the scheme, the author made up the prototype shown (in final form) in Fig. 1. In this diagram, TR<sub>1</sub> operates as a constant current device, allowing a fixed current to flow through the test resistor. In practice, it was found that this requirement could be achieved, with the circuit of Fig. 1, for all values of test resistance from zero up to slightly in excess of 25k $\Omega$ .

A high resistance voltmeter is connected across the test terminals, this being, with the prototype, a 50 $\mu$ A movement in conjunction with

a 200k $\Omega$  series resistor. Actually, a 20,000 ohm per volt testmeter switched to the 10 volt range was employed here.

TR<sub>1</sub> may be looked upon as a grounded base transistor having a fixed emitter current provided by R<sub>1</sub> and the 1 volt which appears across R<sub>3</sub>. The collector current, following the normal output characteristic of a grounded base transistor, then remains almost completely constant for all collector voltages above a low figure depending upon the transistor type employed.

## Results With The Prototype

The prototype was set up as shown in Fig. 1 except that R<sub>1</sub> was a variable resistor and R<sub>2</sub>R<sub>3</sub> a 1.5k $\Omega$  potentiometer. Initially, the voltmeter was omitted, and a milliammeter inserted in series with the -9 volt supply line.

A 50k $\Omega$  variable resistor was then connected across the test terminals,

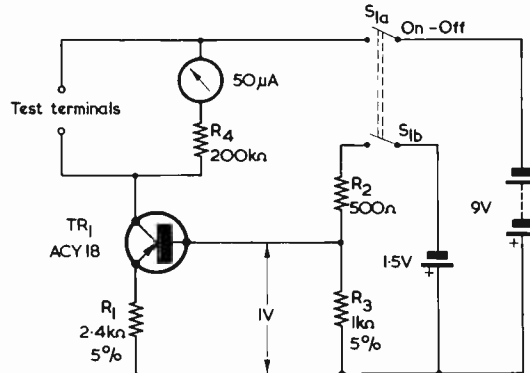


Fig. 1. The prototype linear ohmmeter circuit checked by the author. This gave linear readings of resistance up to 25k $\Omega$ . The non-preferred value of 500 $\Omega$  for R<sub>2</sub> is shown merely because a 1.5k $\Omega$  potentiometer was employed for R<sub>2</sub>R<sub>3</sub>, and this was the resistance given between the slider and the upper end of the track after adjustments had been made. In practice, a 510 $\Omega$  5% resistor would be quite adequate

and  $R_1$ , and the slider of the potentiometer taking the place of  $R_2R_3$ , were adjusted empirically to offer a constant current over the greatest range of test resistance. What were considered to be the best results were obtained when the values specified in the diagram for  $R_1$ ,  $R_2$  and  $R_3$  were given, the collector current remaining fixed at 0.35mA for test resistances from zero up to 25k $\Omega$ . Incidentally, the fact that the adjustments resulted in exactly 1 volt appearing across  $R_3$  was quite coincidental; the writer found that this voltage existed at the junction of  $R_2$  and  $R_3$  at a later stage, when checking the values required in these two resistors.

The values of  $R_1$ ,  $R_2$  and  $R_3$  are not excessively critical and constructors may like to experiment with these in the same way as did the author. There may, also, be discrepancies between different transistors, but these should be small due to the grounded base mode in which the transistor works.

It was felt that a constant current around 0.35mA was sufficiently high to enable the circuit to be checked as an ohmmeter, and the voltmeter was then brought into circuit. Different values of resistance were connected across the test terminals and the indications in the meter were noted. The 25k $\Omega$  maximum resistance figure corresponded to a reading of slightly less than 8 volts in the meter and lower resistances to correspondingly lower figures. Bearing in mind the shunting effect of the meter (which, in combination with a 25k $\Omega$  test resistor, would give a collector load of 22k $\Omega$ ) checks were then made for linearity of the readings. No significant departure

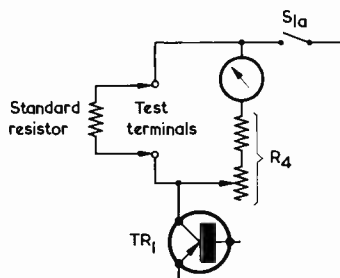


Fig. 2. How the ohmmeter may be adjusted to cater for varying battery voltages.  $R_4$  now comprises a fixed and a variable resistor, the latter being one-fifth to one-tenth the value of the former. Values depend upon the meter movement employed and should be such that the variable resistor is at approximately mid-travel when new batteries are fitted. With a 25 $\mu$ A movement the fixed resistor could be 310k $\Omega$  and the variable resistor 50k $\Omega$ .

from linearity was noted, and accuracy of readings was certainly as good as could be given by a conventional type of ohmmeter.

#### Possible Improvements

Whilst the circuit of Fig. 1 represents a working ohmmeter, some improvements could be incorporated very readily.

The constant current obtained from  $TR_1$  may be varied by adjusting the value of  $R_1$ . If this value is too high, however, the maximum test resistance which can be checked becomes too low; and if the constant current is too low a more sensitive

meter is required and leakage currents in the transistor may become troublesome.

A better choice of meter for the prototype would have been a 25 $\mu$ A movement. This would then have given full-scale deflection, for a test resistance of 25k $\Omega$ , with a series resistor of 325k $\Omega$  (whereupon the actual collector load would be 23k $\Omega$ ). If such a movement were calibrated 0-25, direct readings of resistance in k $\Omega$  would then be provided.

The circuit cannot be provided with a set-zero control, because short-circuiting the test terminals produces a zero voltage reading. However, some adjustment to cater for varying battery voltages is required, and this could consist of a variable resistor in series with the meter, as shown in Fig. 2, the variable resistor being adjusted to give the requisite reading when a standard resistor of, say, 15k $\Omega$  is presented to the test terminals. Adjusting for a test resistance which offers a reading slightly above mid-scale will also help to equalise the error introduced by the shunting effect of the meter. With the 25 $\mu$ A movement, there will then be about 3% shift from linearity for test resistances of 5 and 25k $\Omega$ , such figures comparing very well with the errors quoted for high-grade conventional ohmmeters.

As will be seen, the voltmeter imposes a limiting factor on the accuracy with which readings may be obtained. If, instead of the 25 $\mu$ A meter and its series resistor, a transistorised or valve voltmeter having an input resistance of 1M $\Omega$  were used, the accuracy would be about three times better.

## Improvement in the Carrier Frequency Stability of the BBC's 200 kc/s Transmitter

In 1945 the B.B.C. inaugurated high-precision frequency control of its 200 kc/s transmission of the Light Programme from Droitwich. The long-term frequency stability, which was then within 1 part in  $10^7$ , was considerably improved in January 1963 and since then has been maintained within 5 parts in  $10^9$ .

A further improvement has now been made in the frequency control of the Droitwich 200 kc/s Transmission resulting in a long-term stability which is now within  $\pm 5$  parts in  $10^{10}$ . Due to the use of automatic frequency correction the excursion from nominal does not usually exceed 1 part in  $10^{10}$ .

With the recent increase in broadcasting hours of the Light Programme the Droitwich 200 kc/s transmission is now available for 21 hours daily from 04.00 to 01.00 G.M.T.

Daily comparisons between the frequency of the Droitwich transmission and the National Standard of Frequency are made at the National Physical Laboratory at Teddington and the results are available by application to: The Director, The National Physical Laboratory, Teddington, Middlesex.



# Simplicity and Sensitivity with 3 Transistors

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

*An ingenious reflex design which provides loudspeaker reception on medium and long waves with the use of three transistors only*

SOME TIME AGO THE AUTHOR DESCRIBED A VERY simple earphone circuit which used only 10 components apart from the two transistors and single diode, yet provided the sensitivity given by 5 stages.<sup>1</sup> The circuit now to be described is a development to give coverage of the long wave band in addition to medium waves, and to provide a good output from a miniature loud speaker. It is very suitable for a receiver using one of the easily obtainable plastic cases measuring about 5¼ x 3 x 1¼ in, the components being mounted on a Paxolin panel.

## The Circuit

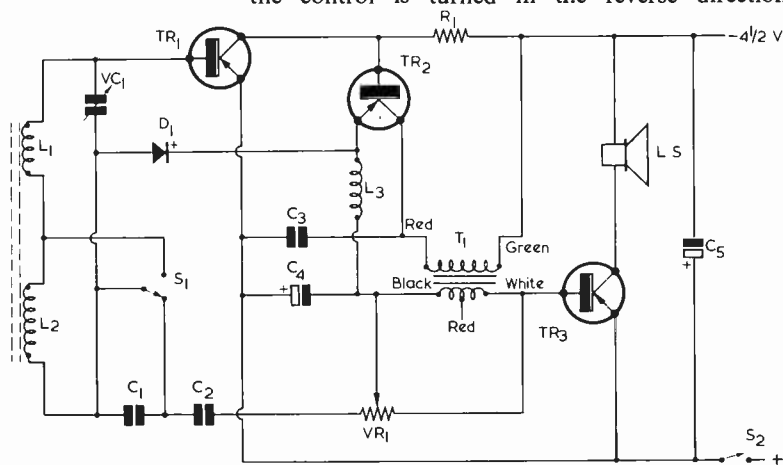
If the circuit diagram is studied it will be seen that the first two transistors are both reflexed amplifiers. This part of the circuit is basically similar to that previously described, though considerable modifications have been made to the reaction control arrangements, first, to suit the long wave band, and secondly to provide true volume control at low settings. In the author's opinion, the latter is essential with loudspeaker receivers.

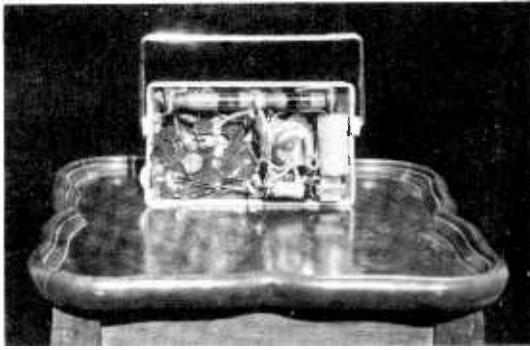
<sup>1</sup> Sir Douglas Hall, "Simplicity and Sensitivity with Two Transistors", *The Radio Constructor*, April 1964.

The signal is picked up by L<sub>1</sub>, or by L<sub>1</sub> and L<sub>2</sub> on the long wave band, and passed to TR<sub>1</sub> as a common emitter radio frequency amplifier. TR<sub>2</sub> gives further amplification as a common collector amplifier, the output appearing across L<sub>3</sub>, and D<sub>1</sub> demodulates. Because TR<sub>2</sub> is a common collector amplifier, and the signal emerges from the emitter, any audio frequency signals which are developed across L<sub>3</sub> will be out of phase with those on the base of TR<sub>1</sub>, so that the usual instability problems which beset double reflex circuits are avoided. All three transistors provide common emitter audio frequency amplification.

Regeneration is obtained by means of a capacitance tap into the tuned circuit, formed by strays (mainly within TR<sub>1</sub>), and C<sub>2</sub> (in series with C<sub>1</sub> on the medium wave band but on its own on the long wave band). Suitable tapping points are thus provided for smooth reaction on all frequencies. The capacitance tap arrangement is interrupted by that part of VR<sub>1</sub> which is between the slider and the C<sub>2</sub> end. As the amount of resistance in this section is reduced reaction increases, and oscillation starts when it is only a few hundred ohms in value. As the control is turned in the reverse direction,

The circuit of the 3-transistors reflex receiver. It should be noted that transformer T<sub>1</sub> has two red leads. The unused centre-tap red lead appears on the component, between the ends coloured black and white





Rear view, without battery

reaction is reduced, and at the same time the tuned circuit becomes increasingly isolated from TR<sub>1</sub> with a consequent loss in sensitivity. A third effect is that the other section of VR<sub>1</sub> tends to short-circuit the secondary of T<sub>1</sub>, thus depriving the base of TR<sub>3</sub> of a signal. In fact, VR<sub>1</sub> functions simultaneously as a reaction control, a radio frequency volume control and an audio frequency volume control, and it is most effective in its action. As with many reaction circuits there is some interaction between the tuning capacitor and VR<sub>1</sub>, but this is only troublesome on very weak stations, and constructors will find that they soon get the knack of using both controls together.

#### Ferrite Aerial

L<sub>1</sub> consists of 40 turns of 32 s.w.g. enamelled wire close-wound, and will tune from about 190 to 500 metres. L<sub>2</sub> has 150 turns of 38 s.w.g. enamelled wire, pile-wound to a length of  $\frac{3}{4}$  in. With L<sub>2</sub> in circuit the range is from about 800 to 2,000 metres. The two coils are mounted at opposite ends of a piece of ferrite rod,  $\frac{3}{8}$  in in diameter, and 5 in long. The coils are mounted so that their windings are in the same direction.

TR<sub>3</sub> obtains its base bias through TR<sub>2</sub> which, for direct current, acts as a resistor between the negative side of the battery and the base of TR<sub>3</sub>. Similarly, the direct current path to the positive battery line passes through the base-emitter junction of TR<sub>3</sub>, which has a direct current resistance of a few hundred ohms. It is this resistance which provides the emitter resistor for TR<sub>2</sub> and base bias for TR<sub>1</sub>. A good many components are saved in this way.

It is essential that TR<sub>1</sub> and TR<sub>2</sub> should be type MAT101, and it is important that TR<sub>3</sub> should be a first grade OC72. With a different, or surplus transistor in the TR<sub>3</sub> position there could be wide changes of current which would upset biasing arrangements and possibly result in excessive current consumption. Again, if a very high amplification transistor were used for TR<sub>3</sub> there might be instability due to the large gain which is already provided by TR<sub>1</sub> and TR<sub>2</sub>.

VR<sub>1</sub> should be a 2k $\Omega$  linear track control for best results. A suitable potentiometer is the Morganite component which is complete with battery switch

and is a neat edgewise control. It is obtainable from Electronic Precision Equipment Ltd.<sup>2</sup> The more common 5k $\Omega$  semi-log type of control could alternatively be used, but the 2k $\Omega$  linear component is better for this particular circuit.

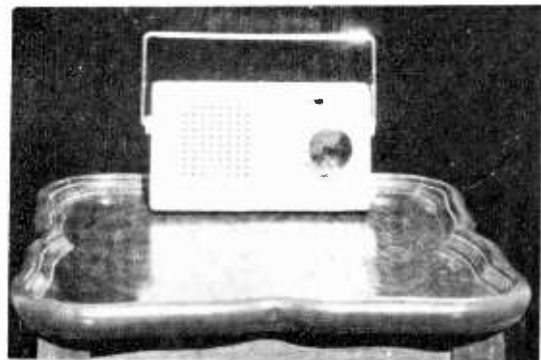
T<sub>1</sub> should be a genuine Rex transformer. There are, apparently, others on the market bearing the type number LT44, but while these may be perfectly good transformers, their characteristics are not necessarily the same—particularly the d.c. resistance of the windings—and they may not therefore prove suitable in the particular circuit described here.

#### Multi-function Component

R<sub>1</sub> has a surprisingly large number of duties to perform. It is the output load for TR<sub>1</sub>, both at radio and at audio frequencies. It is the input load for TR<sub>2</sub> at both frequencies. It is the bias resistor for the base of TR<sub>2</sub> and, indirectly, through TR<sub>2</sub>, it controls the base bias for TR<sub>1</sub> and TR<sub>3</sub>. It thus has an effect on the current passed by each of the three transistors. Also, because it determines the current flowing through TR<sub>1</sub> and TR<sub>2</sub> it also determines the effective internal capacitances offered by those transistors and hence the position of the capacitance tap into the tuned circuit.

Even so, the value for R<sub>1</sub> is not as critical as might appear, since there is considerable stabilisation of d.c. throughout the receiver which helps to compensate for different transistor characteristics. Let us suppose that R<sub>1</sub> is too low in value for the amplification factors offered by TR<sub>1</sub> and TR<sub>2</sub>, TR<sub>1</sub> being a low amplification example and TR<sub>2</sub> having a high amplification factor. There will be a large negative bias on the base of TR<sub>2</sub> which will cause a larger than normal current to flow through this transistor. This will reduce the d.c. resistance of TR<sub>2</sub> which is the effective base bias resistor for TR<sub>3</sub>, and the latter will accordingly tend to pass a large current. But with the base of TR<sub>3</sub> more negative as regards its emitter, the effective emitter resistor for TR<sub>2</sub> is increased in value so that the current flowing through TR<sub>2</sub> tends to drop. At the same time, with the base of TR<sub>3</sub> more negative as regards its emitter the base of TR<sub>1</sub> will become

<sup>2</sup> Electronic Precision Equipment Ltd., 66 Grove Road, Eastbourne.



The external appearance of the prototype receiver

equally more negative as regards its emitter. The result is that  $TR_1$  will pass more current and there will consequently be a larger voltage drop across  $R_1$ , this tending to reduce the current flowing through  $TR_2$ .

As a result of this stabilisation it will be found that the value shown for  $R_1$ —10k $\Omega$ —will suit the majority of transistors that may be used for  $TR_1$  and  $TR_2$ . But if the amplification of  $TR_1$  is low, and that of  $TR_2$  high, it may be necessary to increase  $R_1$  to, say, 12.5 or 15k $\Omega$ . Similarly, if  $TR_1$  is a very efficient specimen, and  $TR_2$  a comparatively poor example, it may be necessary to reduce  $R_1$  to 8.2 or 7.5k $\Omega$ .

The need for  $R_1$  to be increased in value will be shown by a tendency towards harsh reaction, particularly at the high wavelength end of the medium wave band, and for total current consumption to be in excess of 20mA. The need for  $R_1$  to be reduced in value will be shown by a difficulty in obtaining oscillation, particularly at the high wavelength end of the long wave band, and by current consumption being less than 12 to 15mA. There may also be audio frequency instability, indicated by a high pitched squeal, at low settings of the reaction control on the long waveband.

Although, as has been said, 10k $\Omega$  will prove right in most cases, the serious constructor may prefer to replace  $R_1$  by a sub-miniature preset control which can be adjusted, preferably with a milliammeter in circuit, once and for all, to give best results. If no meter is available, the preset control should be in series with a fixed resistor of 7.5k $\Omega$  to prevent any possibility of inserting into circuit a dangerously low value of resistance. Other constructors, who have a milliammeter available, may wish to use any size of 25k $\Omega$  potentiometer, connected into circuit by flexible leads, to determine the correct value, later replacing the potentiometer with a fixed resistor.

Once it has been decided that  $R_1$  is correct, there are no further adjustments to make, and the receiver should give very sensitive results with a large choice of programmes after dark, and at least 3 or 4 stations during the hours of daylight.

## Components List

### Resistors

$R_1$  10k $\Omega$  (see text) 4d  
 $VR_1$  2k $\Omega$  potentiometer, linear track, with switch  $S_2$  (see text) 3'6

### Capacitors

$C_1$  1,000pF 20% ceramic or silver-mica 10d  
 $C_2$  3,000pF 20% ceramic or silver-mica 10d  
 $C_3$  500pF 20% ceramic or silver-mica 10d  
 $C_4$  100 $\mu$ F electrolytic 6V wkg. 1-11.  
 $C_5$  250 $\mu$ F electrolytic 6V wkg. 2-4  
 $VC_1$  500pF variable, solid dielectric. (Prototype used Wavemaster capacitor) 5'0

### Inductors

$L_{1,2}$  See text 6d  
 $L_3$  2.5mH r.f. choke, type CH1 (Repanco) 2'6  
 $T_1$  Interstage transformer, type LT44 (Rex —see text) 5'-

### Semiconductors

$TR_{1,2}$  MAT101 16'6  
 $TR_3$  OC72 3'0  
 $D_1$  OA81 1'-

### Switches

$S_1$  s.p.d.t. miniature slide switch  
 $S_2$  s.p.s.t. (ganged with  $VR_1$ )

### Loudspeaker

75–80 $\Omega$ , 2 $\frac{3}{4}$ –3in. (Prototype used Orion type TP 26G, Henry's Radio Ltd.)

### Cabinet

Prototype employed moulded radio cabinet, 5 $\frac{1}{4}$  x 3 x 1 $\frac{3}{4}$ in, with dial and handle (Henry's Radio Ltd.)

### Battery

4.5 volt battery. Ever Ready type 1289 or similar

### Miscellaneous

Ferrite rod, Paxolin panel, etc. (see text)

## New Feeder Systems for I.T.A. Aerials

The Independent Television Authority has placed a contract with EMI Electronics Limited to supply and install semi-flexible feeder systems to existing aerials at Chillerton Down, Isle of Wight; Black Mountain, Northern Ireland; and Burnhope, Durham.

The feeders will replace the rigid transmission lines now in use, and, when the installation is complete, all I.T.A. aerials throughout Britain will be equipped with the new type of feeder.

Changeover has been made because of the improved reliability of the semi-flexible lines. The semi-flexible feeder is installed as a continuous length, in contrast to the rigid line which is jointed at 12ft intervals. These joints are a possible source of trouble and can be inaccessible in bad weather.

# ELECTRONIC COUNTING with DEKATRONS

## Part 2

By G. W. Pilliner, B.Sc.



*In this concluding instalment on the 2-dekatron and mechanical register counter, our contributor describes the stabilised power pack, the complete assembly, fault-finding and modifications*

### Power Supplies

THE POWER REQUIREMENTS FOR DEKATRON COUNTING circuits are slightly unusual. The requirements for the counter described last month are given in Table 3; and the voltages shown here are typical of dekatron circuitry. The 300 volt supply to the trigger tubes must be stabilised because the sensitivity of the counter depends critically upon the bias and anode voltages applied. If a stabilised power pack giving these outputs is not available, they could be obtained by simple modifications to an existing stabilised unit. However, as it is desirable that the counter should be self-contained, the construction of a suitable power unit will be described. It uses a parallel stabilised circuit with neon stabilisers (Fig. 10 (a)). Sufficient power is available to operate simple ancillary equipment such as a geiger tube and head pre-amplifier.

**Table III**  
Power supply requirements for the two-dekatron counter

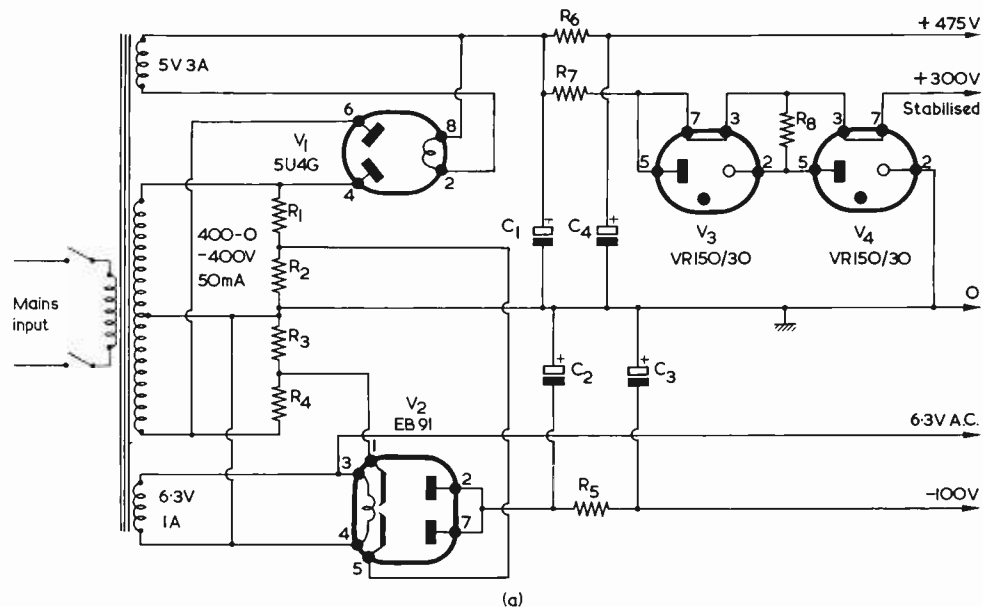
Circuit	Voltage	Current
Dekatron anodes	475 ± 25	750 μA
Trigger anodes	+10	
ECL80 anodes	300	No pulses: 6mA
Bias dividers	-20	100 p.p.s.: 7mA
Negative bias	-105	
ECL80 heater and pilot lamp	6.3 a.c.	0.6A

### Construction Of The Power Unit

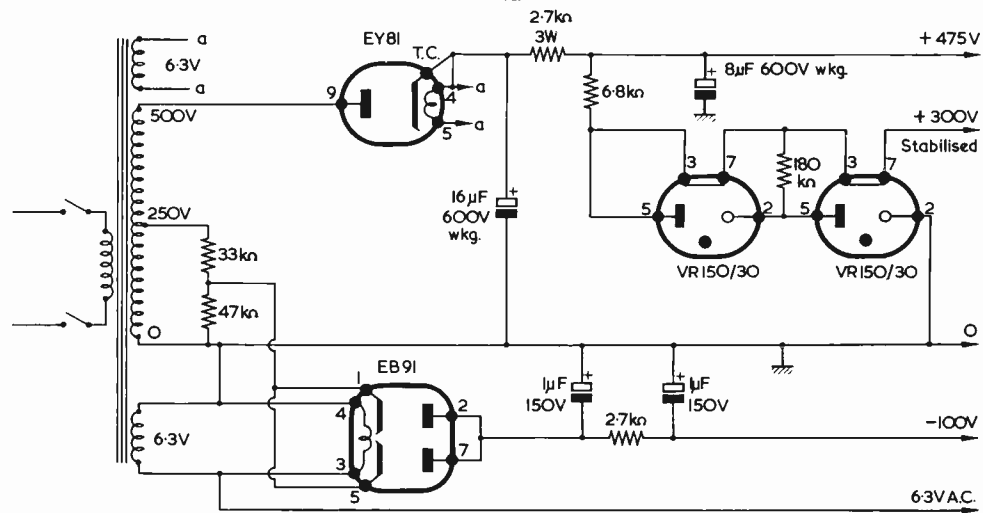
In order that the power chassis and the counter chassis will both fit neatly into a cabinet of reasonable size and shape a chassis size 9 x 4 x 1½ in is used. Drilling details are shown in Fig. 11 and a wiring diagram in Fig. 12. In Fig. 11, holes A have a diameter of 1½ in for octal valveholders, whilst hole B is ⅝ in diameter for a B7G valveholder. Holes C are 4BA clear for mounting octal valveholders and tagstrips, whilst holes D are 6BA clear for mounting the B7G valveholder. It is possible that the valveholders employed may be of different type to those used by the writer, with the result that the mounting holes shown in Fig. 11 will provide a different pin orientation to that given in Fig. 12. In such an instance it may be preferable to drill mounting holes which give the pin orientation of Fig. 12, although such orientation is not at all critical. The tagstrips are shown in Fig. 12 and the writer obtained his by cutting them from a Radiospares 28-way tagstrip.

Holes E in Fig. 11 are ½ in diameter, and are fitted with grommets for the power output leads. Holes F are ⅜ in diameter and take No. 8 self-tapping screws when the chassis is later mounted in the cabinet. Also required are a rectangular cut-out and mounting holes for the mains transformer, and these should be made to suit the component employed. It would be advisable to ensure that the chassis dimensions are adequate for the transformer used before marking out, as a bulky transformer may require a slightly larger chassis.

The specified mains transformer may not be



(a)



(b)

Fig. 10 (a). Circuit of the power supply employed in the prototype  
 (b). An alternative circuit which enables a mains transformer with a 250-0-250 volt h.t. secondary to be used

readily available: the author has used a 350-0-350 volt transformer successfully, but it should be realised that the voltage obtainable is a little lower than desirable—about 440 volts—and that some adjustment in the value of the dekatron anode resistors may in consequence be necessary for reliable operation and, also, that a geiger tube operated from the counter will be working near its lower threshold. Alternatively, a 250-0-250 volt transformer may be used in the circuit of Fig. 10 (b) to give a half wave output of 500 volts: in this case a resistor of 2.7k $\Omega$ , 3 watts, will be

required in series with R<sub>7</sub>, the 475 volt line being taken from the junction of these two resistors. The ratings of the electrolytic capacitors and V<sub>1</sub> must also be increased, as indicated in the diagram. The wiring diagram of Fig. 12 applies to Fig. 10 (a) only.

Two 150 volt neon stabilisers are used in series to provide a 300 volt stabilised line. A resistor of 180k $\Omega$  is wired in parallel with one of the tubes to ensure that both strike. Two pins on the base of the stabilisers are interconnected without being connected to the electrodes of the tube. These



## Components List—Power Unit (Fig. 10 (a))

### Resistors

(All resistors 10%)

R <sub>1</sub>	56kΩ	2 watts
R <sub>2</sub>	39kΩ	1 watt
R <sub>3</sub>	39kΩ	1 watt
R <sub>4</sub>	56kΩ	2 watts
R <sub>5</sub>	2.7kΩ	½ watt
R <sub>6</sub>	2.7kΩ	½ watt
R <sub>7</sub>	6.8kΩ	5 watts
R <sub>8</sub>	180kΩ	½ watt

### Capacitors

(All capacitors are electrolytic)

C <sub>1</sub>	8μF	500V wkg.
C <sub>2</sub>	1μF	250V wkg.
C <sub>3</sub>	1μF	250V wkg.
C <sub>4</sub>	8μF	500V wkg.

### Transformer

Mains transformer, drop-through (see text): primary, to suit local mains supply; secondaries, 400-0-400 volts 50mA, 6.3 volt 1 amp, and 4 or 5 volt 3 amp (to suit rectifier used)

links are used in series with the output lead so that if either stabiliser is not plugged in the trigger tubes will not be subjected to anode voltages in excess of 300 volts.

The circuit and wiring diagram indicate a 5U4 rectifier valve. However, any rectifier capable of handling a 400 volt r.m.s. a.c. input at 50mA (1130 volts peak inverse rating) should be suitable.

It is, of course, important that the electrolytic

### Valves

V <sub>1</sub>	5U4G or 5R4GY (5 volt heaters) or 1W4/500 (4 volt heater) or any other suitable rectifier (see text)
V <sub>2</sub>	EB91
V <sub>3</sub>	VR150/30
V <sub>4</sub>	VR150/30

### Valveholders

2	International Octal
1	B7G
1	to suit rectifier used

### Tagstrips

2	7-way tagstrips (see Fig. 12 and text)
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### Miscellaneous

Chassis, Cut from 18 s.w.g. aluminium	8 x 12in
2 ½in	grommets
4	1in No. 8 self-tapping screws
2	yards 5-core cable
2	4BA solder tags

capacitors be connected the right way round. Those used in the -100 volt bias line have the positive lead connected to chassis; if the can is not insulated already it must be effectively isolated from the chassis.

### Constructing The Cabinet

As facilities to make a metal cabinet were not available, the author's cabinet was constructed of

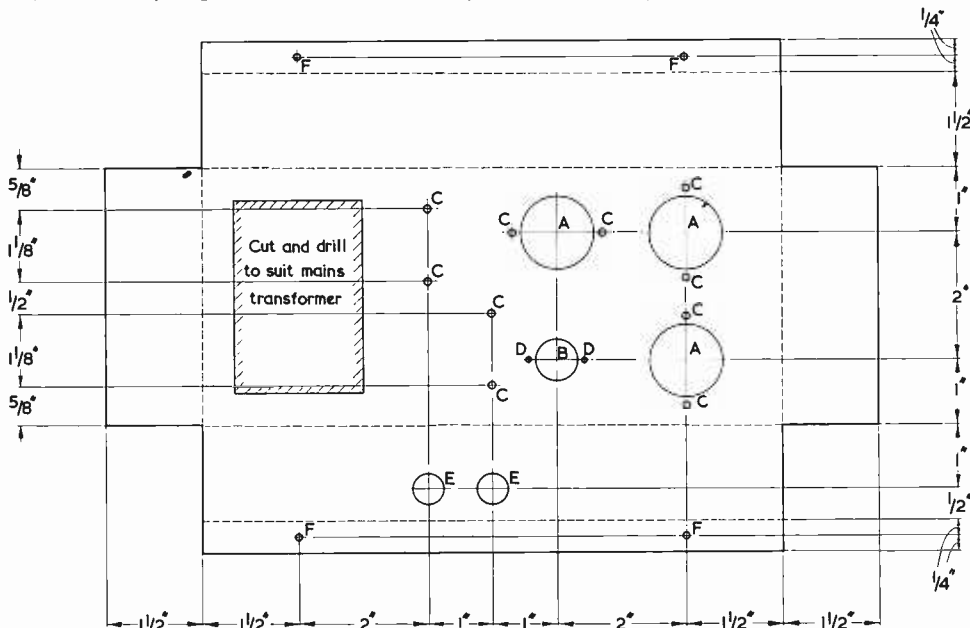


Fig. 11. The dimensions and drilling details for the power chassis. The various holes are discussed in the text. The material is 18 s.w.g. aluminium

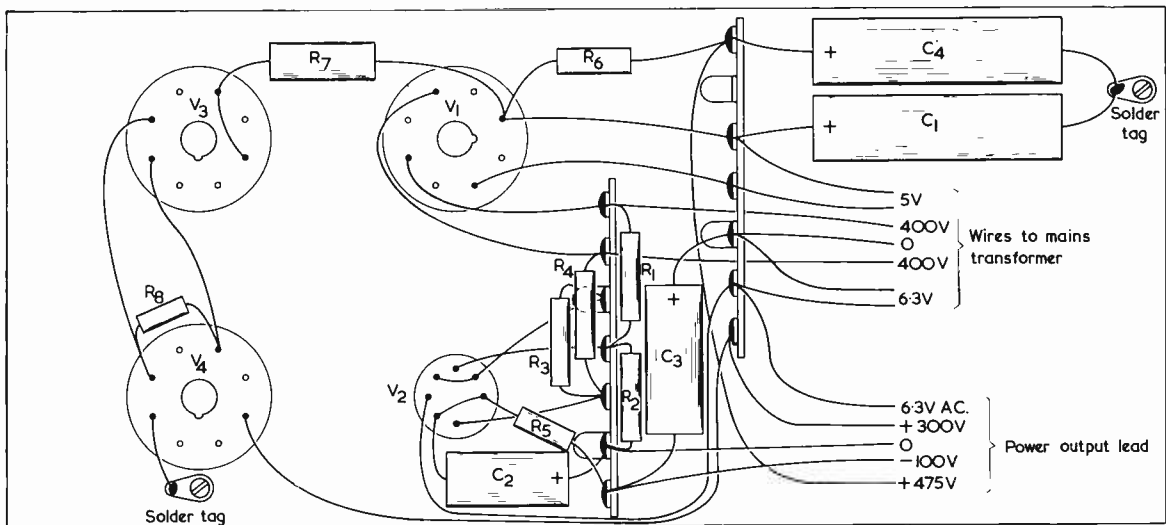


Fig. 12. Power supply layout. This corresponds to the circuit of Fig. 10 (a)

hardboard supported on a wooden frame and mounted on a plywood base. Constructional details of the frame are illustrated in Fig. 13. White deal or other softwood is suitable for the frame; and the individual pieces consist of two 2 x 1 in front pillars 7 $\frac{3}{8}$  in long, two 1 x 1 in rear pillars 7 $\frac{3}{8}$  in long, two 1 x 1 in side rails 9 $\frac{1}{2}$  in long, and two 1 x 1 in front and back rails 11 $\frac{1}{2}$  in long. The base consists of  $\frac{1}{2}$  in plywood measuring 11 $\frac{1}{2}$  x 9 $\frac{1}{2}$  in, and it has a 9 x 3 in cut-out for inspection purposes.

The frame is covered by  $\frac{1}{8}$  in hardboard panels, these having the following dimensions: top panel, 9 $\frac{3}{8}$  x 11 $\frac{1}{2}$  in; front panel 12 x 8 in; rear panel 7 $\frac{3}{8}$  in x 11 $\frac{1}{2}$  in; side panels (two required) 9 $\frac{3}{8}$  x 8 in; inspection panel cover 9 x 3 in. Ventilation holes may be provided in the rear panel.

The 2 x 1 in pillars serve to support the counter chassis. These and the rear pillars are dovetailed into the base because of the otherwise inevitable need to screw or nail into end grain, with its consequent weakness. All joints should be glued. Side and top hardboard panels should be glued into place and pinned with panel pins. The front panel is intended to be screwed to the frame. This panel should be drilled to take the panel components shown in Fig. 14, which are next mounted into position. These components are wired behind the panel as described below. The panel is not screwed into position until this wiring has been carried out and the two chassis mounted and tested.

#### Final Wiring

The reset lead and five-core power cable are now soldered to the appropriate tags on the counter chassis. (See Fig. 8, published last month.) These wires must be sufficiently long to allow the front panel to lie flat in front of the cabinet and the power chassis to be out of the cabinet at the back when the counter chassis is in place; otherwise

servicing will be very difficult. The counter chassis can now be screwed into the cabinet.

The power cable is led through one of the grommets in the side of the power chassis and soldered to the appropriate tags. See Fig. 12. A second power cable to carry supplies to the front panel is taken through the second grommet and soldered. These supplies are 6.3 volt a.c., +300 volt stabilised, +475 volt, 400 volt a.c. (from the transformer h.t. secondary) and chassis. Finally, the mains lead is soldered in place. These last two cables are led under the counter chassis to the front, and the power chassis is screwed in place by means of self-threading metal screws passing through suitably drilled holes in the base.

The front panel wiring can now be started. Apart from the essential sockets and switches, provision has been made for a power output with variable e.h.t. to operate a geiger counter and head pre-amplifier, and for an internal test circuit operating at the mains frequency of 50 c/s, see Figs. 15 (a) and (b). These circuits may now be wired up, using an insulated tag to anchor the 400 volt a.c. wire. (The +300 volt wire can anchor at the power output socket, and the chassis wire at one of the reset switch tags.)

The test circuit uses a neon pilot lamp fed from the 400 volt secondary of the mains transformer via a potential divider chain as shown in Fig. 15 (a). It is biased from the h.t. line so that it strikes only once every cycle. The current through its load resistor provides a pulse for the counter when the neon strikes. If, as was described above, a transformer having a secondary voltage other than 400-0-400 is employed, the value of the 330k $\Omega$  resistor in Fig. 15 (a) may require adjustment.

The input switch on this counter is a three position, centre off, toggle switch. This connects the counter to either the pulse input or the test circuit as required.

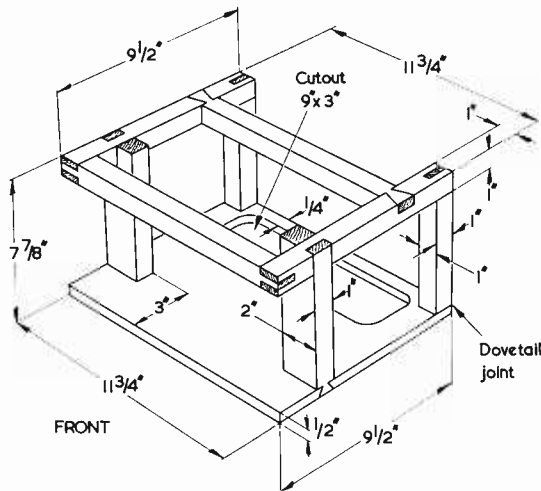


Fig. 13. How the wooden cabinet frame is assembled

Resetting is achieved for the dekatrons by momentarily switching a high resistance in series with the common cathodes of the dekatrons. See Fig. 3 (published last month) in which  $S_1$  is the reset switch. If any cathode other than the output cathode carries the discharge the current through this resistance causes the voltage to rise well above all the guides and even more above the output cathode. Consequently the discharge transfers to the output cathode. The trigger tube cathodes are also connected to the reset line so that the trigger bias drops, thereby preventing them from

triggering on the resetting pulse. The author found difficulty in obtaining a spring loaded switch which would break the circuit when operated, and modified a standard Bulgin switch for the purpose. Originally the switch was open when pushed, and closed when pulled. To modify it so that it would not remain in the "open" position when pressure was released but would spring back, the plastic actuating cone was unscrewed and the moving parts removed from the frame. This cone was carefully filed down to form a curved surface, but the positioning spike was not altered (see Fig. 16). The plastic knob was also removed, and the rod it was screwed on to shortened by  $\frac{1}{8}$  in. The metal spacer on this rod was also shortened by  $\frac{1}{8}$  in. These two alterations are intended to decrease the amount of movement possible. The switch was then reassembled, whereupon it returned to the closed position automatically after it had been operated. After the switch is mounted, it is connected between the reset lead from the counter chassis (see Fig. 8, published last month) and chassis.

When the front panel is completely wired, and all wiring thoroughly checked, the counter is ready for operation. It will be easier to see that everything is operating properly if the front panel is *not* screwed in place until the counter is working correctly.

#### Operating The Counter

When the counter is plugged into the mains and switched on, the hard valves will be seen to be warming up, and the pilot lamp will come on. When the rectifier has warmed up the stabilisers will strike, emitting a lilac glow. Shortly after this

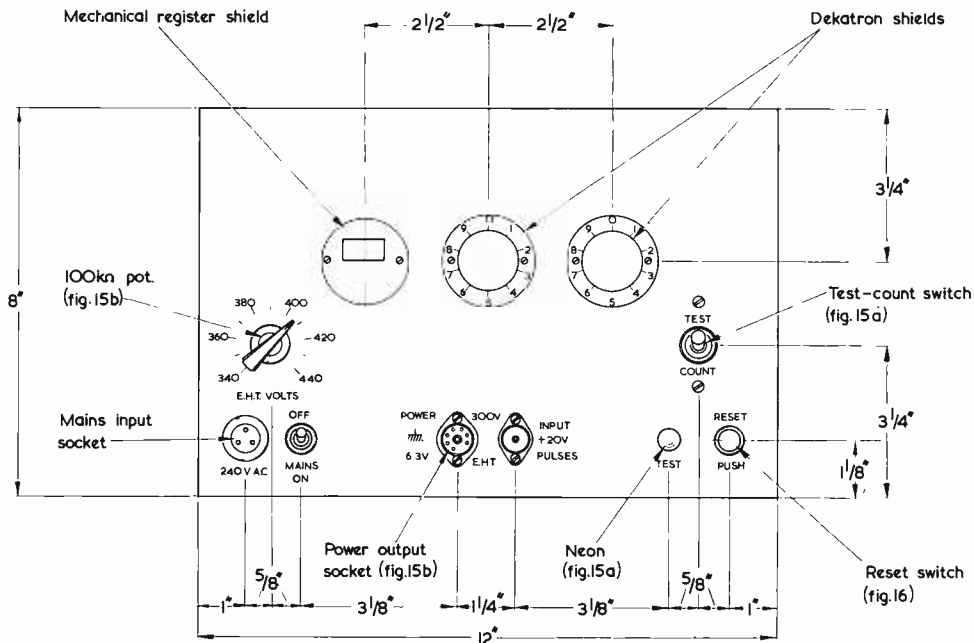


Fig. 14. The front panel layout and panel-mounting components

## Components List—Front Panel (Figs. 14 and 15)

### Resistors

(All fixed values 10%)

- 1 68kΩ ½ watt resistor
- 1 120kΩ ½ watt resistor
- 1 270kΩ 1 watt resistor
- 2 330kΩ 1 watt resistors
- 1 100kΩ potentiometer, linear track

### Capacitor

- 1 0.05μF capacitor, 500V wkg.

### Switches

Test-count switch: centre off, 2 pole changeover (Radiospares)

Mains on-off switch: d.p.s.t. toggle

Reset button: push to break, Bulgin type S410 modified (see text) or similar

### Plugs and Sockets

Mains input: 3-pin plug and socket, type P.360 (Bulgin)

Pulse input: coaxial socket

Power output: B7G valveholder

Connection to counter chassis: coaxial plug

M.E.S. holder and lens for neon bulb

### Miscellaneous

M.E.S. neon bulb (Radiospares)

2 Dekatron shields, Ericsson Telephones Ltd. Type N78211. (Available from Ericsson Telephones Ltd., Tube Division, Beeston, Nottingham)

1 circular piece of black plastic or ebonite, 1½ in diameter, from which to make shield for mechanical register

8BA ½ in countersunk nuts and bolts, screws, coaxial cable, etc.

1 Insulated tag

each dekatron will strike, emitting an orange glow at one of the cathodes, and a faint orange glow will be seen in the trigger tubes as the supplementary diodes strike. There should be no discharge visible at all in the GTR 120W trigger tube; however, this tube may trigger when first turned on. If this discharge is faint, leave the power on for about two minutes, and then switch off. On turning the power on again after a few seconds the discharge will probably either not reappear, or strike and then quench almost immediately. If it does not

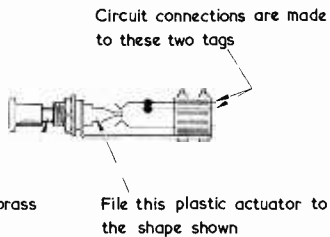
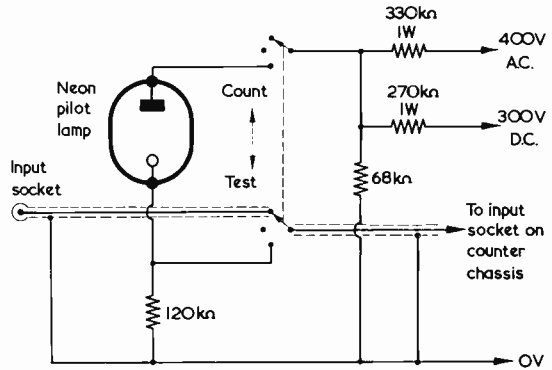
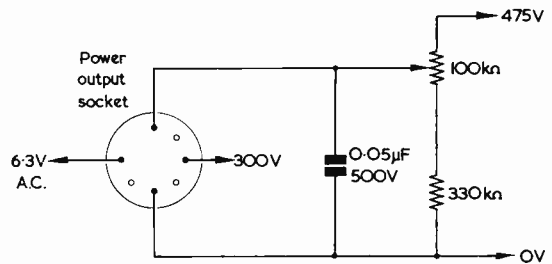


Fig. 16. Switch modifications carried out on the Reset button



(a)



(b)

Fig. 15 (a). Input switching and test circuit. This, and the circuit of (b), are wired up on the front panel itself

(b). Connections to the power output socket and the variable e.h.t. circuit

do this, alter the trigger bias as described in the fault finding section below.

Next, check that the reset button transfers the dekatron discharge to the "O" cathode (i.e. the top cathode). Move the input switch to the "test" position; the counter is then receiving fifty pulses per second. The right hand dekatron discharge will make a complete revolution round the cathodes five times a second, moving the discharge in the second dekatron on one position in a clockwise direction each time it does so. The register will receive one pulse every two seconds. The trigger tubes will be seen to flash every time the associated part of the circuit passes a pulse. On moving the input switch to the "count" position the counter

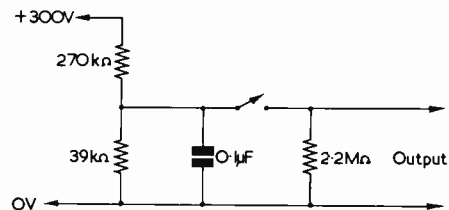


Fig. 17. A circuit which provides manual operation of the counter

will count positive pulses of 20 volts or more from any external source connected to the input socket, up to a maximum frequency in the region of 800 pulses per second.

### Fault Finding

It is considerably easier to trace faults in cold cathode circuits than in normal valve circuits because each time a tube conducts a visible discharge is apparent. So, if the counter is not operating properly, turn the input switch to the "test" position and observe each tube in turn to find which stage is faulty. If an inspection of the wiring and solder joints of the faulty stage does not reveal the fault, follow the procedure outlined in the relevant section below. One frequent cause of trouble is low insulation resistance in coupling capacitors. A leakage resistance of  $10M\Omega$  in  $C_2$  or  $C_3$  for instance, can change the guide bias by more than 3 volts, i.e. 20%.

#### (a) No pulse discharge visible at all

Check supply voltages and input connections. Measure the voltage at the junction of  $R_1$  and  $R_2$  and compare with Table 4. Check  $C_1$  for leakage resistance. If this does not reveal the fault assemble the switch input circuit shown in Fig. 17 (described in more detail later) and connect it to the input. If the counter can now be operated in the "count" position a fault in the test circuit is indicated.

#### (b) Trigger tube $V_1$ fires but does not quench

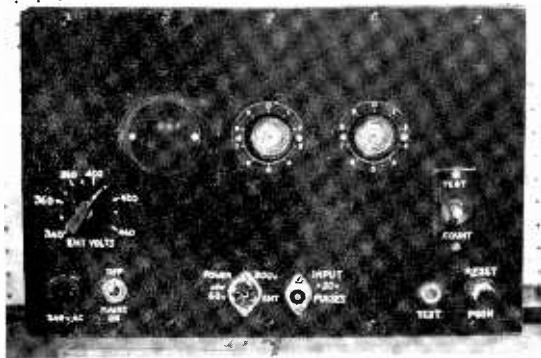
This will be due to incorrect supply voltages. Check that the stabilised h.t. is 300 volts. Check that  $R_1$ ,  $R_2$ ,  $R_5$  and  $R_6$  have the correct values.

#### (c) Trigger tubes fire erratically

This will be due to incorrect biasing or pulses of less than 20 volts. Proceed as in section (b). If this fails to reveal the fault, assemble switch input circuit as in section (a). If the second trigger tube is faulty check the output cathode resistor  $R_{12}$  and the bias voltage on this cathode.

#### (d) A dekatron fails to transfer or transfers erratically

This will be due to the anode voltage being too



Front panel view of the completed unit

Table IV

Operating voltages for the two-dekatron counter  
Measured to chassis with a high resistance voltmeter  
(resistance  $5 M\Omega$  or more).

$V_1$ Anode	275V
Trigger	135V
Junction of $R_1$ and $R_2$	160V
$V_2$ Anode	190V
Guides	15V
Junction of $R_7$ and $R_{10}$	15V
Output cathode	+ 18V with discharge on this cathode
	- 19V with discharge on any other cathode
$V_4$ Triode grid	approx. 0V
Triode anode	40V
Common cathode	0V
Pentode control grid	- 90V
Pentode anode	280V
Across $C_6$	280V

low, or a fault in the guide coupling or bias circuits. The leakage resistance of the coupling capacitors should be checked. Measure the voltage at the junction of  $R_7$  and  $R_{10}$  (or  $R_{107}$  and  $R_{110}$ ) and compare with Table 4. Interchange the two dekatrons to establish that the fault is in the circuit and not in the tube itself. Check on the values of all components in the trigger anode circuit and guide circuit, as efficient transfer will only occur if the time constants of the two coupling circuits are in correct relation to one another. If the anode voltage is low and cannot be raised, substituting a  $680k\Omega$  resistor for  $R_{11}$  (normally  $820k\Omega$ ) will increase the anode current sufficiently. Failure to transfer from the output ("O") cathode can be due to the output cathode bias dropping to too low a value on load—this effect would be more noticeable when both tubes were in the "O" position. In this case increase  $R_{22}$  to  $10k\Omega$ .

#### (e) Mechanical counter fails to operate at all

Check first that  $V_3$  triggers each time  $V_{102}$  reaches the output cathode. The faint lilac flash will be more readily visible if the pilot lamp is temporarily turned off by loosening it in its holder. If  $V_3$  does not trigger, see section (f). If  $V_3$  does trigger the fault is in the flip-flop circuit. If it is working normally, a voltmeter connected between either anode and h.t. positive will give a sharp kick once every two seconds when the input switch is in the "test" position—a negative kick for the triode and a positive kick for the pentode. Failure to do so indicates a fault in one of the coupling circuits.

#### (f) $V_3$ fails to trigger

The production spread for trigger characteristics of the GTR 120W is large. It is therefore possible that a fault here is due to this cause. Failure to trigger indicates too low a bias voltage, and may

be rectified by decreasing  $R_{15}$ . This can be done quite easily if a number of resistors in the megohm range are available from the spares box. Additional resistors are temporarily soldered in parallel with  $R_{15}$  until a suitable combination is found. The value of the combination is measured and then replaced by a single resistor of the same total resistance.

*(g)  $V_3$  goes into continuous discharge*

Excessive voltage on either the trigger or anode can cause this fault. (See also section (i).) The explanation may be the same as in section (f); in this case adjustment of the value of  $R_{13}$  in the same manner as described in that section will effect the cure.

*(h)  $V_3$  fires erratically*

Reliable firing does require that a considerable amount of light falls on the cathode, and the tube may become erratic if this does not occur. The illumination from a correctly positioned pilot lamp is much more than the essential minimum.

*(i) Mechanical register operation is sluggish or unreliable*

It seems that the characteristics of these registers may vary considerably. The author's original unit required 25mA to operate it and the armature dropped back when the current fell to below 5mA. The time constant of  $C_8 R_{20}$  in the pentode grid circuit was adjusted by trail and error to obtain the best performance from the register. Increasing the value of  $R_{20}$  increases the pulse fed to the coil of the register, whilst decreasing  $R_{20}$  reduces the pulse. It must be noted that the circuit values given are for operating the register in a horizontal position, and that a considerably larger pulse is required for operation in a vertical position.\*

**Input Circuits**

The counter will operate on any pulsed input within its maximum frequency limit, providing the pulse has a positive-going front of more than 20 volts. The trigger tube input circuit will also operate reliably with a sinusoidal input: a minimum of 25 volts r.m.s. at 50 c/s being required.

**Geiger Tube Input**

Fig. 18 gives a circuit for obtaining suitable pulses from a geiger tube of the halogen quenched type, such as the Mullard MX108, MX168 (end window types) or MX115 ( $\delta$  type). No difficulty should be experienced in the construction of this pre-amplifier unit providing care is taken to keep the stray capacitance of leads to the geiger tube itself to a minimum. It can be operated from the power take-off plug on the counter, or provided with independent power supplies.

\* A "legitimate" adjustment for operating current is given by judicious bending of the anchorage for the armature restoring spring. This point will be fairly obvious from an examination of the register with its cover removed. Adjustments on mechanical registers of this type were discussed in "In Your Workshop" in the June 1963 issue.—EDITOR.

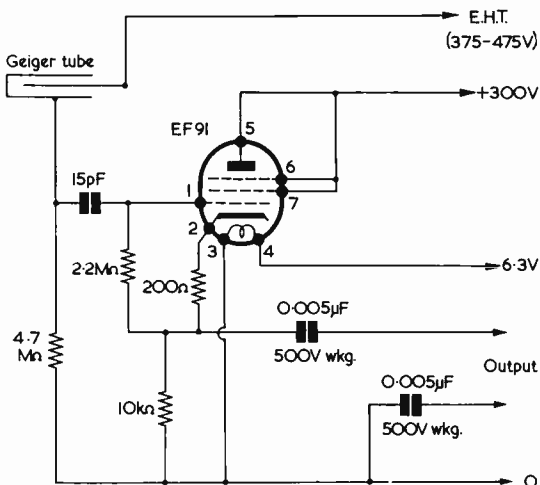


Fig. 18. A suitable geiger tube pre-amplifier

**Mechanical Counting**

Fig. 17 illustrates a circuit for mechanical switching operating from the 300 volt line on the power output socket. It will give a single positive pulse of some 30 volts upon closing the switch. Contact bounce is prevented from triggering the counter twice by the time constant of the input capacitor of the counter and the 2.2M $\Omega$  resistor.

**Use As A Timer**

When operated in the "test" position the counter is operating at 50 pulses per second, and can thus be used for measuring time intervals up to about 24 hours. The electronic circuit is capable of a resolution of  $\frac{1}{50}$  of a second, but the mechanical switching reduces the attainable accuracy to the limits set by the reaction time of the operator.

**Replacing The Mechanical Register With More Dekatrons**

The circuit shown in Fig. 3 (published last month) for each dekatron stage can be repeated as many times as desired. The maximum speed of counting is set by the tubes used at 600-1000 pulses per second, but there is no reason why six or even seven dekatron stages should not be used in series. Construction can follow the same lines as suggested for the two dekatron unit. It is recommended that the distance between dekatrons be reduced to 2 $\frac{1}{2}$ in and the width of the chassis be reduced by  $\frac{1}{2}$ in on each side. Thus (allowing 1 $\frac{1}{2}$ in from the edge of the chassis to the centre of the nearest valve base), the size of a chassis for a six stage counter will be 14 $\frac{1}{2}$  x 5 x 1 $\frac{1}{2}$ in deep.

**Increasing The Speed**

Dekatron counters can be operated at speeds up to 20,000 pulses per second. However, this requires the use of hard valve triggering circuits and the faster single pulse dekatron. In addition,

for measurements to be accurate at this sort of speed electronic rather than manual control is desirable. The author is at present working on such a counter, intended primarily for use in frequency measurement and the accurate timing of short intervals, and it is intended to publish details of this some time in the future.

#### Conclusion

The prototype counter has now been in use for almost a year, and has been found completely reliable. While it must be admitted that a resettable mechanical register would be desirable (and very costly), in every other way this unit appears equivalent to similar instruments available commercially.

#### Corrections

In Part 1 of this series, the values of  $C_{101}$ ,  $C_{102}$  and  $C_{103}$  were omitted from the Components List (see page 84, September issue), these being  $0.001\mu\text{F}$ ,  $0.001\mu\text{F}$  and  $0.002\mu\text{F}$  respectively.

The illustration at top of page 83 is shown inverted.

#### Availability of Dekatron Tubes

We have been advised by Hivac Ltd., Stonefield Way, Victoria Road, South Ruislip, Middlesex, that they have taken over the production and distribution of those tubes previously handled by Ericsson Telephones. The tubes GTE175M, GC10B and GTR120W are now available direct from Hivac Ltd. at 7s. 6d., 29s. and 1s. 6d. respectively.  
—Editor.

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## Two Filmstrips Announced by the Mullard Educational Service

Two further colour filmstrips have been announced by the Mullard Educational Service. Their titles are: *Introduction to Colour Television*; *The Principal Periodic Elements*.

#### Introduction to Colour Television: 27 Frames

Although this filmstrip has been produced mainly as an aid to technical colleges running courses on Colour Television Servicing, it could also find application in the teaching of "A" level physics.

Preliminary frames cover the physics of colour and include reflection, the spectral response of the eye, additive and subtractive mixing, filters, chromaticity, etc. Principles of sequential and simultaneous colour television systems are given in later frames and the filmstrip ends with a description of the various display devices which have been developed.

#### The Principal Periodic Elements: 44 Frames

This filmstrip has been produced at the request of a number of chemistry and physics teachers who have been using various wallcharts depicting the periodic table. The principal purpose of the filmstrip is to highlight the more commonly taught elements against the background of the various wallcharts which are used mainly for reference purposes because they give more detailed information.

In this filmstrip, 43 of the 92 elements have been chosen—selection being made as a result of a consensus of opinion expressed by a number of teachers.

Each frame of the filmstrip deals with one of these elements and gives the following information:

1. Element symbol, atomic number and atomic weight.
2. Isotopic abundance.
3. Electron disposition.
4. Chemical character.

Both strips are available from the distributors, Unicorn Head Visual Aids Ltd., 42 Westminster Palace Gardens, London, S.W.1. Price 25s. per strip, including comprehensive teaching notes.

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## New Avo Valve Data Manual

Avo (MI Group) has just published the 17th edition of its world-famous Valve Data Manual.

This international reference book, an essential for the servicing engineer, gives data on more than 8,000 valves in one volume otherwise available only by holding individual literature from every valve manufacturer.

Among the sections of the book are details of commercial equivalents of Service valves and Service equivalents of commercial valves; valve equivalents; test data for receiving and small transmitting valves (giving electrode connections and basing details); test data for tuning indicators, high voltage rectifiers and Russian valves.

The Manual also gives special data on all valve testers made by Avo since 1937.

The new Avo Valve Data Manual is available from the Spares Department, Avo Limited, 92-96 Vauxhall Bridge Road, London, S.W.1, and costs £1 15s. (post free).

# NEWS AND COMMENT . . .

## Private Eye

We referred in our August notes to the "Big Brother" implications of the use of CCTV by the Police, and there are, of course, other mechanical means which could be used to invade people's privacy such as miniature tape recorders, hidden microphones, midget cameras and so forth.

A recent B.B.C. sound programme "Under Observation" dealt, among other things, with these mechanical methods and considered their use in commerce, industry, maintenance of law and order, etc., and whether they constituted, or could constitute, a threat to privacy in this country. The conclusions were not all reassuring.

We were somewhat surprised when having coffee in a sandwich bar in Oxford Street to notice a small TV camera suspended from the ceiling. On the menu there was a notice saying that the camera was not trained on customers but on the counter display of food. This puzzled us considerably, surely it was not meant to be spying on employees in case they stole a leg of pork?

It was in fact all perfectly innocent, we had not observed a small TV screen near the entrance, just above pavement level, and the whole idea was publicity for the sandwich bar.

## Computer Humour

Every now and then one learns of limitations in the use of computers. A recent example, from America, concerned examination results in which, among other errors, some students were given passes in subjects which they never sat! Apparently the mistakes were made because the codes at the head of some candidates papers were incorrectly made out so, almost needless to say, the human element was given the blame.

A recent letter to *The Financial Times* contained a most amusing little tale which ran something like this: a man had two watches, one of which had stopped and the other which lost 10 seconds every day. The computer was given the problem of deciding which one to retain—it was—to retain the one that had stopped.

The "reasoning" was that the watch losing 10 seconds every day would only give the correct time

once every 12 years, whereas the other would give the correct time once every 12 hours.

## Who Goes There?

An electronic detector has now been designed that warns of trespassers and intruders by monitoring elastic waves broadcast through the earth by footsteps. It is so sensitive that it can locate a man creeping through undergrowth even though he is not making any audible noise.

The device, made by the Texas Instrument Company of Dallas, picks up and registers sounds which are beyond the range of human hearing. It operates on a seismic principle somewhat like the sharp-eared American Indian scouts of long ago who pressed an ear to the ground to listen for far-off riders.

There are two parts: a portable control instrument weighing eight pounds and a seismometer weighing just under a pound. They are connected by wire. The seismometer can be placed in the earth up to a mile from the area to be monitored.

The operator can quickly learn to identify the source of an alarm and to distinguish it from natural noises that may trigger the instrument. Potential uses for the instrument include guarding industrial plants, warehouses, wharves and freight terminals.

## Electronic Organists Beware

In a church in Rhodesia with an electronic organ queer things can

happen to the music, sometimes for example it is punctuated by a series of bangs like a machine gun firing. On one memorable occasion, in the middle of accompanying the hymn "Lead Kindly Light", the music suddenly stopped and a voice filled the church with the words "This is the news".

Apparently the organ was imported just after the war and no one knew how to put it together properly. It is no surprise to learn that an appeal has been launched for funds for a new organ.

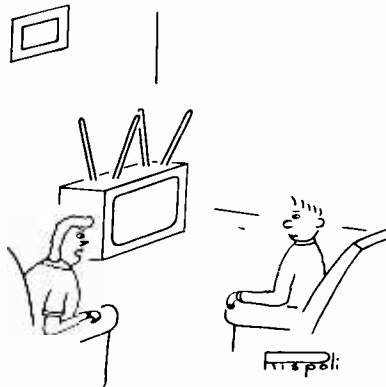
## New TV Rental Company

A new television rental company, Rental Services, an associate of Standard Telephones and Cables Limited, started operations on a national scale in September.

The company has no ordinary retail outlets but a chain of 37 regional depots, supported by mobile service units in nearly every town in the country. This ensures a genuine 24 hour service, which means that no one need be without a picture for long should his set develop a fault. Further depots are scheduled for opening before the end of the year.

Only one television set is used, the latest 23in KB 405/625 line Slimline (with legs), made by the consumer products division of STC. This means that all the company's resources are devoted to one type and size of set so that service problems are minimised. This ensures a rapid service to users in all parts of the country. Cost of rental is a deposit of £9 and a payment of 9s. per week.

*'Clown! That's not what I meant by 'turn it over'!*







*This month, Smithy the Serviceman, aided as always by his able assistant Dick, devotes his tea-break to showing that relays still play an important part in electronics and, also, that they can allow a large number of circuits to be remotely controlled with a minimum quantity of inter-connecting wires*

“LET US SUPPOSE,” SAID SMITHY unexpectedly, as he replaced his empty mug on his bench with a bang, “that you want to switch a piece of mains-operated equipment on or off from a distance, and you’ve only got two wires between the equipment and the place you want to switch it on and off from.”

“Can you,” asked Dick, “run the mains through those two wires?”

“No,” replied Smithy. “This is because they’re too long and they insert too much resistance. Also, it’s necessary to avoid having mains voltages on them.”

Dick sipped ruminatively at his tea.

“The obvious thing,” he replied, “would be to fit a relay at the equipment and energise this by way of the two wires. The relay contacts should be in series with the mains connection to the equipment whereupon the relay could switch it on and off.”

“Exactly,” said Smithy triumphantly.

There was silence for a moment.

“I don’t get this,” remarked Dick, puzzled. “We’ve been sitting here for the last few minutes, quietly having a cup of tea whilst we rest from our labours, and you suddenly start asking questions right out of the blue about switching bits of equipment on and off from a distance. Then, when I rightly suggest that you should use a relay you carry on just as though you’ve won an argument. We haven’t even been talking about relays, and we certainly haven’t been arguing about them.”

#### 405-625 Switching

“But I have,” replied Smithy. “I met an old mate of mine last night, and he started holding forth about relays being out of date and destined for the scrap-heap. To which I replied that relays may represent an old-fashioned method of controlling electrical circuits, but that they still keep popping up in new designs all the time.”

“Relays are rather intriguing devices,” admitted Dick. “I was standing outside the telephone exchange last night, and I could hear the old selectors rattling and banging about inside like nobody’s business. It was quite fascinating to think that those magnetically operated switches were clattering away due to people picking up their phones and dialling.”

“Well I’m glad somebody else thinks the same as me,” said Smithy. “So far as simple relays are concerned, you can have quite a bit of fun working out experimental circuits for them. And they’re used to a considerable extent in commercial equipment, too. For instance, did you know that Plessey showed a relay at this year’s R.E.C.M.F. exhibition which fitted inside a little TO-5 transistor can. Imagine it, a complete relay in the same size can as an ACY18!”

Smithy’s eyes grew round as he considered this latest wonder in the world of micro-miniaturisation.

“Another thing,” he added, “is that a lot of new TV sets are using a relay to carry out the 405-625 switching.”

“Are they?” responded Dick,

interested. “How does it work?”

“Come over here,” invited Smithy, “and I’ll show you.”

Dutifully, Dick brought his stool and his cup of tea over to Smithy’s bench and settled himself comfortably alongside the Serviceman. Smithy drew over his note pad and started to sketch out a circuit.

“Now, you know,” he began, “that the normal type of 405-625 switch goes right across the printed circuit board of the receiver, and that it has contacts all over the shop to switch the i.f. stages and so on. The present scheme is to have the sliding section of this switch actuated by a relay. Or, to be more accurate, by a double solenoid.”

With a flourish Smithy finished his circuit and put down his pencil. (Fig. 1.)

“And this,” he remarked, “is the simple scheme that’s used. You have a switch on the v.h.f. tuner which, if you’re switched to a 405 line channel, connects to the right hand solenoid coil. When, however, you set the tuner to u.h.f., the switch changes over and connects to the left hand solenoid coil. The result is that this coil becomes energised and attracts the core, which snaps over to the left and takes the sliding section of the 405-625 switch with it. A cunning feature of the system is that one of the contact groups on the 405-625 switch then disconnects the circuit to the left hand solenoid. So the only time that current flows through the solenoid is when it’s pulling the core into its centre because, as soon as the core has reached its new position, the solenoid

current is cut off. The same thing happens when you turn the v.h.f. tuner back to a 405 line channel. The switch in the tuner applies current to the right hand solenoid coil, whereupon this pulls the core towards its centre, bringing the sliding section of the 405-625 line switch back to the 405 line position again. Once more, the solenoid current is of a momentary nature only, because the contacts on the switch break the solenoid circuit as soon as the 405-625 switch takes up its new position."

"That is neat," remarked Dick. "Where do you get the current to drive the solenoid? From the rectified h.t. supply, or something like that?"

"Oh no," said Smithy. "The solenoid coils run off the raw a.c. from the mains. Which means that the core will probably have to be laminated or be made of ferrite material to keep the losses down."

Smithy picked up his mug and examined its contents.

"Well, I'm blowed," he said, surprised. "I must have been nattering away for at least the last five minutes without even thinking of tea. I've got some ground to make up."

With the automatic movements instilled by time-worn usage, Dick took Smithy's disreputable tin mug over to the motley crew of utensils which disgraced the Workshop sink. In the meantime, a thought suddenly occurred to the Serviceman, and he started rummaging in the drawer beneath his bench.

"Ah, here we are," he remarked, as Dick returned with his recharged mug. "I knew I had one knocking around here somewhere."

"One what?"

"One relay," replied Smithy. "One Post Office relay type 3000."

He handed the relay to Dick, then drank deeply of the contents of his mug.

"These Post Office relays," continued Smithy, refreshed, "are excellent jobs for playing around with because they're rugged and very reliable. Provided, of course, you treat them properly. Do you know the names of the various parts of the relay?"

"Well," said Dick, thoughtfully. "The winding part is obvious enough. And so is the armature. I'm not too certain about the correct names for the other bits, though."

"Fair enough," said Smithy, taking the relay from him and pointing at it with his pencil. (Fig. 2 (a).) "Let's go through the more important parts now. The winding is, as you say, obvious

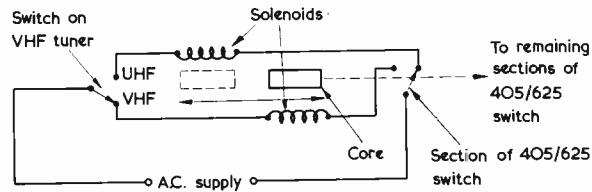


Fig. 1. Achieving 405-625 line switching with two solenoids

enough and it's placed on the core of the relay to form the coil. One end of the coil is secured by the coil nut to the yoke, whilst the other end presents a pole face to the armature. The armature is kept in position by the armature retaining screw and, when the relay is energised, the appropriate contact is raised by the contact lifting pin. The buffer block is a shaped piece of insulating material which keeps the fixed contacts in their proper position. And, finally, there is the residual stud."

"What's that for?"

"To enable the relay to de-energise reliably," replied Smithy. "When a current flows through the winding and the relay is energised, a magnetic circuit is set up through the core, the yoke and the armature. If the armature were allowed to come into direct contact with the pole face it might remain held on after de-energising, due to the residual magnetism in the components in the

magnetic circuit. You prevent this happening by ensuring that the armature is never allowed to come in direct contact with the pole face. This little job is undertaken by the residual stud, which is made of a non-magnetic metal. Some relays of this general type have an adjustable screw to do the same thing. (Fig. 2 (b).) The screw is made of non-magnetic material and you adjust it to give the desired amount of spacing between armature and pole face when the relay is energised."

### Two Oldies

"All that," pronounced Dick, "seems simple enough."

"It's a piece of cake," agreed Smithy. "Nevertheless the exercise is well worth while. It's surprising how many people there are who aren't too clear on the proper names and functions of the parts of a relay. Anyway, let's have a go at a few relay circuits!"

Once more, Smithy lifted his mug

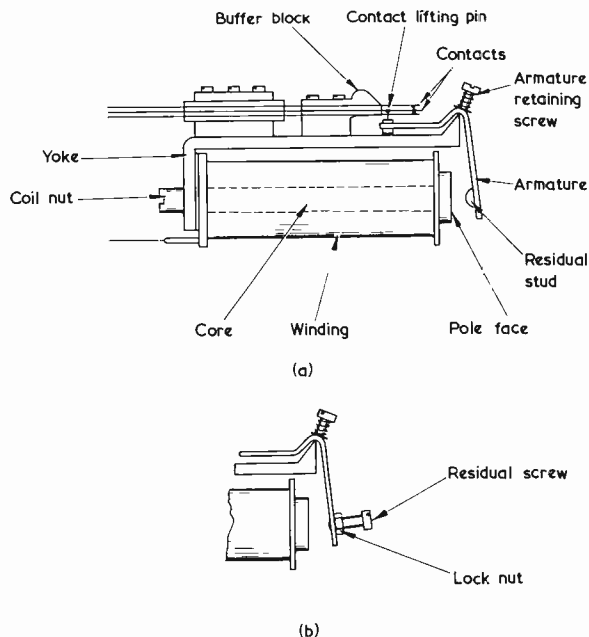


Fig. 2 (a). The principal parts of a standard relay  
(b). In some relays an adjustable screw provides the residual gap

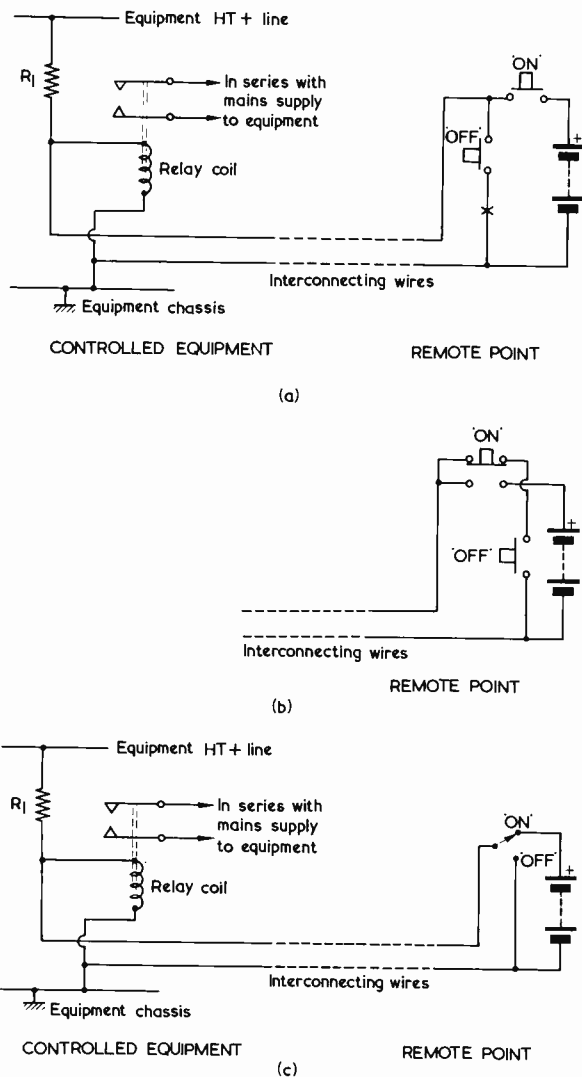


Fig. 3 (a). A simple remote control circuit for switching mains operated valve equipment  
 (b). The risk of short-circuiting the battery if both buttons are accidentally pressed at the same time is obviated by using this circuit at the remote point. A suitable component for the "On" button is the Bulgin type S.357, which would match with a Bulgin type S.365 for the "Off" button  
 (c). An alternative switching circuit at the remote point

and quenched his thirst.

"Let's first have a bash," he continued, "at that application I mentioned just now. The one where you switch a piece of mains-operated equipment from a distance."

"But there's nothing to it," protested Dick. "All that is needed is a relay which controls the mains input supply."

"True enough," replied Smithy. "But there are some crafty ways of

doing it, nevertheless. Let's suppose, for instance, that the equipment employs valves and that it has a transformer in its power supply circuit to isolate it from the mains. If this is the case, we can use a neat little circuit like this."

Smithy sketched out the circuit on his pad. (Fig. 3 (a).)

"What we have here," he said, "is a battery at the remote point which has sufficient voltage to

energise the relay. To switch on the equipment we press the 'On' button, whereupon the battery voltage is applied to the winding of the relay, which then energises and switches on the equipment. An h.t. voltage may appear immediately in the equipment, or it may appear after a short while, according to the type of h.t. rectifier used. At any event, as soon as h.t. appears the 'On' button at the remote point can be released, because the relay is now energised from the equipment h.t. supply via resistor  $R_1$ . I should add, by the way, that the operating voltage of the relay will be considerably smaller than the h.t. voltage in the equipment, with the result that  $R_1$  can have a value which is much higher than the resistance of the relay winding. The voltage appearing across the relay winding, as supplied by  $R_1$ , should, of course, be fairly close to that provided by the remote battery."

"I see," said Dick. "What happens when you want to switch off?"

"You merely," replied Smithy, "press the 'Off' button. This short-circuits the relay winding, whereupon it de-energises and switches off the mains supply to the equipment. So far as the h.t. current drawn via  $R_1$  is concerned, this merely increases slightly when the 'Off' button is pressed."

"That's a neat circuit," commented Dick. "I hadn't thought of de-energising the relay by shorting out its winding."

"The main advantage of the circuit," said Smithy, "is that the drain on the battery at the remote point is very low, since it's only required to energise the relay over the period until h.t. comes on in the controlled equipment. As you can guess, the battery must, of course, be connected right way round. A slight disadvantage is that you have to keep the 'On' button pressed until h.t. appears, and you have to keep the 'Off' button pressed until you're certain that the h.t. electrolytics in the equipment have discharged. Another disadvantage is that the battery is short-circuited if both buttons are accidentally pressed at the same time, although the short-circuit current can be reduced to a reasonably safe value by inserting a resistor of around 100Ω or so in series with the 'Off' button at the point I've marked with a cross. Or, again, you could use an 'On' button having two break contacts which isolate the 'Off' button when it's pressed. (Fig. 3 (b).) Yet another approach is to use a normal switch at the remote point. Like this."

Smithy scribbled once more on his pad. (Fig. 3 (c).)

"In this instance," he said, "the battery at the remote point is connected all the time you're switched to 'On'. It's necessary, here, to choose a value for  $R_1$  which causes the voltage across the relay, with the battery disconnected, to be almost exactly the same as the battery voltage. The result is that, after h.t. comes on in the controlled equipment, negligible current flows from the battery, or into it. With the previous push-button circuit the value of  $R_1$  isn't quite so critical."

"Won't the h.t. current drawn by the relay through  $R_1$  upset operating conditions in the equipment?"

"Not usually," replied Smithy. "Most h.t. supply systems have a few milliamps to spare, and you choose a relay which can operate with whatever spare current is available. The idea could, incidentally, also be used with mains-operated transistor equipment having an isolating mains transformer. In this instance the d.c. voltage from the equipment power supply rectifier will be considerably lower than occurs in valve equipment, and everything would have to be scaled down voltage-wise, and scaled up current-wise. Provided that the current drawn from the power supply by  $R_1$  when the relay winding is short-circuited is not excessive, then the circuit would work just as well as with the valve equipment."

"Well," commented Dick. "I must say that the idea is quite a new one on me."

"Actually," confessed Smithy, "it's a bit of an oldie. There's another old relay circuit which I'll briefly mention also. Despite its simplicity, it doesn't seem to be at all well known amongst beginners."

Smithy sketched out another circuit on his pad.

"This little circuit," he said, "is for a flasher, or a periodic on-off switch. (Fig. 4 (a).) What happens is that, when you apply the power supply, the voltage across the relay winding commences to rise, the rate of increase being governed by the capacitor in parallel with it. After a period the voltage across the winding becomes sufficiently high for the relay to energise, whereupon its contacts break the connection to the series resistor. The capacitor now discharges into the relay winding, and the voltage across the latter reduces until it reaches de-energising level. The armature then releases, its contacts complete the circuit to the series resistor, and the voltage across the winding rises once more

until the relay energises again. Whereupon the circuit goes through another cycle. The controlled circuit is switched on and off by another pair of contacts on the relay."

"Won't you need," asked Dick, "a whacking great value in the capacitor across the relay winding?"

"Not really," said Smithy. "With a normal P.O. relay having a coil resistance of  $2,000\Omega$  or so, a parallel capacitor of  $500\mu\text{F}$  will give an overall cycle of about 2 to 3 seconds. But you need to experiment a little because there are several variables

in the circuit. The reason why the circuit works is that the energising voltage of the relay is higher than the de-energising voltage. Both of these voltages vary for different relays, so you need to play around with different values of series resistance and parallel capacitance to get the particular on-off timing that you need. The series resistor, by the way, needs a value about 5 to 10% lower than that which just causes the relay to energise without the parallel capacitor connected."

"What about the power supply?"  
"You'll need a fairly high voltage

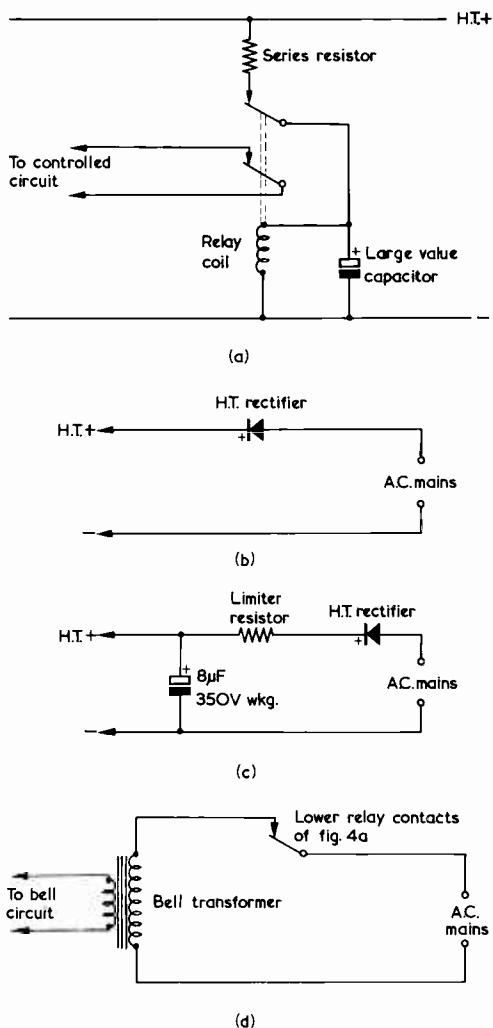


Fig. 4 (a). A simple flasher, or periodic switch, circuit  
(b). In most instances the circuit of (a) may be run direct from the mains supply after a half-wave h.t. rectifier  
(c). If a higher energising voltage is required, a reservoir capacitor may be added, as shown here  
(d). Using the relay to control the supply for a domestic bell system

here," said Smithy. "About 100 to 250 volts d.c. is the thing if you want long cycles without too high a value in the capacitor across the relay winding. In many cases a single rectifier in series with the mains supply will provide an adequate power supply. (Fig. 4 (b).) This will apply positive half-cycles to the resistor, and the capacitor across the relay winding will prevent the relay from chattering. If you need a higher effective supply voltage, add a reservoir capacitor after the rectifier. (Fig. 4 (c).) A BY100 and an 8 $\mu$ F capacitor with a 47 $\Omega$  limiter resistor should be more than adequate here."

"That's another circuit I haven't seen before," commented Dick. "It seems to be just right for those odd gimmicky jobs you bump into now and again. Like having lights going on and off all the time and so on."

"It's a useful little gadget," admitted Smithy. "Incidentally, if you've got the ordinary type of front door bell and you want a bit of a chuckle, it's not a bad idea to connect the relay contacts in series with the bell supply. Set up the relay circuit for about  $\frac{1}{2}$  second on and  $\frac{1}{2}$  second off, and the effect is quite impressive. You needn't have it running all the time because the relay contact will still complete the bell circuit when the power is disconnected from the switching circuit. And don't forget to ensure that there's adequate insulation between any mains supply connections and the bell wiring. The best thing to do, in this respect, is to have the relay contacts in series with the mains supply to a bell transformer primary." (Fig. 4 (d).)

"I'll try out that idea," said Dick, "at our own house."

"I should," grinned Smithy. "It beats those ding-dong efforts hollow!"

### Relay Circuits

With which words, Smithy once more drained his battered mug and held it up. Obediently, his assistant

took it over to the Workshop sink for replenishment.

"What," asked Smithy, as Dick busied himself with the teapot, "were you doing outside that telephone exchange, anyway?"

"When?"

"Last night."

"How on earth," asked Dick, "did you know that I was outside the exchange last night?"

"You said you were just now. You were listening to the selectors rattling round."

Dick returned with Smithy's mug.

"I was just," he said carefully, "hanging around."

"On your own?"

"I could have been on my own."

"Stood up?" enquired Smithy sympathetically.

Dick flushed.

"Of course I wasn't stood up," he snorted indignantly. "It was just that I happened to find myself hanging about outside the telephone exchange, that's all."

"Listening to the selectors?"

"That's right."

Smithy quaffed his tea. A kindly paternal smile creased his face as he lowered the mug on to his bench.

"There's nothing to be ashamed of," he said soothingly, "in being stood up. I've been stood up stacks of times during my life."

Dick looked incredulously at the Serviceman.

"You've been *what*?"

"Stood up," replied Smithy cheerfully. "I never used to mind. If I was stood up, I just used to go back home and play around with a few radio components or fix an odd set for someone."

"Did you," asked Dick curiously, "have many girl friends?"

"Oh yes," said Smithy. "My greatest romance was with a girl called Flora, who used to do the filleting down at the fishmonger's. I went round to that shop for months, just to watch her working away on the old plaice there. Eventually, I plucked up enough courage to ask

her for a date."

"Did she agree to come?"

"Definitely," said Smithy. "I pride myself on having been quite presentable in those days."

"And what happened?"

"She stood me up."

"Did you know any other girls?"

"Plenty of them," replied Smithy enthusiastically. "After the Flora business, I started going round the local pet-food shop. That's where I met Freda. Real dab-hand at weighing out the old horse-meat was Freda."

"What happened with her?"

"She stood me up, too."

"Blimey," said Dick. "What a glittering youth you must have had."

"It wasn't too bad at all," said Smithy happily. "Thinking about it nowadays, I often feel that the prettiest one of them all was Florence at the butcher's. She could cut off a bit of black pudding to the nearest pennyweight, and if you ever caught her chopping up the offal it was like watching poetry in motion, mate."

"Charming," said Dick. "And did *she* keep a date with you?"

"Oh no," replied Smithy. "She stood me up as well."

"Didn't you ever," queried Dick, "spend *any* time with girls?"

"Not really," replied Smithy, cheerily. "But I didn't half learn a lot about radio!"

"Perhaps," commented Dick hastily, "we ought to be getting back to those relays again."

"As you like," said Smithy obligingly.

He took another draught from his mug.

"One of the first points about relays," continued Smithy, further sustained by the precious fluid, "is that, when you have complicated relay circuits, you want to drop what is sometimes called the 'attached' method of circuit presentation, and go over to the 'detached' method."

"I think I know what you mean there," said Dick. "Isn't the 'attached' method the one where you show relay windings as coils, with the contacts directly in line with them? Like the circuits we've been using up to now?"

"That's right," agreed Smithy. "This type of presentation is quite O.K. with simple relay circuits, and it shows very clearly which contact is pulled in by the relay and what circuits are made or broken when the relay energises. If, however, you have a complicated relay circuit with lots of interconnections between contacts, it becomes difficult to trace out the connections when the 'attached' type of circuit diagram is

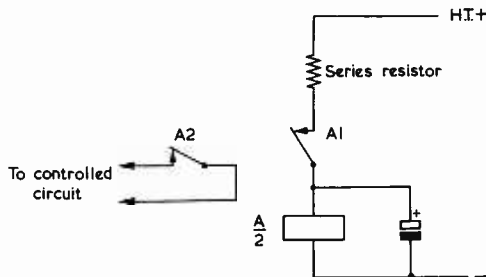


Fig. 5. The circuit of Fig. 4 (a) shown with the "detached" method of presentation

used. It's better then to go over to the 'detached' type of presentation."

"And that," chimed in Dick, "will be the type where the relay windings are all shown as rectangles, and where the contacts may be positioned anywhere in the diagram."

"You've got it," confirmed Smithy, sketching out a further circuit. (Fig. 5.) "As an example, here is the 'detached' version of that periodic switch we looked at just now. Each relay winding in a 'detached' diagram is shown as a rectangle, and the contacts appear at any convenient place in the diagram. Sometimes, the resistance of the winding is shown in the rectangle which represents it. It's important to note that, unless otherwise indicated, all contacts are shown in the position they take up when the relay is de-energised. The windings are usually designated by a letter and a figure, whereupon the letter indicates the relay, and the figure tells you the number of contact sets. For instance, I've labelled the winding in my sketch as  $\frac{A}{2}$ . This means that the winding is that for relay A, and that it has two sets of contacts. These are then labelled A1 and A2. O.K.?"

"Sure," said Dick. "Let's have a look at some other relay circuits using this type of presentation."

"Fair enough," replied Smithy. "We'll start off with a nice simple circuit which allows you to control three circuits from a remote point by means of three interconnecting wires. If one of the latter is an earth return you only need two actual wires."

Smithy tore the top sheet off his pad, and started to draw out his circuit diagram on the new, clean sheet. (Fig. 6 (a).)

"This is how it goes," he continued. "We have two relays, A and B, these being controlled by two switches, S<sub>1</sub> and S<sub>2</sub>, at a remote point. When both switches are off both the relays are de-energised, and the relay contacts complete a circuit from terminal X to terminal Y via contacts A1 and B1. If we now close switch S<sub>1</sub>, relay A energises, whereupon we get a circuit from terminal X to output terminal A via contacts A1 and B2. If we open S<sub>1</sub> and close S<sub>2</sub>, relay A is de-energised and relay B is energised, giving us a circuit from terminal X to output terminal B via contacts A1 and B1. And, if we close S<sub>1</sub> and S<sub>2</sub> both relays energise, giving us a circuit from terminal X to output terminal A+B, via contacts A1 and B2. Simple, isn't it?"

"If," said Dick, "you can do this

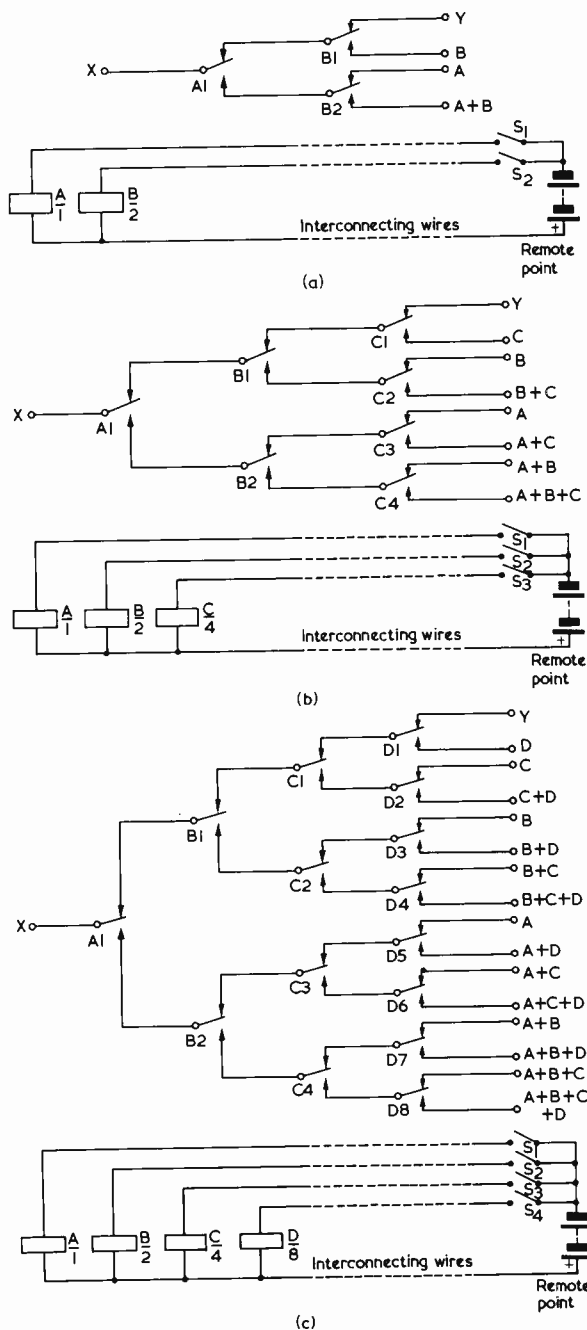


Fig. 6. Relays allow a number of circuits to be remotely controlled over a small number of interconnecting wires. In (a) three circuits are controlled over three wires, in (b) seven circuits are controlled over four wires, and in (c) fifteen circuits are controlled over five wires

with two relays, what happens when you use three relays?"

"With three relays," said Smithy, busy once more with his notepad,

"you need four interconnecting wires, or three wires and an earth return. And you get seven output terminals in the control circuit. This

is the circuit. (Fig. 6 (b).) Relay A is energised by switch  $S_1$ , relay B by switch  $S_2$  and relay C by switch  $S_3$ . The output terminals available then become A, B, C, A+B, A+C, B+C and A+B+C. Quite natty, isn't it?"

"I'll say," agreed Dick. "Let's trace out one of the controlled circuits. How about A+C?"

"Well," said Smithy, "to get A+C you turn on switches  $S_1$  and  $S_3$  to energise relays A and C. The result is that you get a circuit from terminal X to output terminal A+C via contacts A1 energised, B2 de-energised, and C3 energised."

"If," said Dick, "you get seven remotely controlled circuits with three relays what happens with four relays?"

"You get," replied Smithy, "no less than fifteen! I'll sketch out one way of doing it, based on what we've done up to now."

Smithy worked industriously over his notepad.

"This is the circuit," he said, after some moments. (Fig. 6 (c).) "As you will see, the output terminals are A, B, C, D, A+B, A+C, A+D, B+C, B+D, C+D, A+B+C, A+B+D, A+C+D, B+C+D, and A+B+C+D. Which isn't bad, when you consider that you're controlling all these circuits from a remote point over five wires, or four wires and an earth return."

"Relay D," said Dick critically, "has got a lot of contact sets on it."

"True enough," agreed Smithy. "In practice, it might be helpful to use two relays here and share the contacts between them. Both relay windings would be in parallel, of course."

#### Fewer Interconnecting Wires

"I wonder," said Dick, "if it

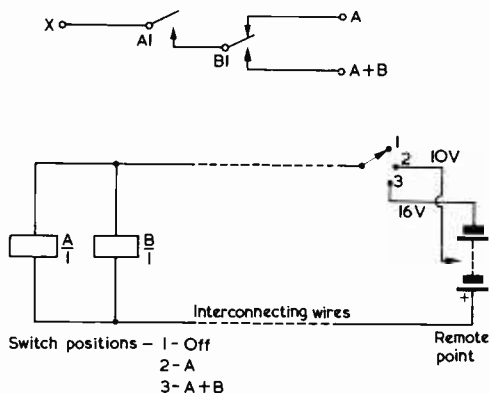


Fig. 7. Obtaining two switch functions over two interconnecting wires. Relay A energises at 10 volts and relay B energises at 16 volts

would be possible to get multi-circuit selection using fewer inter-connecting wires."

"That's quite possible," replied Smithy, "and there are all sorts of dodges you can get up to here, by using a.c. or d.c. energising voltages, by incorporating diodes and so on. The simplest method of controlling two or more relays over a single pair of lines is simply to use relays having different sensitivities. If you have two such relays with their windings in parallel you can get an arrangement like this."

Once more, Smithy's pencil went to work. (Fig. 7.)

"In this circuit," he said, "relay A energises at 10 volts, whilst relay B energises at, say, 16 volts. So, if you put 10 volts across the remote lines only relay A energises, whereas if you put 16 volts across the lines both relays energise. So you get two controlled circuits, these being A and A+B."

"You could add a third relay," cut in Dick, "energising at, say, 22 volts. Then, 10 volts across the lines gives you A, 16 volts would give you A+B, and 22 volts would give you A+B+C."

"True enough," agreed Smithy, "but you're still getting only three controlled circuits. I think a better idea would be to use something like zener diodes. Let's see what happens if we have a zener diode in a two relay circuit."

Smithy tore another sheet from his notepad, and frowned thoughtfully for a moment as he gazed at the unsmooth surface of the new sheet.

"I've got it," he said suddenly, his brow clearing. "All we need is an ordinary diode in series with one of the windings and a zener diode in series with the other. What you have to remember here, incidentally, is

that a zener diode acts as an ordinary diode for forward current. Here's the circuit. (Fig. 8 (a).) Let's say that both relays energise at 10 volts and that the zener diode,  $D_2$ , is a 6 volt type. We can start off by setting the remote switch so that it applies -10 volts to the upper interconnecting wire. With this polarity  $D_1$ , which is an ordinary diode, offers a short-circuit. So 10 volts appears across the winding of relay A and it energises. At the same time,  $D_2$  acts as a zener diode and drops 6 volts, so that relay B does not energise. If we turn the remote switch to select -16 volts on the upper interconnecting wire, 6 volts is dropped across zener diode  $D_2$  and 10 volts appears across the winding of relay B. So both relay A and relay B energise. The next position of the remote switch puts +10 volts on the upper control line. This polarity causes  $D_2$  to act as an ordinary diode and  $D_1$  to become non-conductive, whereupon only relay B energises. So the circuit gives you A, A+B, and B, over a single pair of control lines."

"Why not make  $D_1$  a zener diode as well?" asked Dick. "You could then put +16 volts on the upper interconnecting wire and get both relays energised."

"There's no point," replied Smithy. "You've already got A+B by applying -16 volts, so there's no necessity to repeat the process with +16 volts."

"Oh yes, of course," said Dick. "I'd forgotten about that. Can we use a circuit like this to get seven controlled circuits from three relays, as we had previously?"

Again Smithy pondered. After some moments, he drew out a further circuit. (Fig. 8 (b).)

"So far as I can see," he said, "you can only get five controlled circuits. Still, that's not too bad, considering you've only got two interconnecting wires, one of which may be an earth return."

"Your circuit," remarked Dick suspiciously, "looks very simple."

"It's not too difficult," confirmed Smithy, "and I should mention, before we start, that all relays energise at 10 volts. Let's commence by setting the remote switch to put -10 volts on the upper interconnecting wire.  $D_1$  is an ordinary diode and the supply polarity is such that it acts as a short-circuit, whereupon relay A energises. At the same time,  $D_2$  acts as a 6 volt zener diode, so relays B and C remain de-energised. We next set the remote switch to put -16 volts on the upper

interconnecting wire. Again, relay A energises. So does relay B, because  $D_2$  drops 6 volts whilst  $D_3$ , which is a zener diode passing forward current, acts as a short-circuit. Relay C remains de-energised, because 12 volts is dropped across  $D_4$ . The next remote switch position puts  $-22$  volts on the upper interconnecting wire, whereupon all three relays energise. The fifth position of the remote switch puts  $+10$  volts on the upper interconnecting wire. This polarity causes  $D_1$ , which is an ordinary diode, to be non-conductive, and so relay A does not energise. Neither does relay B, because  $D_3$  acts as a zener diode dropping 6 volts. But relay C *does* energise, because  $D_4$  now conducts in the forward direction. We next switch to  $+16$  volts, whereupon relay C energises again. So also does relay B, diode  $D_2$  functioning as a short-circuit and diode  $D_3$  functioning as a 6 volt zener diode."

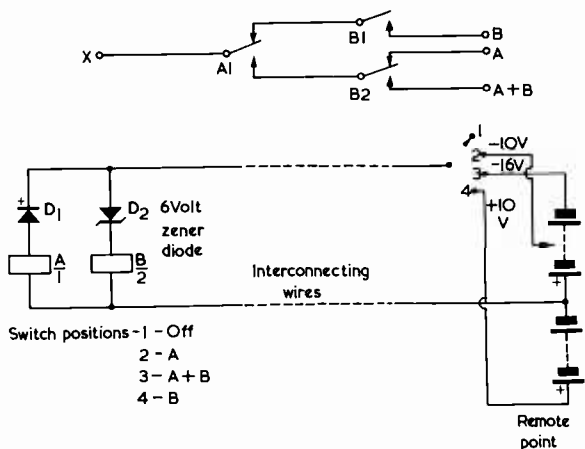
Smithy paused for a moment.

"So," he continued, "we've managed to get five control functions, these being A, A+B, A+B+C, C and B+C. The missing ones are B and A+C, but I don't think you'll be able to get those without making things rather more complicated."

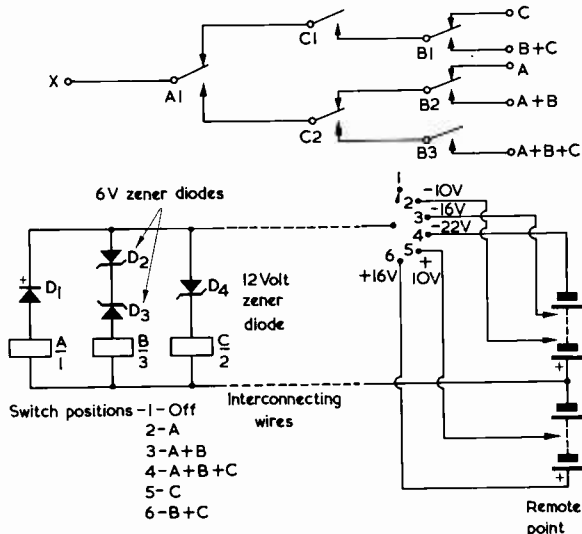
### Practicability

"Are circuits of this type practicable?" asked Dick.

"Oh yes," said Smithy. "The one using two relays will be particularly easy to get into operation. A P.O. relay type 3000 with two contact sets and a  $500\Omega$  coil will, normally, energise at 10 volts, and will remain de-energised at around 6 volts. You could use two such relays in the two-relay circuit. (Fig. 8 (a).) The zener diode in this circuit could be an OAZ203, which will drop a little more than 6 volts at 20mA when the  $-16$  volt potential is selected. The consequent dissipation of 120mW in this diode is comfortably within its maximum figure of about 300mW at  $25^\circ$  C. without a cooling clip. Relay A only needs one contact set whilst relay B needs two. If you want both the relays to energise at the same voltage, it would be better to use two contact sets on relay A as well, leaving one disconnected. In practice, however, the circuit would function just as well if relay A had a lower energising voltage than relay B and so, if you have a type 3000 relay with a  $500\Omega$  coil and only one change-over contact set on hand, it would be quite O.K. to use this for relay A. The diode  $D_1$  could be a germanium diode having a high p.i.v. to accommodate the back



(a)



(b)

Fig. 8 (a). A simple circuit employing two relays, which enables three circuit functions to be controlled via two interconnecting wires. The relays could be P.O. type 3000 with  $500\Omega$  coils.  $D_2$  may be an OAZ203 and  $D_1$  a silicon diode with a fairly high p.i.v. An economic choice here would be the OA210

(b). A circuit which controls no less than five functions by way of two interconnecting wires. Some care in relay and zener diode selection is required here, and the circuit should be attempted only by the more experienced constructor who appreciates the principles involved

e.m.f. from the winding of relay A when this de-energises, but I'd prefer to use a silicon diode myself. A type OA210 would be more than adequate here."

"What about the three-relay circuit?" (Fig. 8 (b).)

"I would recommend that circuit," said Smithy, "to the experimenter, who understands the principles involved and is prepared to play

around a bit, rather than to the beginner. The main thing to remember is that relays B and C require the same energising voltage, and that it is not too important if relay A has a slightly lower energising voltage than the other two. One point is that relay B requires three contact sets whereas relay C requires only two. If you used the same relay types, relay B would then require a



slightly higher energising voltage. This could be overcome by fitting relay C with three contact sets and only using two, or by inserting a little resistance in series with the winding of relay C so that its effective energising voltage becomes the same as that of relay B. The zener diodes could be from the OAZ200-OAZ213 range, but you want to take care you don't exceed their 300mW dissipation figure at 25° C. This figure goes up to 400mW at 25° C., by the way, if you add a cooling clip measuring 30 by 15mm. And, finally, I should point out that the voltage figures I've been quoting with these circuits

have been for purposes of illustration only. The circuits could be designed around any other similar voltages, depending upon the sensitivity of the relays used."

Smithy raised his mug once more and drained its contents.

"Any more tea?"

"It's all gone, I'm afraid," said Dick. "You finished the pot off last time."

"Then," said the single-minded Smithy, "it's back to work!"

"Just," grumbled Dick, "as I was getting nicely settled in, too."

As he rose reluctantly from his stool, a sudden thought occurred

to him.

"Tell me, Smithy," he asked, "are the relays we've been talking about professional relays?"

"Professional relays?" repeated Smithy, puzzled. "Well, the Post Office types are used in professional equipment, so they *must* be professional relays."

"I'd have thought," replied Dick, hastily moving out of Smithy's reach, "that they were all armature relays!"

**EDITOR'S NOTE**—The second of Smithy's 'oldies', that shown in Fig. 4 (a), appeared originally in "Suggested Circuits" in our March 1958 issue.

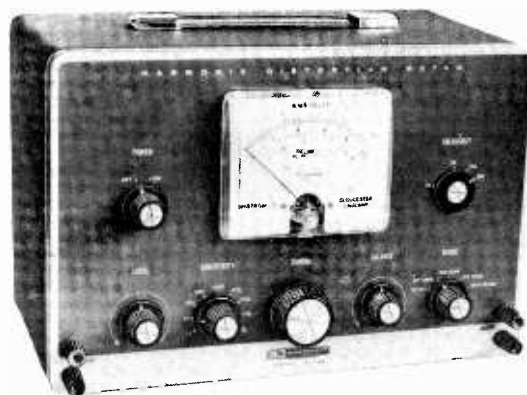
## TRADE NEWS . . .

# Heathkit Harmonic Distortion Meter Model IM-12U

### SPECIFICATION

Frequency: ... ..	20-20,000 c/s in three ranges.
Distortion Ranges: ... ..	0-1, 3, 10, 30 & 100% full scale.
Voltmeter Ranges: ... ..	0-1, 3, 10, 30 volts full scale.
Input Resistance: ... ..	300kΩ.
Minimum Input voltage for Distortion Measurement: ... ..	0.3 volts.
Output Voltage for Monitoring: ... ..	2.5 volts at full scale meter reading.
Accuracy:	
Voltmeter: ... ..	± 5% of full scale.
Distortion: ... ..	± 5% of full scale + 0.1%.
Valve Complement: ... ..	5879, 12AT7, 12AX7, 12BY7A, OA2, EZ81.
Power Requirements: ... ..	100-125, 200-220, 225-250 volts 50-60 c/s, 30 watts ac.
Dimensions: ... ..	13in wide x 8½in high x 7in deep.
Net Weight ... ..	14½lb.
Shipping Weight: ... ..	18lb.

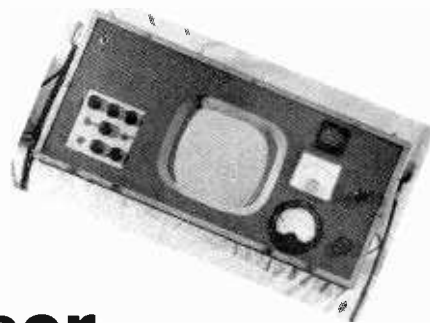
Resourceful engineering, traditional in Heathkit test equipment, has reduced the highly complex and costly equipment required for harmonic distortion measurements to a simple-to-use, low cost instrument without sacrificing accuracy, stability or quality. When used with an audio generator such as the Heathkit AG-9U, this instrument will accurately measure harmonic distortion at any frequency between 20-20,000 c/s. The IM-12U indicates the residual signal in an amplifier under test, after the fundamental frequency is eliminated, to give an accurate reading of hum, noise and harmonic distortion. Distortion is indicated directly on the meter in



The Heathkit Harmonic Distortion Meter Model IM-12U

ranges of 0-1, 3, 10, 30 and 100% full scale and noise level measurements, down to -60dBm, are read on a separate dB meter scale. The 4½in meter has a 200μA movement with easy-to-read scales of 0-3, 0-10 volts and -10 to +2dB.

The valve voltmeter section of the IM-12U uses a twin triode amplifier with negative feedback. The output of this amplifier is available at the output terminals so that the waveforms of the voltages, measured on the meter, may be visually monitored with an oscilloscope such as the Heathkit 10-12U. Price (kit) £24 15s. 0d. (Ass'd) £34 0s. 0d.



# Electronic Car Ignition Analyser

JOHN G. DEW, B.Sc.

*How to build a comprehensive electronic ignition analyser for car engines from a discarded TV set plus a few extra components! The analyser described in this article has been in regular use at a garage, and most of its component parts were obtained from an early television receiver obtainable at virtually negligible cost. The techniques used can be readily copied by the more experienced constructor or service engineer, what is probably the most important proviso being that the deflection coils employed for horizontal deflection should have about the same resistance as those used by the author*

A MOTOR CAR ENGINE, LIKE ANY OTHER PART OF complicated machinery, is often in need of servicing and fault-finding. Such a process can be done by removing and testing each component separately, but this is an expensive and time-consuming job which will often provide the wrong answers. A method is needed which will give an overall picture of the engine's performance in one examination.

The method which is becoming increasingly popular with modern garages is the ignition analyser, which examines the performance of the car's electrical system. Since most faults are reflected in some way by the electrics, this method will find the most faults in the shortest time.

Basically, an ignition analyser is an oscilloscope adapted for very high voltage inputs, capable of operating on irregular synchronising pulses, and giving a large bright trace. The method of operation is as follows: the very high voltages present at the sparking plugs of the engine are suitably attenuated and fed to the vertical deflection system of a cathode ray tube. Simultaneously a trigger circuit provides a synchronised horizontal deflection. Examination of the resulting trace will give the operator a clear picture of the operating conditions within the engine under test.

In addition to the oscilloscope section, an analyser will usually contain a stroboscope, tachometer, voltmeter and ammeter.

It should be emphasised that the prototype described here is strictly a "one off" job, and subsequent constructors may have to be prepared to do a little experimenting.

## The Cathode Ray Tube

The first problem encountered by the author was that of obtaining a reasonably large cathode ray tube which would produce a trace bright enough to be visible under normal lighting conditions; this would normally necessitate a large, expensive electrostatic tube. The problem was solved by the acquisition of a rather venerable nine inch domestic television set. This was an early Defiant console model, with the power supply in the lower section and the main chassis above it. Unfortunately, the type number had been lost in its travels, but the set was typified by a bank of controls in front which were rather like miniature rheostats; one loosened the knobs and adjusted the sliders vertically up or down. Other features of the receiver will be apparent from the text which follows. The set incorporated a 9in MW22-7 electromagnetic cathode ray tube, together with a power pack in which the mains transformer had a 6kV winding for the e.h.t. supply.<sup>1</sup> Should the reader intend to construct an analyser the author feels sure

<sup>1</sup> E.H.T. supplies derived from a mains transformer winding were described, in the days when they were commonly used, as "lethal" to distinguish them from the "non-lethal" supplies obtained from the line output transformer. The term "lethal" is no misnomer, as the current capability of such circuits is more than adequate to cause death. They must be handled with very great care and must be installed in equipment in such a manner that it is impossible for anyone to make accidental contact to the e.h.t. output. This is of particular importance in garages, which normally have concrete floors having high conductivity to earth. It must also be stated, and for similar reasons, that a "live" chassis set connected directly to the mains supply should not be employed in equipment of this type. In this instance it would be necessary to use an isolating transformer such as one of those manufactured by Radiospares Ltd. (see "Radio Topics" in the May 1965 issue) so that the chassis can be completely isolated from the mains.—EDITOR.

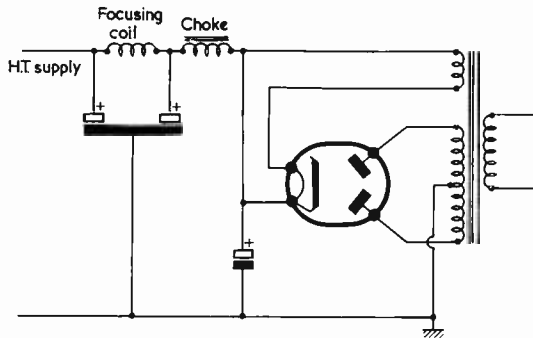


Fig. 1. The original method of supplying focusing coil current

that there are many such television sets available, at the expense of a few shillings.

The tube, tube mount, deflection coils, focusing coil and power pack were all removed and utilised in the final instrument.

### The Focusing Coil

When the author attempted to get the tube operating, the first snag arose. The tube was focused by a focusing coil instead of the more modern permanent magnets, and some 100mA of d.c. were required. Originally the coil had been placed in the h.t. supply, as in Fig. 1, but the h.t. consumption of the new instrument was not expected to approach 100mA, and so an alternative source of power had to be found.

As the coil resistance was about 200Ω, a supply of only 20 volts was required, and this was obtained in an unusual way. Since the mains transformer was a very heavy duty type, the primary tapping was used to supply 20 volts a.c. to a transistor acting as a rectifier—see Fig. 2. The transistor needs a heat sink, of course—about 4 sq. in. of aluminium, insulated from the chassis, is sufficient. The circuit may offend the purists, but it has the merit of working effectively.<sup>2</sup>

It is most important to note that the whole

<sup>2</sup> In Fig. 2 the maximum reverse emitter-base voltage for the transistors specified (40 volts) may be exceeded. However, the circuit functions adequately in practice and it is, of course, possible to use an alternative type of rectifier. L<sub>3</sub> was originally a smoothing choke from a transistorised a.c./d.c. converter. The required inductance should be 0.2 henrys or more at 100mA, with a d.c. resistance not exceeding 5Ω.—EDTROR.

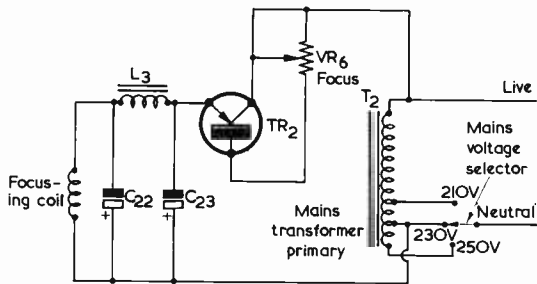


Fig. 2. Power supply for the focusing coil

focus circuit is connected to one side of the mains supply and may be "live", whereas the remainder of the chassis employed by the author is isolated from the mains by the mains transformer. In consequence, the electrolytic cans *must* be insulated from the chassis, and the transistor cooling fin *must* be mounted on an insulating block. If possible it should be arranged that the circuit is connected to the neutral side of the mains.

### The Power Supply

The power pack from the original TV set was built on its own separate chassis. The outputs obtainable were

- 6kV at 1mA
- 450V d.c. at 250mA
- 6.3V a.c. at 10A

The final circuit, after the removal of several chokes and the audio output transformer, was as Fig. 3.

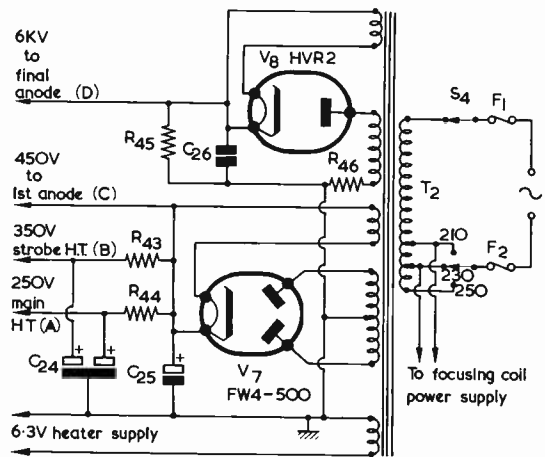


Fig. 3. The modified power pack

It can be seen that the circuit is not complicated and that apart from the e.h.t. circuit it may be replaced by a standard mains transformer giving 300–300 volts at 100mA and 6.3 volts at 3A, together with, say, an EZ81 rectifier. The e.h.t. circuit could be replaced by an r.f. oscillator or, say, a transistor converter operating from a 12 volt battery.

### Vertical Amplifier

The circuit of the vertical amplifier is shown in Fig. 5. The high voltage waveform is obtained at the h.t. terminal of the ignition coil. As this voltage may exceed 20kV, a valve would shudder if this were applied directly to its grid; instead, a capacitive potential divider is used. The upper arm consists of three 10pF, 7kV working capacitors in series; the lower arm is switched, and consists of a combination of C<sub>4</sub>, C<sub>5</sub> and C<sub>6</sub>. The 10pF 7kV capacitors were obtained from the author's spares box, origin unknown. If a constructor is

unable to obtain these, or similar equivalents, it is possible to make up the voltage divider with resistors, and this point is discussed later.

It may appear strange that, with an input of 20kV, a two-stage amplifier is required! However, the circuit is a current amplifier and requires negative feedback (about 14dB is used), so the gain must be high.

V<sub>1(a)</sub> is a straightforward triode amplifier; the coupling capacitor is quite large (0.47μF) to retain low frequency gain. V<sub>1(b)</sub> cathode is not decoupled, so increasing the output impedance. (Whereas a voltage amplifier requires a low output impedance, a current amplifier needs a high one.) T<sub>1</sub> is the vertical output transformer salvaged from the aforementioned TV set; almost any vertical output transformer should work, the main requirement being high primary inductance.

Current feedback is introduced by putting a small resistance in the output circuit and applying the voltage drop across it to the cathode of V<sub>1(a)</sub>. Note that the negative connection of C<sub>7</sub> is not returned to chassis.

### Synchronising Circuit

Sync for the timebase is taken from a connection on one sparking plug, usually number one (the one nearest the front of the engine). This gives one sync pulse for each rotation of the distributor, and provides correct synchronisation to enable all the high voltage waveforms to be examined. The input signal is attenuated by R<sub>11</sub> (see Fig. 6) which consists of ten 1MΩ resistors in series. The attenuator switch S<sub>1(b)</sub> is on the same switch as the vertical input selector S<sub>1(a)</sub>.

The signal passes into a "concertina" phase splitter which provides no voltage gain, but supplies two outputs of opposite phase; the positive-

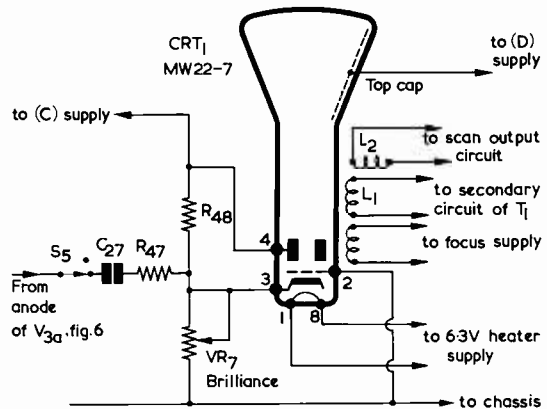


Fig. 4. The circuit around the cathode ray tube

going signal is selected by S<sub>2</sub> and passed to a limiter stage V<sub>2(b)</sub>. The cathode of this valve is held at about 20 volts positive by R<sub>21</sub> and R<sub>22</sub>, so that the input signal must exceed about 15 volts before any output is obtained.

The resultant negative-going signal is then passed to a monostable multivibrator (or univibrator) V<sub>3</sub>, which functions as follows. As the grid of V<sub>3(a)</sub> is returned to the positive supply, the valve conducts heavily, and the current flowing in VR<sub>1</sub> causes the cathode to have a fairly large positive voltage. However, the grid of V<sub>3(b)</sub> is connected to chassis, and so this half of the valve is "cut off", i.e. no anode current flows.

If a negative pulse is now applied to the grid of V<sub>3(a)</sub>, its anode current decreases, as does the voltage drop across the common cathode resistor, and V<sub>3(b)</sub> can draw current. Now both halves of the valve can amplify and, as they are cross-coupled

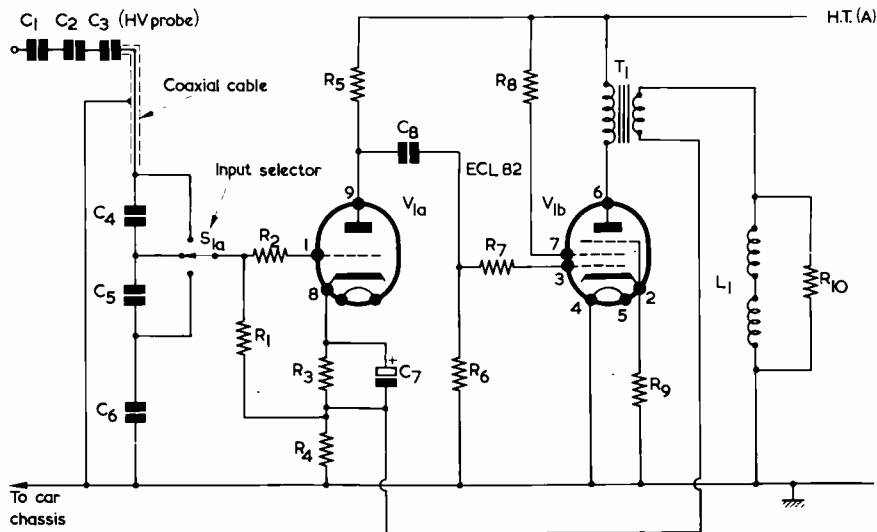


Fig. 5. The vertical amplifier

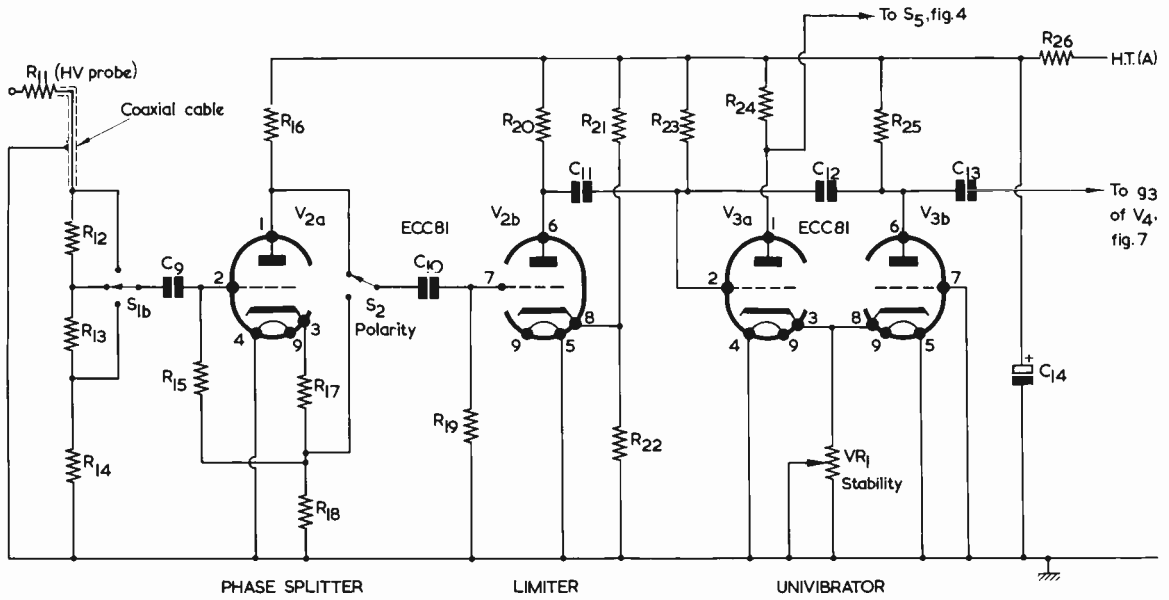


Fig. 6. The synchronising circuits.  $S_2$  reverses polarity, when desired

by  $C_{12}$ , the circuit becomes unstable and the working point flies off in search of a non-linearity; it finds it when  $V_{3(a)}$  is cut off and  $V_{3(b)}$  is fully conducting.

This state of affairs cannot continue, though, because the grid of  $V_{3(a)}$  will begin to become more positive, at a rate controlled by the time constant of the coupling capacitor  $C_{12}$  and the grid resistor  $R_{23}$ . After a while the grid will become sufficiently positive for  $V_{3(a)}$  to conduct, the switching action will occur again, and the *status quo* will have been restored until the next trigger pulse arrives.

The result of the input pulse has been a rectangular output pulse; the values of  $C_{12}$  and  $R_{23}$  have been chosen to give a pulse duration of 0.7mS, which is long enough to drive  $V_4$  in the timebase. The high

voltage waveform, itself, is of too short a duration to provide reliable triggering.<sup>3</sup>

#### Flyback Blanking

In order to obtain flyback blanking for the c.r.t., the positive-going pulse from the anode of  $V_{3(a)}$  is applied to the cathode of the tube via  $C_{27}$ ,  $R_{47}$  and a switch  $S_5$ . See Fig. 4.

#### Timebase Circuit

The trigger pulse from  $V_{3(b)}$  is applied to the suppressor grid of the pentode  $V_4$  in Fig. 7. An EF91 was chosen for this position, as it has a separate connection to  $g_3$  (often  $g_3$  is connected

<sup>3</sup> An alternative univibrator circuit is discussed at the end of this article.—EDITOR.

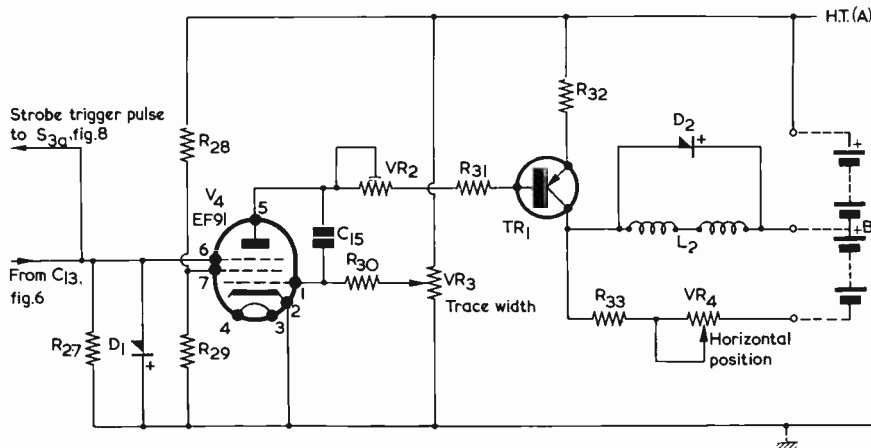


Fig. 7. The timebase and scan output stage

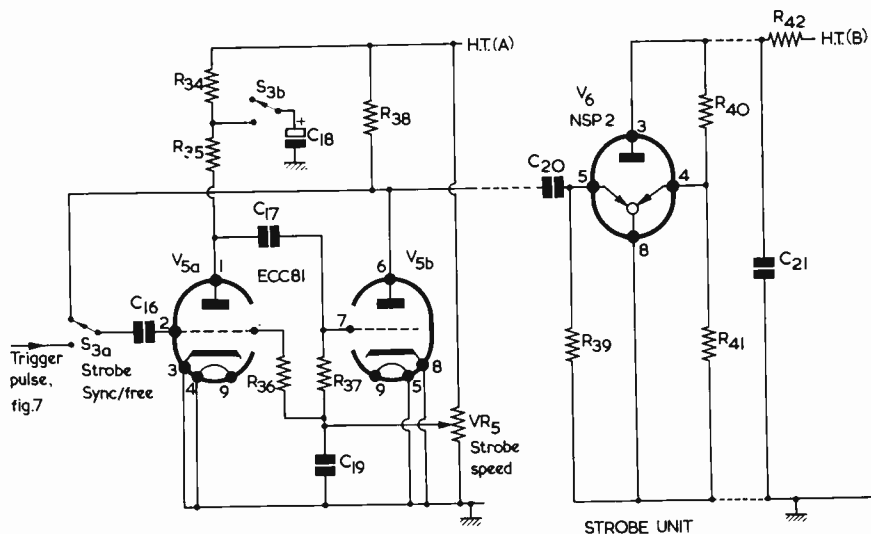


Fig. 8. The stroboscope and trigger circuits

internally to the cathode). The diode  $D_1$  is used to prevent the suppressor grid becoming positive and drawing grid current.  $D_1$  must have a peak inverse voltage rating of at least 300 volts, although the current rating need only be low. A BY100 could be used, but its rating is far in excess of that required.

$V_4$  is a Miller integrator similar to the Miller-Transitron circuit used in many oscilloscope timebases, but without the coupling capacitor between screen and suppressor grids.

Normally the valve is saturated, because the control grid is returned via  $R_{30}$  to the positive supply line. However, when a negative pulse is applied to the suppressor grid the anode current falls to zero, and the anode-grid coupling capacitor  $C_{15}$  is charged up via the anode resistor  $R_{31}$  and  $VR_2$ . When the suppressor grid pulse is removed anode current can flow, but this produces a voltage drop across the anode load; this drop is coupled to the control grid, so reducing anode current. The result is a gradual linear increase of anode current as the capacitor  $C_{15}$  discharges, until saturation is again reached. The rate at which the anode current increases is controlled by the potentiometer  $VR_3$ .

At this point in the construction another difficulty became apparent; the low frequency of operation made it impossible to couple  $V_4$  to the deflection coils with an output transformer. The circuit normally operates at about 8 to 10 scans per second, at which frequency any normal transformer would make a sawtooth totally unrecognisable. D.C. coupling to a power transistor was the obvious answer, hence the inclusion of  $TR_1$ .

#### Horizontal Output Stage

As the anode current of  $V_4$  flows directly through the base-emitter circuit of  $TR_1$ , connection of

the deflector coils in the collector circuit would result in a deflection across one half of the screen only. Thus the combination of  $R_{33}$  and  $VR_4$  is used to offset the collector current.

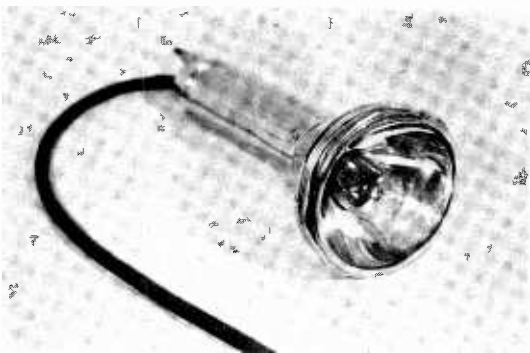
The diode  $D_2$  is included to protect  $TR_1$  from voltage peaks occurring, not during flyback—as might be at first supposed—but when the negative supply lead is disconnected, an appreciable current flows through  $R_{33}$  and  $L_2$ . When the negative supply is disconnected the current in  $L_2$  collapses rapidly, causing a high voltage peak which could damage  $TR_1$ , were it not for the presence of  $D_2$ .<sup>4</sup>

The power supply for the transistor must provide 6 and 12 volts with good regulation and freedom from hum. Although there is no reason why a mains power supply should not be used, provided the smoothing was adequate, it was decided to employ the tapped 12 volt car battery,  $B_1$ . This should be a separate battery, well insulated from its surroundings.

#### The Stroboscope

The stroboscope, or "timing light", is built around an NSP2 flash tube, available from Service Trading Co., 47-49 High Street, Kingston, Surrey. The tube consists of a cold cathode, main anode and two trigger electrodes in a low pressure neon mixture. The anode and cathode are well separated, and the application of up to 450 volts does not cause breakdown. However, a negative pulse applied to one trigger electrode can easily cause

<sup>4</sup> As a guide, the d.c. resistances of the deflector coils employed by the author were: horizontal, 10Ω; vertical, 5Ω. The author feels that this is a reversal of their original rôles, but that it was, in any case, desirable to use the higher sensitivity coil for horizontal deflection to reduce the current demand on  $TR_1$ . Because of the relatively low resistance in the coil employed for horizontal deflection, adding  $D_2$  has little effect on the scan. The effect on the trace given by connecting this diode into circuit is just perceptible.—EDITOR.



The strobe unit in its case

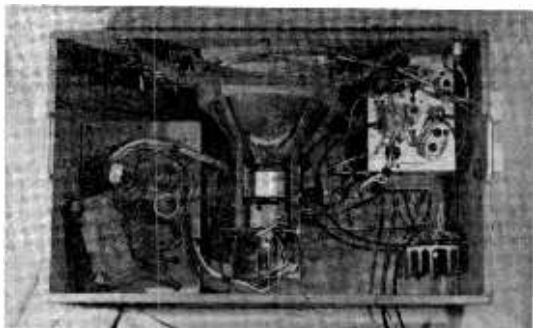
a small discharge, because the triggers are close to the cathode. This low power discharge produces ionisation of the main gap, and very heavy currents can flow. To supply these currents—which may amount to 100 amps or more—a capacitor is connected between anode and cathode; this capacitor must be a paper type, for such high currents flowing in an electrolytic type would soon heat it up and destroy it.

The capacitor is charged up from the h.t. supply via  $R_{42}$ . See Fig. 8. To obtain the maximum light output, the capacitor should charge up almost completely between each discharge. For a 96% recharge the time constant of  $C_{21}$  and  $R_{42}$  should not exceed one third of the time of one cycle, i.e.

$$3CR < \frac{1}{f}$$

where  $f$  is the repetition rate.

In the circuit of Fig. 8 the values of  $C_{21}$  and  $R_{42}$  give  $f=28$  c/s, or 1650 c.p.m. However, as each sparking plug fires only once for every two revolutions of the crankshaft (because of the 2:1 reduction in the distributor drive), the strobe will flash only once every two revolutions of the engine. This allows synchronised operation up to 3,300 crankshaft r.p.m.; under free-running conditions the 1650 r.p.m. limit applies. For higher flash speeds  $R_{42}$  should be reduced in value, to 2k $\Omega$  or 3k $\Omega$ ; this will increase the h.t. consumption.



Interior view showing layout of the principal components. The main power supply is to the left of the c.r.t. whilst the analyser chassis is to the right.  $TR_1$ , mounted on its heat sink, is at rear right

The maximum permissible flash rate for the NSP2 depends on the value of  $C_{21}$ , as follows:

$C_{21}=4\mu F$	$f_{max}=35$ c/s
$3\mu F$	50 c/s
$2\mu F$	80 c/s
$1\mu F$	150 c/s
$0.5\mu F$	250 c/s

These speeds should not be exceeded, nor should the flash rate be increased beyond 250 per second.

### Stroboscope Trigger Circuit

The stroboscope requires to be synchronised with the car engine; it is also useful to operate it independently, to enable the performance of electric motors, etc. to be checked. The double-triode  $V_5$  carries out both of these functions. When switch  $S_3$  is in the upper position the stage operates as a free-running multivibrator, the speed of which is controlled by  $VR_5$ . In the lower switch position  $V_5$  is converted into a two-stage amplifier, which amplifies the negative-going sync pulses from  $V_3$ . The  $1\mu F$  capacitor,  $C_{18}$ , is also switched into circuit in this mode, to decouple most of the anode load of  $V_{5(a)}$  and so reduce the gain; otherwise, stray capacitance could easily cause oscillation.

The output pulse is differentiated by a  $0.001\mu F$  capacitor,  $C_{20}$ , and a 100k $\Omega$  resistor,  $R_{39}$ , and applied to trigger 1 of the NSP2. Trigger 2 is held at a positive potential to assist the production of a discharge.

### Construction

The circuits were assembled on an aluminium chassis measuring 9 x 6in, with 2in sides. Owing to the number of controls, a 6in square aluminium panel was bolted to one flange, and was drilled with nine  $\frac{3}{8}$ in diameter holes to accommodate the control spindles.

Valveholders for  $V_1$  to  $V_5$  were mounted on the chassis, together with the output transformer  $T_1$  and the  $2\mu F$  capacitor  $C_{21}$ . Two tagstrips were used, one with eight tags, one with three; a small number of stand-off insulated solder tags was also used. The components were all supported by their own leads, the only one requiring a mounting clip being the  $32\mu F$  capacitor  $C_{14}$ .

Interconnecting wires were required as follows:

- a six-core cable to the power pack, for heater current and earth return, h.t. positive supply, stroboscope h.t., and mains switch.
- a four-core cable to the c.r.t., completing the vertical deflection and brightness control circuits.
- a three-core cable supplying h.t., earth and trigger potentials to the strobe tube unit.
- a two-core lead to  $TR_1$ , completing the anode circuit of  $V_4$ .

### The Power Transistor

Transistor  $TR_1$  may dissipate up to 4 watts, and so an adequate heat sink is required. The author used a cast aluminium sink, but a sheet of aluminium about 6in square—shaped as convenient—should be adequate. The heat sink carries a

tagstrip on which are mounted R<sub>32</sub>, R<sub>33</sub> and D<sub>2</sub>. Interconnecting leads run to V<sub>4</sub>, the horizontal deflection coils and the 12 volt battery.

If the transistor is bolted directly to the heat sink, with no insulating mica washer, the sink will be at h.t. potential, and should be well insulated from its surroundings.

### General Layout

All the assemblies were mounted in a cabinet measuring 30 x 16 x 11 in. This was constructed of ½ in angle iron, with a base of ¾ in plywood; the other surfaces were made of hardboard.

An aperture for the tube face was cut centrally in the front panel, and the c.r.t. was mounted behind this. The mounting from the original TV set was employed—this consisted of a heavy rubber mounting which fitted around and supported the tube face, and an assembly which supported the tube neck and focusing coil.

The front panel was cut away on one side of the tube to accommodate the main control panel, and on the other side holes were cut to take the meters. The TR<sub>1</sub> assembly was bolted to the side of the cabinet, behind the main chassis.

Apart from the high voltage leads, all external connections were made via 3 pin, 5 amp plugs and sockets, as follows:

- socket 1; battery supply
- socket 2; strobe earth, h.t. and trigger
- socket 3; earth, tachometer connection and voltmeter.

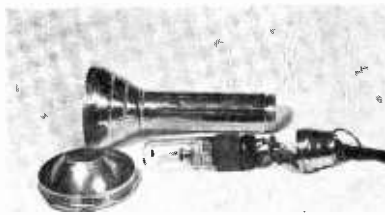
### Meters

When carrying out tests, a tachometer (or rev. counter) is a very useful instrument to have incorporated in the analyser. The one used by the author is transistorised, and draws its power supply from the 12 volt car battery. The circuit is described in a separate article entitled "An Electronic Tachometer".<sup>5</sup> Normally the input to the tachometer is taken from the C.B. terminal on the ignition coil of the car under test, but provision is made for taking it from the anode of the strobe tube, so giving a direct indication of the flash rate under free-running conditions. No calibration of VR<sub>5</sub> is then necessary.

Also mounted on the front panel are a good quality voltmeter with a range switch giving 1V, 10V, 20V and 100V full scale deflection, and an ammeter (20–0–20).

### The Strobe Unit

The NSP2 tube was housed in a converted torch case. The bulb mount was removed and the hole in the reflector enlarged to take the glass envelope of the NSP2. The two U2 batteries were removed and replaced by a tube of insulating material (actually a piece of corrugated air hose from a car heater). It was found that the flash tube was held firmly when it was pushed inside.



How the strobe unit is assembled

The components R<sub>39</sub>, R<sub>40</sub>, R<sub>41</sub> and C<sub>20</sub> were mounted on an octal valveholder which had the mounting lugs removed, and the holder was fitted on to the pins of the NSP2. Connection to the main chassis was made with a length of 3 core, 5 amp rubber sheathed cable, via a plug and socket.

### Calibration Of The Vertical Amplifier

In order to measure the applied voltages, a calibrated graticule for the tube face is required.

The most elegant method is to apply the a.c. voltage from the e.h.t. winding on the mains transformer. Measurement of the rectified d.c. voltage gives the peak value of the a.c., and from observation of the resultant trace the graticule may be calibrated.

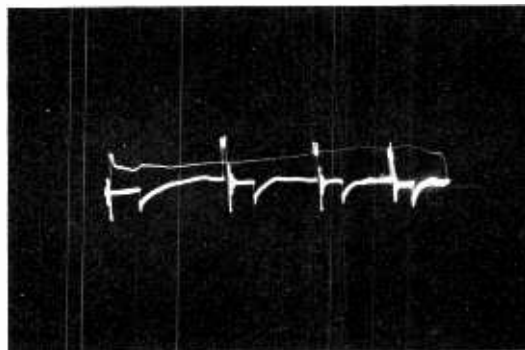
Alternatively a low a.c. voltage may be applied to the grid of V<sub>1(a)</sub> to determine the sensitivity of the vertical amplifier, and the attenuator ratio may be calculated to obtain the overall sensitivity.

The original graticule consisted of a sheet of ¼ in acetate scribed with 1kV lines up to 10kV, and with one at 20kV.

### The High Voltage Probes

The ten 1MΩ resistors making up R<sub>11</sub> were soldered together in series; one end of the chain was connected to the inner conductor of a co-axial socket, the other end to 12 in of rubber sheathed high voltage ignition cable (obtainable from any garage).

The body of the probe was 6 in of Paxolin tube, ¼ in external diameter, into which the resistor chain was inserted. The co-axial socket was attached to one end of the tube, and the high voltage cable



A typical trace, as provided by the analyser

<sup>5</sup> John G. Dew, "An Electronic Tachometer." *The Radio Constructor*, July 1965.



was led out of the other through a Paxolin and aluminium end-cap. The cable terminated in an adaptor consisting of a crocodile clip, to which was soldered the top of a discarded sparking plug. In use, the plug lead is removed, the crocodile clip is attached to the sparking plug and the plug lead is replaced on the adaptor.

The other probe was similar in construction, except that it housed three 10pF, 7kV capacitors joined in series. Its high voltage lead adaptor was a modified suppressor with the resistive element removed. In use, the coil centre lead is removed, the adaptor screwed in and the coil lead is screwed into the adaptor.

Should difficulty be experienced in obtaining the three 10pF 7kV capacitors, it is permissible to replace them with ten 1M $\Omega$  resistors, as in the sync input probe. The capacitors C<sub>4</sub>, C<sub>5</sub> and C<sub>6</sub> must then be replaced by resistors of 6.8k $\Omega$ , 3.3k $\Omega$  and 3.3k $\Omega$  respectively. There is a certain loss of high frequency response when using this method, due to the capacitance of the coaxial cable, but the effect is not serious.

The leads from the probes to the instrument were 10ft lengths of coaxial cable, with coaxial plugs to fit into the sockets on the probes. If the plugs fit loosely, a spot of solder is recommended!

### The Car Ignition System

To assist the understanding of the tests which may be carried out, a short description of a car ignition system will be given.

In a four stroke engine (as opposed to the two stroke used in motor cycles) the piston first descends to draw in petrol vapour and air, then rises to compress this mixture. At some point near the top of the stroke a spark is passed between the electrodes of the sparking plug to ignite the mixture.

The spark is obtained from the ignition circuit shown in Fig. 9. Normally the contact breakers in the distributors are closed, and a fairly large current (several amps) flows through the primary winding of the coil. When the piston reaches the top of its travel the contacts open, and the rapidly

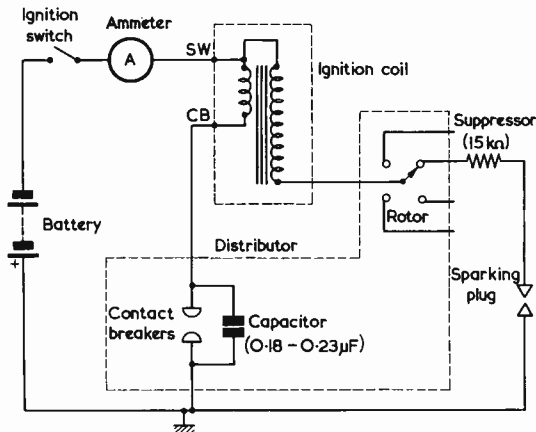


Fig. 9. A typical ignition system

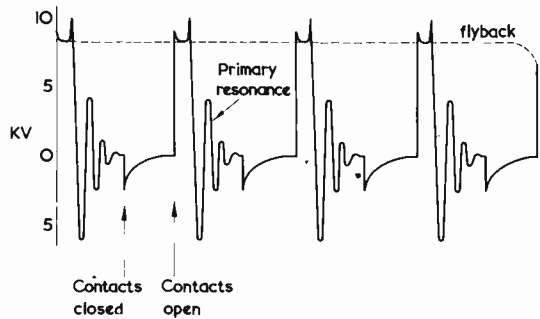


Fig. 10. An ideal high voltage trace, as given by a 4 cylinder engine

collapsing magnetic field in the coil induces a very high secondary voltage. The primary winding would normally resonate with the capacitor, but the breakdown of the appropriate sparking plug causes heavy damping. Thus a discharge is obtained for a short while until the secondary current falls, when the spark is quenched, and the primary circuit can oscillate for a few cycles. The contacts then close, the primary current rises to saturate the core, and the cycle is repeated.

### Setting Up The Analyser

The 12 volt battery B<sub>1</sub> is connected and the mains supply is switched on. The earth lead is connected to the car chassis, the high voltage "pattern" lead is attached to the ignition coil centre lead, and the "sync" lead is connected to number one plug. The engine is started, and after the brilliance and focus controls have been adjusted, the "stability" control is set to give a steady trace, as in Fig. 10. With the slow-running adjustment on the carburettor set to give about 1,000 r.p.m., the "width" control may be set so that the trace just fills the screen.

### Trace Examination

Examination of the following points may be carried out:

(a) *Plug Firing Voltage.* This may be measured with the aid of the graticule, and should lie between 7 and 10kV. If one or two plugs fire below this voltage, the plug points are set too close; if above, the points are fouled or too wide. If all the firing voltages are low, this may indicate a weak mixture or poor compression; if all are high, a rich mixture is likely.

(b) *Coil open-circuit voltage.* Remove one plug lead, and a very high voltage will appear on the trace; this is the output of the coil on open-circuit, and should exceed 20kV. Failure to do so indicates a faulty coil or contact breakers.

(c) *Rotor Voltage Drop.* Short-circuit one plug lead to earth and a low firing voltage will appear on the trace, representing the voltage drop between rotor and distributor cap. If the voltage exceeds 4kV, the rotor and distributor cap require examination.

(d) *Condition of Capacitor.* The number of

cycles of primary oscillation should exceed four: if not, the capacitor is faulty.

(e) *Condition of Contact Breakers.* The downward peak observed when the contacts close should be of reasonable amplitude—otherwise the contacts require cleaning or replacement.

(f) *Condition of Distributor Bearings.* Horizontal “jitter” of the trace, i.e. random variations of the time of opening and closing of the contacts, is due to worn distributor bearings.

(g) *Cylinder Condition.* Note the speed of the engine, remove one plug lead and note the drop in speed. Repeat with the other leads; the speed drop should be the same for all. If removal of one plug lead causes only a small drop, the cylinder concerned is not working efficiently—suspect a burnt exhaust valve.

(h) *Air Cleaner Condition.* Removal of the carburettor air filter should not affect engine speed. If it does, the filter needs cleaning.

(i) *Ignition Timing.* Set the stroboscope to synchronised operation and use it to illuminate the timing marks (usually found on the crankshaft pulley). The marks should coincide on tick-over; if they do not, adjust the ignition timing until they do. When the engine is speeded up the marks should appear to separate, indicating that the automatic advance is operating correctly.

(j) *Battery Condition.* Switch off the engine and measure the battery voltage. Operate the self-starter and note the new voltage. If it is less than 10 volts (or 5V on a 6V system) the battery is in poor condition.

(k) *Contact Test (auxiliary test).* Switch on the ignition and turn the engine until the contact breakers are closed. Measure the voltage on the non-earthed, or moving, contact; this should not exceed 0.2 volts. If it does, the contacts require attention.

This concludes the test sequence.

To get the best out of the instrument, experience must be gained in its use. The tests outlined above are only a guide, and short cuts and additions can be made after practice.

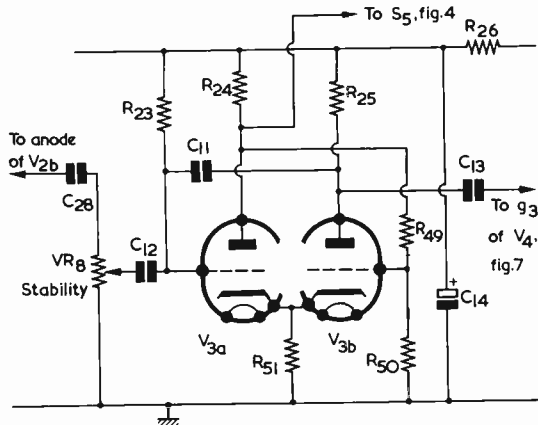


Fig. 11. An alternative univibrator circuit. This may be employed in place of the corresponding circuitry shown in Fig. 6

Finally, it might be pointed out that, with a few simple modifications, the instrument would make an excellent display oscilloscope for low-frequency waveforms. The vertical amplifier has a good frequency response—from 20 c/s to 20 kc/s—which is all that may be expected from magnetic deflection. The sync circuits, with the elimination of the limiter stage, will accept almost any waveform with impunity.

#### Additional Note

Since writing the above the author has obtained some further experience with the analyser. Results have been fully up to expectations but it has been noticed that there has been a tendency towards critical settings in the Stability control VR<sub>1</sub>. If this is considered undesirable, the alternative univibrator circuit shown in Fig. 11 may be employed, this replacing the corresponding circuitry in Fig. 6. Constructors building the instrument may employ either the Fig. 6 or the Fig. 11 univibrator, or they may prefer to commence with the Fig. 11 version.

#### Components List

##### Resistors

(All fixed valves  $\frac{1}{2}$  watt,  $\pm 20\%$  unless otherwise specified)

R <sub>1</sub> 2.2M $\Omega$	R <sub>14</sub> 22k $\Omega$	R <sub>27</sub> 1M $\Omega$	R <sub>40</sub> 56k $\Omega$ , 1 watt
R <sub>2</sub> 22k $\Omega$	R <sub>15</sub> 120k $\Omega$	R <sub>28</sub> 10k $\Omega$ , 1 watt	R <sub>41</sub> 10k $\Omega$
R <sub>3</sub> 1.2k $\Omega$	R <sub>16</sub> 10k $\Omega$	R <sub>29</sub> 33k $\Omega$ , 2 watts	R <sub>42</sub> 6k $\Omega$ , 10 watts, wirewound
R <sub>4</sub> 13 $\Omega$	R <sub>17</sub> 2.2k $\Omega$	R <sub>30</sub> 470k $\Omega$	R <sub>43</sub> 500 $\Omega$ , 5 watts, wirewound
R <sub>5</sub> 10k $\Omega$	R <sub>18</sub> 10k $\Omega$	R <sub>31</sub> 47k $\Omega$	R <sub>44</sub> 2k $\Omega$ , 10 watts, wirewound
R <sub>6</sub> 330k $\Omega$	R <sub>19</sub> 180k $\Omega$	R <sub>32</sub> 0.5 $\Omega$ , wirewound	R <sub>45</sub> 50M $\Omega$ , 3 watts
R <sub>7</sub> 22k $\Omega$	R <sub>20</sub> 47k $\Omega$	R <sub>33</sub> 10 $\Omega$ , 5 watts, wirewound	R <sub>46</sub> 180k $\Omega$
R <sub>8</sub> 4.7k $\Omega$ , 2 watt	R <sub>21</sub> 120k $\Omega$ , 1 watt	R <sub>34</sub> 47k $\Omega$	R <sub>47</sub> 180k $\Omega$
R <sub>9</sub> 680 $\Omega$ , 1 watt	R <sub>22</sub> 10k $\Omega$	R <sub>35</sub> 4.7k $\Omega$	R <sub>48</sub> 560k $\Omega$
R <sub>10</sub> 330 $\Omega$	R <sub>23</sub> 470k $\Omega$	R <sub>36</sub> 470k $\Omega$	†R <sub>49</sub> 1.2M $\Omega$
R <sub>11</sub> 10 $\times$ 1M $\Omega$	R <sub>24</sub> 47k $\Omega$	R <sub>37</sub> 470k $\Omega$	†R <sub>50</sub> 100k $\Omega$
R <sub>12</sub> 47k $\Omega$	R <sub>25</sub> 100k $\Omega$	R <sub>38</sub> 47k $\Omega$	†R <sub>51</sub> 4.7k $\Omega$
R <sub>13</sub> 22k $\Omega$	R <sub>26</sub> 2k $\Omega$ , 2 watts	R <sub>39</sub> 100k $\Omega$	*VR <sub>1</sub> 3k $\Omega$ , wirewound
			VR <sub>2</sub> 25k $\Omega$ , wirewound, preset
			VR <sub>3</sub> 1M $\Omega$ , linear carbon

- VR<sub>4</sub> 20Ω, wirewound
- VR<sub>5</sub> 100kΩ, wirewound
- VR<sub>6</sub> 2kΩ, wirewound
- VR<sub>7</sub> 100kΩ, linear carbon
- †VR<sub>8</sub> 250kΩ, linear carbon

#### Capacitors

(All capacitors 350V wkg. unless otherwise specified)

- C<sub>1</sub> 10pF, 7kV wkg.
- C<sub>2</sub> 10pF, 7kV wkg.
- C<sub>3</sub> 10pF, 7kV wkg.
- C<sub>4</sub> 5,000pF, paper
- C<sub>5</sub> 0.01μF, paper
- C<sub>6</sub> 0.01μF, paper
- C<sub>7</sub> 100μF, electrolytic, 12V wkg.
- C<sub>8</sub> 0.47μF, paper
- C<sub>9</sub> 0.01μF, paper
- C<sub>10</sub> 0.047μF, paper
- C<sub>11</sub> 0.0047μF, paper
- C<sub>12</sub> 0.01μF, paper
- C<sub>13</sub> 0.047μF, paper
- C<sub>14</sub> 32μF, electrolytic
- C<sub>15</sub> 0.022μF, paper
- C<sub>16</sub> 0.033μF, paper
- C<sub>17</sub> 0.033μF, paper
- C<sub>18</sub> 1μF, electrolytic
- C<sub>20</sub> 0.001μF, paper
- C<sub>21</sub> 2μF, paper ("Nitrogol" Dubilier type), 400V wkg.
- C<sub>22</sub> 500μF, electrolytic, 25V wkg.
- C<sub>23</sub> 500μF, electrolytic, 25V wkg.
- C<sub>24</sub> 32+32μF, electrolytic, 450V wkg.
- C<sub>25</sub> 8μF, electrolytic, 450V wkg.
- C<sub>26</sub> 0.1μF, paper, oil filled, 7kV wkg.
- C<sub>27</sub> 0.47μF, paper
- †C<sub>28</sub> 0.01μF, paper

#### Semiconductors

- TR<sub>1</sub> OC35, OC36, XC141, GET573
- TR<sub>2</sub> OC28, OC36
- D<sub>1</sub> 300 p.i.v. at 1mA, e.g. OA210 (see text)
- D<sub>2</sub> OA81

#### Valves

- |                  |               |                  |
|------------------|---------------|------------------|
| V <sub>1</sub>   | ECL82         | B9A base         |
| V <sub>2</sub>   | ECC81 (12AT7) | B9A              |
| V <sub>3</sub>   | ECC81 (12AT7) | B9A              |
| V <sub>4</sub>   | EF91 (6AM6)   | B7G              |
| V <sub>5</sub>   | ECC81 (12AT7) | B9A              |
| V <sub>6</sub>   | NSP2          | octal (see text) |
| V <sub>7</sub>   | FW4-500       | B4               |
| V <sub>8</sub>   | HVR2          | B4               |
| CRT <sub>1</sub> | M22-7         | B8B              |

(Note: V<sub>7</sub> and V<sub>8</sub>, provided with the original receiver are now obsolete. More modern types could be employed here.)

#### Transformers

- T<sub>1</sub> TV Vertical Output Transformer
- T<sub>2</sub> Primary; 0-210-230-250V  
Secondary; 300-0-300V, 100mA  
4kV, 1mA  
6.3V, 3A  
4V, 3A  
4V, 0.65A, high insulation

#### Switches

- S<sub>1(a)(b)</sub> 2-pole, 3-way rotary
- S<sub>2</sub> 1-pole, 2-way toggle
- S<sub>3(a)(b)</sub> 2-pole, 2-way toggle
- S<sub>4</sub> 1-pole, 1-way toggle
- S<sub>5</sub> 1-pole, 1-way toggle

#### Fuses

- F<sub>1</sub> 1A
- F<sub>2</sub> 1A

\* Only required if univibrator circuit of Fig. 6 is used.

† Only required if univibrator circuit of Fig. 11 is used.

## RADIOISOTOPE POWERS NAVIGATION BEACONS

THE RELATIVELY SMALL AMOUNT OF CHARGE which can be stored in a small battery is a serious limitation for certain long term applications in remote places. Solar cells are often used to re-charge the batteries of space vehicles, but are useless for powering a transmitter during a long arctic or antarctic night.

The United Kingdom Atomic Energy Authority has recently developed a new type of power supply for marine navigational lights which are required to function unattended for long periods of time. The power for this type of light is derived from the heat given out by a radioactive source of 700 curies of strontium-90 (a beta emitter) in the chemical form of strontium titanate. The heat is first converted into a 400 mv. electrical output by means of bismuth telluride thermocouples.

It is then transformed into a 6 volt supply by a tunnel diode converter.\* The output from this converter is used to charge a storage battery. The power from the latter is again transformed to a higher voltage which is fed to the xenon flash tube in the navigational light.

These navigational lights are known by the name RIPPLE (Radioactive Isotope Powered Pulsed Light Equipment). One type, RIPPLE-1, is lead shielded, whilst another type, RIPPLE-2, is shielded with a tungsten alloy. Small radio transmitters which are used for navigational and other purposes in remote places will doubtless be powered by similar means in due course.

\* J. B. Dance, "220 Amp Tunnel Diodes", *The Radio Constructor*, Vol. 18, No. 9, p. 617 (April 1965).

# The Story of the Valve

## Part 3

C. H. Gardner



*In the third article of his 4-part series, C. H. Gardner deals with what is probably the most important part of the valve—its cathode-heater assembly*

**I**N THESE DAYS OF TRANSISTORS WE may be apt to forget that the valve, unlike the semi-conductor, has “consumable” parts which limit its useful life. Such things as broken heaters, insulation breakdown and misplaced electrodes could all cause failure of the valve, but perhaps the greatest problems in practice have been concerned with the life of the cathode. Many of these problems are common to both directly and indirectly heated cathodes, and the latter will be dealt with here in order to illustrate the complexity of the matter. The overcoming of these problems must be considered as a major development in the history of the valve.

### Indirectly Heated Cathode

An indirectly heated valve employs a heating filament which is insulated from the cathode proper by a coating of, generally, aluminium oxide. The cathode consists of a nickel tube into which the insulated heater is inserted. This nickel tube may be coated with a mixture of strontium and barium carbonates which are converted into oxides whilst the valve is being processed after assembly and when it is being

pumped. The gases released during this chemical change are sucked away by the evacuating pump. The valve is then “aged” by running the heater at a higher than normal temperature with a positive potential applied to the other electrodes. This “ageing” causes a certain percentage of metallic barium and strontium to be formed in the emissive coating and it is the structure of the aged coating, containing atoms of these metals, which provides the effective emissive material. The chemical process is involved, and an important point to note is that, should any oxygen remain in the valve after evacuation or should it be released from the glass or metallic components whilst the valve is in operation, this will reoxidise the all-important barium and strontium metallic atoms. The result will be a reduction in the emission of the valve.

It will thus be seen that an important stage in valve development was given, firstly, by attaining a very high vacuum and, secondly, by ensuring that this high vacuum would be maintained whilst the valve was in operation.

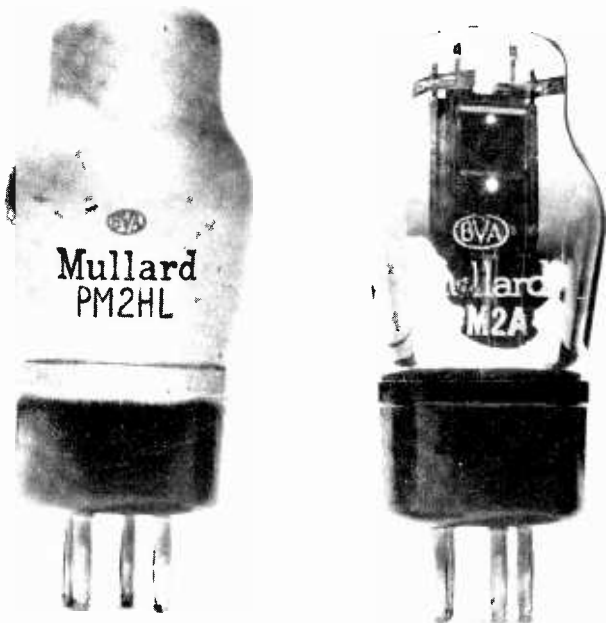
The ability to obtain and maintain

the necessary high vacuum was the result of considerable improvements in the pumping equipment together with the firing of “getters” to remove the last traces of gas as pumping was being completed and just before the valve was sealed off. Also, the internal components of the valve were raised to a high temperature to drive off any occluded gases, the components being raised to the necessary temperature by eddy currents induced in them from alternating currents of suitable frequency passed through a coil surrounding the bulb. The getter was fired in a similar manner just before the sealing-off process took place.\* These processes occurred in sequence on a rotating machine, the assembled valve being fed in by an operator and the pumped, gettered and sealed valve being removed on the completion of the cycle.

Various materials have been used for getters, the necessary piece of material being fixed at a suitable point of the assembly. This vital process has many complications, as it is not easy to ensure that the fired getter reaches all the gas molecules or that the final residue is not deposited in undesirable places.

The amount of chemical, physical and engineering research and

\* Depending upon the processing used, the getter might alternatively be fired as a separate operation after sealing off, with equivalent results.



Two popular battery valves of the early 1930's—The PM2HL and PM2A. These had 2 volt filaments and were widely used in portable receivers

development necessary to improve the plant and processing in these directions whilst, at the same time, speeding up production may be well imagined. The development has been continuous ever since the 1920s.

#### Design Difficulties

The design and manufacture of the cathode presented many difficulties. A typical example was given by the development of resistance between the nickel tube and the emissive material as the valve was in use, this being often due to minute traces of impurity in the nickel core. The growth of such interface resistance would gradually affect the performance of the valve.

In order to obtain maximum efficiency, the spacing between grid and cathode should be as small as possible. In the very early valves this spacing was quite considerable and, even some twenty years ago, it was usual to find a spacing of a seventh of a millimetre or so. Reduction of this spacing has gradually taken place as the result of improved forms of grid construction and greater rigidity of assembly,

and a big step was given by the evolution of a cathode with flat sides and coated with the emissive material by a new method. This provided a hard smooth surface which allowed a cathode-grid spacing of less than a twentieth of a millimetre. The old method of spraying on the emissive material provided a random roughness of such a nature that very fine cathode-grid clearances caused far too great a spread of valve characteristics. The older type of cathode construction sometimes caused cathode material to be carried over to the grid, resulting in this electrode itself emitting. In the case of rectifying valves such material could cause sputtering between cathode and anode, often with dire consequences to associated components.

We cannot leave the subject of the all-important cathode without reference to the heater itself and to the insulation between cathode and heater. There were conflicting requirements for this insulation. Series operation and circuit requirements resulted in many cases, in a considerable difference of potential between cathode and heater. At the same time, good conduction of heat

from the heater to the cathode was of importance in order to keep wattage low and heating time within reasonable limits. The insulation had, also, to be of such a nature that it would withstand the heating and cooling of the heater as the set was switched on and off.

Alumina (aluminium oxide) was the material generally used for this insulation. It coated the heater and obviated the earlier arrangement in which the heater was contained in an insulating tube of magnesium oxide. Gradual improvement over a considerable number of years in the technique of coating the heater and in the purity of the alumina has made leakage or breakdown of the cathode-heater insulation virtually a thing of the past, in spite of the increased potentials now often present. Heating-up time has also been considerably improved.

Breakdown of the heater itself was a fairly common trouble with the earlier valves. Considerable strain was put on the heater wire by the frequent heating and cooling caused by switching the set on and off. With the reduction in valve size and, consequently, the size of the cathode tube, heater design called for some ingenuity. Basically, the heater consisted of a spiral of wire. Later, the coiled coil heater came into general use, the heater being bent back on itself to form an inverted V. More recently the single wire has been replaced by a stranded wire providing greater flexibility. The later constructions have also been effective in the reduction of hum.

Rather a high proportion of space has been devoted to the development of the cathode-heater assembly, but it must be pointed out that without a considerably high performance in this component not only would a reasonable degree of reliability and life for the valve have been unobtainable but the development of the remainder of its assembly would have been impossible.

#### General Assembly

A major development which has been of general application has been the change in the general assembly towards greater rigidity, reduction in size and improvement in r.f. performance. At the same time, alteration in construction has required much modification of the manufacturing plant.

This major development in construction will be dealt with next month, in the concluding article in this series.

*(To be concluded)*

IN LAST MONTH'S ARTICLE IN THIS SERIES WE continued our discussion on the triode valve, and started by examining the operation of grid current bias. We then described the manner in which an a.f. amplifier triode may be coupled to the output of a diode detector, and finished by discussing the grid leak detector.

We shall now deal briefly with another type of detector—the infinite impedance detector—after which we shall proceed to the characteristics and constants of the triode.

### The Infinite Impedance Detector

The basic circuit of the *infinite impedance detector* appears in Fig. 322. In this diagram an amplitude modulated r.f. signal appears across the tuned circuit and is applied to the grid of the triode. The detector load is in the cathode circuit, and consists of  $R_1$  with  $C_1$  in parallel.  $R_1$  could have, typically, a value of  $100k\Omega$ , and  $C_1$  a value of  $200pF$  at frequencies in the range occupied by the medium and long wavebands.

but too low a value in this capacitor is liable to result in undesirable changes in performance.<sup>1</sup>

It is desirable that the anode of the infinite impedance detector should have a low impedance path to chassis, and this may be provided by connecting a *bypass capacitor* between anode and chassis, as represented by  $C_2$  in Fig. 324 (a). Such a capacitor should offer a low reactance both at audio and at radio frequencies (whereupon it “bypasses” these frequencies to chassis) and a representative value would be  $0.2\mu F$ . A series resistor,  $R_2$ , is also introduced in this diagram. This resistor forms, with  $C_2$ , a decoupling filter which ensures that r.f. and a.f. voltages on the anode of the triode do not appear across the h.t. supply lines, where they might become coupled into other stages in the equipment.  $R_2$  and  $C_2$  also prevent undesired r.f. and a.f. couplings from other stages to the detector.  $R_2$  is not essential if there is no risk of such couplings. A secondary function for  $R_2$  is to reduce the h.t. voltage applied to the triode, should this be desired.

# understanding

## INTRODUCING MUTUAL CONDUCTANCE AND ANODE A.C. RESISTANCE

By W. G. Morley

The operation of the infinite impedance detector is quite simple. It can be considered initially as a cathode follower, in which the cathode goes positive when the grid goes positive. The presence of  $C_1$  modifies the cathode follower action, however, because this capacitor becomes charged by the positive peaks of the r.f. signal appearing on the grid. Between positive peaks the capacitor discharges into  $R_1$ , with the result that the voltage across this resistor takes up the form shown in heavy line in Fig. 323. This is similar to the waveform given by a diode detector, and an average a.f. voltage appears in the waveform which corresponds to the a.f. which originally modulated the r.f. signal.

The infinite impedance detector draws negligible current from the tuned circuit which connects to its grid and offers, in consequence, a very high input impedance. It is from this factor that the term “infinite impedance” derives. The impedance may be increased by reducing the value of  $C_1$ ,

# radio

The waveform of Fig. 323 shows that there is both an r.f. voltage and an average direct voltage across the cathode load of the infinite impedance detector. This is the same situation as occurs with the diode detector load, and we remove these two unwanted voltages in much the same manner as we did with the diode detector. The final circuit is shown in Fig. 324 (b), in which  $R_3$  and  $C_3$  form a low-pass filter to attenuate the r.f. voltage, whilst  $C_4$ , which has a low reactance at audio frequencies, prevents the direct voltage from being passed to

<sup>1</sup> If the value of  $C_1$  is made too low, the valve may present a negative resistance to the tuned circuit, with a consequent increase in Q and a tendency towards oscillation. (Negative resistance is given when an increase in voltage causes a decrease in current. Oscillation will be discussed in a later article.)



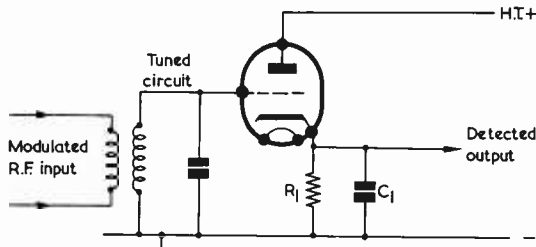


Fig. 322. The basic infinite impedance detector

the following stage.  $R_4$  ensures that the average voltage on the right hand plate of  $C_4$  is at chassis potential, and may serve as the grid resistor for a following a.f. amplifier valve.

As with the diode detector, it is necessary to keep the a.c./d.c. cathode load ratio close to unity if distortion at the higher modulation depths is to be avoided.<sup>2</sup> This requirement may be satisfied by giving  $R_4$  a value which is four or more times that of  $R_1$ .

The main advantage of the infinite impedance detector is that it has a high input impedance. Because of this it offers very little damping on any tuned circuit to which it is connected, whereupon the Q of the latter remains virtually unaltered.

#### Valve Characteristics And Constants

Apart from the fact that we looked at the  $I_a V_g$  characteristic curve of the triode in the August issue we have not yet discussed in detail the characteristics and constants of the triode. There are three important constants, and they provide a measure of the valve's capabilities. As we shall see later, these constants also apply to amplifying valves having more complicated electrode structures than has the triode, but we shall discuss them in terms of the triode only at this stage. Triode characteristics and constants were not dealt with immediately after we introduced the triode valve because the writer feels that it is more helpful for the beginner to gain an understanding of simple applications and circuits first. It is easier to grasp

<sup>2</sup> See "Understanding Radio" in the June 1965 issue.

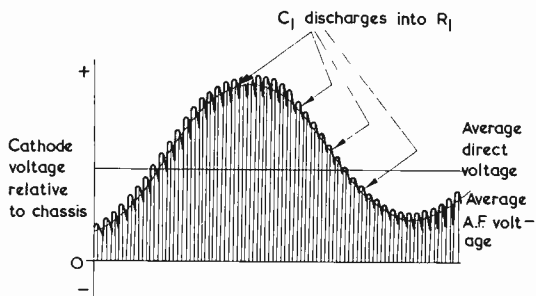
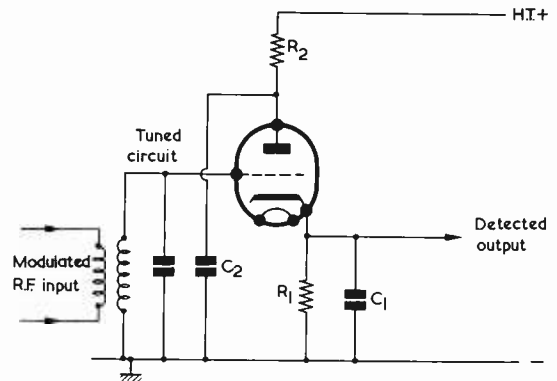


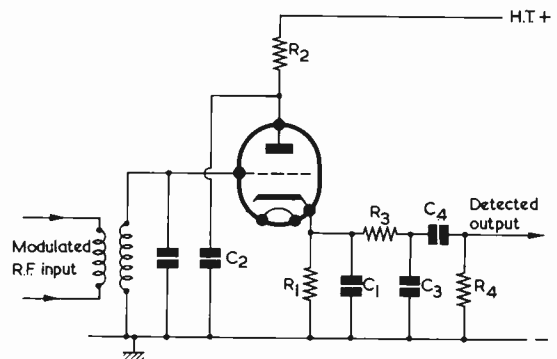
Fig. 323. The waveform appearing at the cathode of the triode in Fig. 322 is shown here in heavy line. The positive r.f. half-cycles of the signal are added to assist the explanation

the purpose of valve characteristics and constants after a basic knowledge of the manner in which the valve is to be used has already been acquired. It may be added that a valve constant is a figure which represents a particular attribute of the valve. The two constants we shall discuss this month are closely connected with sets of curves which illustrate the valve's characteristics, and the sets of curves will be dealt with at the same time.

The characteristics and constants we shall now consider may all be found by means of the circuit shown in Fig. 325. This is similar in principle to Fig. 299 in the August issue, which we employed for obtaining  $I_a V_g$  (anode current-grid voltage) curves, with the exception that we now have a variable anode voltage provided by a potentiometer, and the grid voltage available cannot go positive



(a)



(b)

Fig. 324 (a). In a practical infinite impedance detector, it is desirable to have a by-pass capacitor between anode and chassis.  $C_2$  carries out this function here.  $R_2$  gives decoupling, and may be used also to provide a lower voltage on the anode than that available on the h.t. positive line

(b). For practical operation, the infinite impedance detector needs a filter to remove the r.f. voltage across the cathode load. This is provided here by  $R_3$  and  $C_3$ . Also needed is capacitor  $C_4$ , which has a low reactance at audio direct frequencies and which prevents the average direct voltage appearing at the output

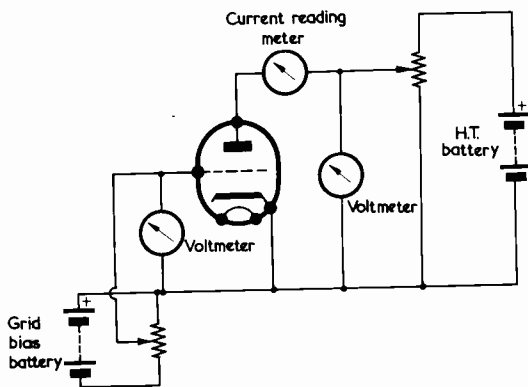


Fig. 325. A circuit which allows the characteristics of a triode to be found. Sources of direct voltage other than batteries may, of course, be employed

of the cathode. As we saw in the previous article, the grid is not normally allowed to go positive of the cathode in practical applications and so characteristics are not given for positive grid voltages.<sup>3</sup> The circuit given in Fig. 325 enables us to vary both the anode voltage and the grid voltage, and to measure the anode current which flows.

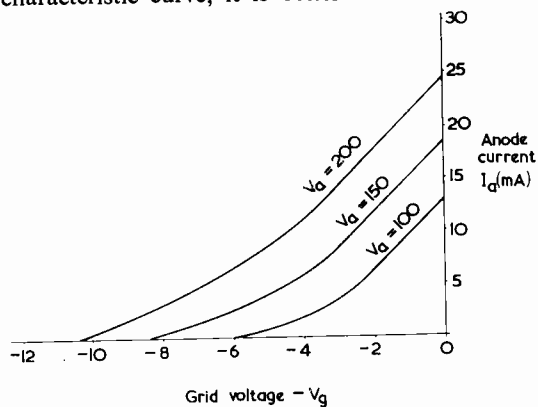
### Mutual Conductance

Since we have already examined the  $I_a V_g$  curve, this provides a useful starting point for the first constant which we shall consider. Fig. 326 (a) shows the  $I_a V_g$  curves for a typical voltage amplifier triode at anode voltages of 100, 150 and 200.<sup>4</sup> These curves tell us that, as grid voltage goes more positive, the anode current increases. They also tell us, obviously enough, that a change in grid voltage causes a corresponding change in anode current.

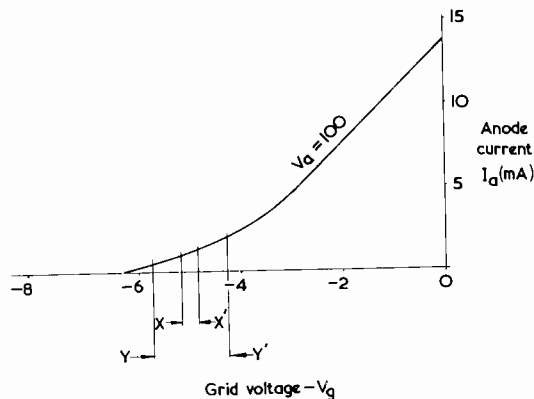
The latter attribute is defined by the first constant to be discussed, this being *mutual conductance*. The mutual conductance of a valve is the ratio of change in anode current to change in grid voltage, the anode voltage remaining constant. Mutual conductance is expressed in milliamperes per volt. If, at a constant anode voltage, we change the grid voltage of a triode by 1 volt and find that this causes the anode current to change by 2mA, then the triode has a mutual conductance of 2mA per volt. This may be abbreviated to 2mA/volt or 2mA/V. It is not necessary to find the ratio by using a change in grid voltage of exactly one volt. If we had measured the change in anode current for a change in grid voltage of 0.25 volt, and found it to be 0.5mA, then the mutual conductance (which is the ratio of change of anode

current to change of grid voltage) would have been  $\frac{0.5}{0.25} = 2\text{mA per volt}$ , just as before.

The lower ends of the curves of Fig. 326 (a) are noticeably curved and we would find that if, on the  $V_a = 100$  curve for instance, we attempted to find the mutual conductance by measuring the change in anode voltage for a change in grid voltage between X and X' in Fig. 326 (b), we would get a different answer than we would for a grid voltage change between Y and Y'. This is entirely due to the pronounced curvature at these points. Normally, mutual conductance measurements are taken at the straighter, or more *linear*, parts of the  $I_a V_g$  curve where the same ratio is more likely to result for both large and small changes in grid voltage. If mutual conductance measurements *have* to be taken for a grid voltage which appears at a pronouncedly curved portion of the  $I_a V_g$  characteristic curve, it is better to use as small a



(a)



(b)

Fig. 326 (a). Typical  $I_a V_g$  curves for a voltage amplifier triode  
(b). Measurements of mutual conductance at a curved section of the  $I_a V_g$  characteristic may give different results according to the magnitude of the change in grid voltage

<sup>3</sup> This statement may appear to conflict with the fact that, in the grid current bias and grid leak detector circuits we examined last month, the grid was allowed to go very slightly positive of the cathode during positive signal peaks. However, this method of operation was due to the requirement, in these circuits, that the grid should function as the anode of a diode, whereupon small positive excursions at the grid become inevitable. The positive grid voltage and grid current in these two instances are kept to a low figure by reason of the associated circuit design.

<sup>4</sup> These are the same curves as appeared in Fig. 300 in the August issue, but without the section corresponding to positive grid voltage.



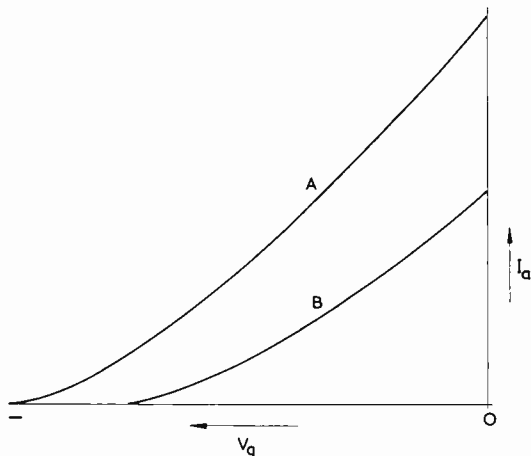


Fig. 327. Two  $I_a V_g$  curves drawn on the same axes. Curve A has a steeper slope than curve B and represents a higher mutual conductance

grid voltage change as practicable, in order to obtain an accurate answer for the particular grid voltage concerned. In valve manufacturers' literature, mutual conductance is normally quoted for specific values of anode voltage and grid voltage, and these figures will almost inevitably apply to a linear part of the  $I_a V_g$  characteristic curve.

Mutual conductance may also be referred to as *slope*. This is because the mutual conductance figure defines the "slope" of the  $I_a V_g$  curve. In Fig. 327, curve A has a steeper "slope" than has curve B, whereupon it represents a higher mutual conductance.

The abbreviation employed for mutual conductance is gm, and the definition for mutual conductance may be expressed in the following equation:

$$gm = \frac{dI_a}{dV_g} \quad (V_a \text{ constant}).$$

Non-mathematical readers should not worry about the letter "d" which appears before " $I_a$ " and " $V_g$ ". In the fraction this letter merely signifies that the denominator ( $dV_g$ ) is "change in  $V_g$ " and that the numerator ( $dI_a$ ) is "corresponding change in  $I_a$ ". To quote our previous example, if the change in grid voltage ( $dV_g$ ) is 1 volt and the corresponding change in anode current ( $dI_a$ ) is 2mA, then the equation tells us that  $gm = \frac{2}{1} = 2\text{mA per volt}$ . We

would get the same answer with the grid voltage change of 0.25 volts and the corresponding anode current change of 0.5mA which was also mentioned. The term " $V_a$ " appearing in the equation stands, of course, for anode voltage.

In American terminology, "mutual conductance" is usually referred to as *transconductance*, or *grid-plate transconductance* (the term "plate" being employed instead of "anode"). Mutual conductance is also expressed in micromhos, instead of in mA per volt. To understand why this unit is employed

we have to go back to our basic electrical quantities.<sup>5</sup> Resistance is measured in ohms, and is equal to  $\frac{E}{I}$  where E is the applied e.m.f. in volts and I is the current, in amps, which flows. Conductance is the reciprocal of resistance, and the basic unit of conductance is the mho (the word "ohm" spelt backwards). Thus, conductance (in mhos) =

$\frac{1}{\text{resistance (in ohms)}}$  If a circuit component has a

resistance of 3 ohms, it has a conductance of  $\frac{1}{3}$  mho.

Since conductance is the reciprocal of resistance, it is equal to  $\frac{I}{E}$ . Now, our mutual conductance is

$\frac{dI_a}{dV_g}$ , which is also a current divided by a voltage,

and we may see, in consequence, how the term "mutual conductance" derives. "Mutual" means

"conjointly shared" and so "mutual conductance" refers to a conductance which is conjointly shared between grid and anode. A mutual conductance of 2mA per volt may be expressed, in terms of amps

and volts, as 0.002 amps per volt or  $\frac{0.002}{1}$  mhos. It

is more convenient to use the micromho (one millionth part of a mho) than the mho, whereupon

our mutual conductance becomes  $\frac{0.002}{1} \times 1,000,000$

= 2,000 micromhos. It may be seen from this

that, to express mutual conductance in micromhos, it is only necessary to multiply the mA per volt figure by 1,000. Similarly, a mutual conductance figure in micromhos may be changed to mA per volt by dividing by 1,000.

A final point is that a set of  $I_a V_g$  curves, such as those shown in Fig. 326 (a), are referred to as the *mutual characteristics* of the valve concerned. They may also be described as the *transfer characteristics*.

#### Anode A.C. Resistance

The second important constant we shall consider is the *a.c. resistance*, or *anode a.c. resistance*, of a triode. This is not a new concept to us because, in the July issue, we examined the a.c. resistance of the diode. We saw that the resistance to an alternating current offered by a diode depends upon the slope of the  $I_a V_a$  characteristic curve. The a.c. resistance offered was demonstrated by considering the alternating current which flowed at a known alternating voltage, and it was pointed out that this a.c. resistance had no connection with the d.c. resistance of the diode.

The same applies to the triode, and we may define anode a.c. resistance as the ratio of change in anode voltage to the corresponding change in anode current, grid voltage remaining constant. Anode a.c. resistance is expressed in ohms. As was pointed out when we dealt with the diode, the term "anode a.c. resistance" is abbreviated

<sup>5</sup> Resistance and conductance were covered by "Understanding Radio" in the October 1961 issue.

to  $r_a$ . If a change in anode voltage of 10 volts corresponds to a change in anode current of 2mA, or 0.002 amps, then the anode a.c. resistance in ohms is  $\frac{10}{0.002} = 5,000$ .

We may express anode a.c. resistance in the form

$$r_a = \frac{dV_a}{dI_a} (V_g \text{ constant}).$$

In this equation, the letters "d" carry out the same function as with the mutual conductance equation. The term " $dI_a$ " means "change in  $I_a$ " and the term " $dV_a$ " means "corresponding change in  $V_a$ ". The similarity of the equation to that for resistance,  $R = \frac{E}{I}$ , is readily apparent.

We explained anode a.c. resistance with the diode by drawing its  $I_a V_a$  characteristic curve and we shall now do the same for the triode. However, the grid of the triode introduces a complicating factor, and it is necessary, if a full picture of the performance of the triode is to be given, to draw not one  $I_a V_a$  characteristic curve, but a relatively large number of curves, each corresponding to a different grid voltage. A typical example is shown in Fig. 328, in which we see a "family" of  $I_a V_a$  curves with grid voltage as parameter.<sup>6</sup>

We can find anode a.c. resistance at any grid voltage and anode voltage, or at any grid voltage

<sup>6</sup> A parameter is a constant in a family of functions which can be given arbitrarily chosen values. In this instance, the grid voltage is a parameter because curves are drawn at  $V_g = 0$ ,  $V_g = -2.5$ , and so on. In the  $I_a V_g$  curve of Fig. 326 (a), anode voltage is the parameter.

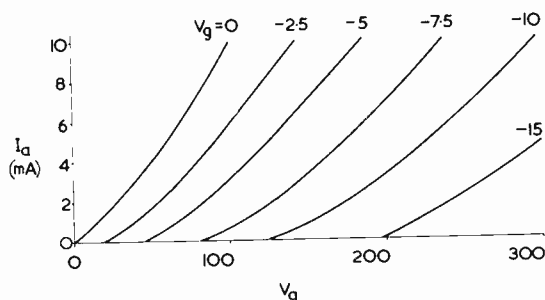


Fig. 328. A set of  $I_a V_a$  curves for a typical voltage amplifier triode. Each curve corresponds to a different grid voltage

and anode current, by checking the slope of the  $I_a V_a$  curve at the corresponding point. In valve manufacturers' literature, anode a.c. resistance is normally quoted for specific values of anode voltage and grid voltage, these applying to a relatively linear section of the  $I_a V_a$  curve.

Anode a.c. resistance can be looked upon in the same manner as the internal resistance of an a.c. generator. It may also be referred to as *anode impedance* or *anode incremental resistance*, and, in American literature, as *plate resistance*.

A set of  $I_a V_a$  curves, such as those shown in Fig. 328, are described as the *anode characteristics* of the valve.

#### Next Month

In next month's issue we shall describe the remaining important constant of the valve, this being amplification factor.

## Club Events

### The Slade Radio Society

Hon. Sec.: D. Wilson, 177 Dower Road, Sutton Coldfield.

**November 12th**—Film Show presented by Don Wilson. The programme will include some of the latest instructional films on radio subjects in addition to films of more general interest.

**November 26th**—Annual General Meeting.

### Derby and District Amateur Radio Society

Hon. Sec.: F. C. Ward, 5 Uplands Avenue, Littleover, Derby.

**November 20th and 21st**—Second R.S.G.B. Top Band Contest.

### Northern Heights Amateur Radio Society

Hon. Sec.: A. Robinson, G3MDW, Candy Cabin, Ogden, Halifax.

**November 10th**—Tape Recorders, by F. Thistlethwaite.

**November 16th**—Mullard Film Show, Bradford.

**November 24th**—Electronic Logic, by G. E. Craven.

### The Roding Boys' Society

An invitation is extended by the Society to any local boy, interested in radio or science generally, to visit Wanstead Community Centre, The Green, London, E.11, any Tuesday at 7 p.m. More distant boys can write to R. J. Lipscombe, 187 Markhouse Road, Walthamstow, London, E.17.

# RADIO TOPICS . . .

by Recorder

**M**ORE AND MORE ARE TRANSISTORS popping up their little TO-5 heads in the hitherto valve-dominated territory of British domestic TV. The recent London exhibitions which took the place of the Radio Show That Never Was demonstrated very clearly how TV receiver manufacturers are gradually allowing the semiconductor to oust the valve. Hybrid chassis, in which some stages use transistors and others use valves, are already in production by Pye, G.E.C. and Rank-Bush Murphy.

Transistor TV receivers are not by any means new in this country, of course, and it will be remembered that Perdio introduced their transistorised portable model way back in 1962. A point of difference here is that the Perdio model was fully transistorised and could be operated from a battery as well as from the mains, whereas the hybrid receivers which have appeared this year are intended for mains operation only. What has happened is that TV manufacturers feel that it is to their advantage to replace some of the valve stages in a mains-driven receiver by equivalent transistor stages. The result is, of course, a considerable saving in space and dissipation of heat.

Provided they're treated properly, transistors are inherently more reliable and have a longer life than valves, whereupon it becomes possible to produce, say, an i.f. strip in which the transistors are permanently wired in alongside the capacitors and resistors, as opposed to the valve version in which bulky heat-radiating valves sit in their holders at all angles.

## Performance

The fact that transistorised TV circuits are neater and smaller than their valve equivalents represents only a small advantage so far as the TV manufacturer is concerned. Generally, it is necessary to use more transistor stages than valve stages to achieve a particular performance and this is not helpful from the point of view of cost. Also, and with one exception, the use of transistors does not bring about any important improvement in performance com-

pared with that already offered by valves. The main things that transistors do are to save space, increase reliability, considerably reduce heat dissipation and cause less power to be drawn from the source of supply. The exception just mentioned, by the way, occurs when transistors are employed instead of valves in u.h.f. tuners. In these tuners, transistors offer improved noise performance figures.

The general approach with current hybrid receivers is to fit transistors in both u.h.f. and v.h.f. tuners, or in a single "integrated" tuner covering u.h.f. and v.h.f., and in the vision and sound i.f. strips. Timebase circuits and output stages continue to employ valves.

An example of hybrid design is given by the newly introduced Pye 31F receiver. In this model four transistors are fitted in the integrated v.h.f.-u.h.f. tuner, these being followed by three transistors in the vision i.f. strip. There is a two-transistor sound i.f. strip which works, on 405 lines, with a 38.15 Mc/s sound i.f. taken from the collector circuit of the second vision i.f. transistor and, on 625 lines, with a 6 Mc/s intercarrier signal taken from the a.g.c. detector. Two further transistors are used as a.g.c. amplifiers, a.g.c. being applied to the integrated tuner and to the first vision i.f. transistor.

All the remaining stages in the 31F receiver employ valves.

Of particular interest in this set is the manner in which a single power supply circuit provides power for all the heaters as well as the transistors. The "hot" side of the mains input passes through voltage selector resistors and a thermistor to a silicon diode type BY114. This passes positive half-cycles into the heater chain, the lower end of which is terminated by a 1,000 $\mu$ F electrolytic capacitor and a parallel resistor network. The rectified voltage across the 1,000 $\mu$ F capacitor is smoothed by a resistor and a second 1,000 $\mu$ F component, whereupon 14 volts positive of chassis becomes available for the transistor circuits. So, the dropping circuit not only uses a half-wave rectifier instead of a heat radiating ballast resistor but it also offers a convenient d.c. supply

for the transistors. The transistors in the vision and sound i.f. strips are n.p.n. types, and the positive supply enables them to be wired in common-emitter mode with the emitter resistors returned to chassis.

Despite the doldrums in which TV sales are at present stated to be calmed (and I'm *not* mixing my metaphors!) there is definitely no shortage of bright new ideas in the design laboratories of TV manufacturers. This gradual encroachment by the transistor into domestic television receivers is a development which should be of considerable interest during the next five years or so.

## 180 Not Out!

If you look elsewhere in this issue you'll see that G. A. French's article this month carries the number 180. There has been a "Suggested Circuit" by G. A. French in every *Radio Constructor* since the series started, and this means that "Suggested Circuit" No. 180 marks the end of a period of no less than 15 years.

It is difficult to tell whether this constitutes a record because, so far as I'm aware, there is no other journal *throughout the world* which runs a continual feature similar to the "Suggested Circuit" series. No competing achievement against which "Suggested Circuits" may be compared is, therefore, available.

Readers may be interested to learn that the series is of value not only to amateur constructors but also to professional engineers including, in particular, engineers engaged in making production line processing and test equipment. We quite often hear from commercial firms which are using ideas taken from "Suggested Circuit" articles, some of these having been published more than five years ago.

I understand that, in next month's issue, G. A. French is going to start his sixteenth year of "Suggested Circuits" by describing a device which enables you to give an extremely mystifying demonstration of extra-sensory perception (with a certain amount of simple electronic gadgetry to help the astral messages along). It sounds just the thing for that Christmas party!

## Burnt-Out C.R.T.s

Have you got a television cathode ray tube with a burnt-out heater? If so, the following idea, which has been sent in to us by R. W. T. Horne of Jedburgh, Roxburghshire, may help you out. But, please note, we offer no guarantee of success. Also, there are some pretty high and

dangerous voltages involved, so take full precautions against shock.

"It occasionally happens," writes Mr. Horne, "that the tube in a television set which has previously given a bright and well-contrasted picture suddenly decides to develop an open heater which, it is generally accepted, means a hefty bill for a new tube. But in many instances this needn't be the case, for I have found that in about 70% of heater failures they can be very simply and satisfactorily welded, with no other equipment than the TV set itself!

"The method is as follows. Remove the tube base and short over the filament sockets in order to complete the heater chain. Connect one of the heater pins to chassis, and connect another lead to the top cap (anode) of the line output valve. Lengths of wire with crocodile clips at each end are useful for these connections. Attach the other end of the lead from the line output valve to an insulated screwdriver, and switch on the set, keeping the screwdriver well away from the chassis.

"When the line timebase has reached its full output, touch the heater pin which has been left un-earthed with the screwdriver, when sparks will be seen flying inside the neck of the tube. *Immediately* the sparks cease (and the line output stage stops running) draw away the screwdriver and switch off. Then check the continuity of the heater, whereupon it will be found that an r.f. weld has taken place.

"In several cases when I have carried out this treatment the tube has given a further two or three years of useful life. Occasionally, the resultant weld has been a poor one, and the heater has gone open-circuit again in a few days, but on repeating the process a second time the results have been completely satisfactory."

Many thanks to reader Horne for passing on the idea; and I think I should warn that a very heavy direct current will flow through the line output transformer primary as soon as the heater break is bridged over, and that you could conceivably end up with one c.r.t. repaired and one line output transformer burnt out! The best idea might be to use an old throw-out TV which still has the line timebase working for repairs of this nature.

#### Discharging Electrolytics

And, finally, a little tip which also has to do with TV servicing.

Normally, the reservoir and smoothing electrolytic capacitors in a TV set discharge pretty rapidly

after the set has been switched off because, even if the valves are cold, there are still one or two fixed potential dividers across the h.t. lines to provide a discharge path. (Such potential dividers normally supply lower voltages for screen-grid circuits and the like.) Nevertheless, the occasional snag may be encountered in which, due to, say, a break in the h.t. supply circuit, the electrolytics remain charged after switching off. It then becomes necessary to discharge them before working on the receiver.

The thing *not* to do is to discharge the electrolytics by popping a screwdriver across them. TV h.t. electrolytics have values of the order of 200 $\mu$ F and the resultant sound, when they're short-circuited, is like a pistol shot. What is more, the

short-circuit doesn't do one little bit of good to the electrolytic, the screwdriver, or the nerves of anyone in the vicinity!

A good plan is to knock up a little servicing aid consisting of a crocodile clip, a flexible lead, a test prod and a 1 watt resistor having a value between 47 $\Omega$  and 100 $\Omega$ . Mount the resistor at the crocodile clip, connecting it between the clip and the flexible lead. The test prod is fitted at the other end of the lead. All that is then required, when working on a set in which the electrolytics may need to be discharged, is to fix the crocodile clip to the chassis. Applying the test prod to the electrolytics after switching off results in their becoming quickly and safely discharged via the resistor—and without fireworks!

# IN

THE **Radio Constructor**

## NEXT MONTH

### Simple Square Wave Generator

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### Improvised Variable Resistors

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continued on page 269

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6K8G	3/3	30L17	11/6	ECCF86	10/-	EM85	8/9	PL83	6/-	UF86	9/-
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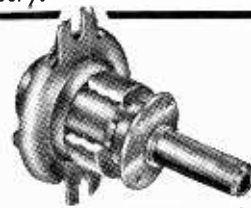
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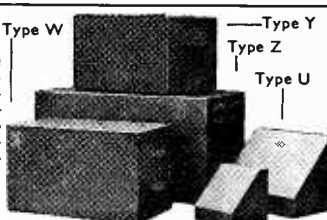
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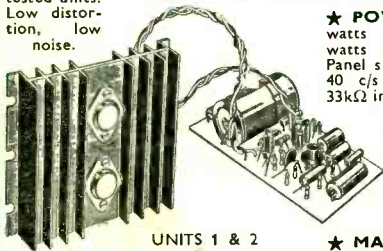


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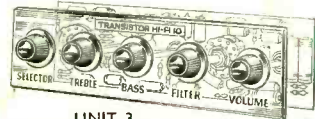
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X20 AMPLIFIER Kit £7-19-6 Built £9-19-6 Mains unit 99/6

### 5 WATT AND 1 1/2 WATT PACKAGED AMPLIFIERS

- ★ 6-Transistor push-pull printed circuit designs
- ★ Size only 2 1/2" x 2" x 1 1/4"
- ★ 5 watt 18 volt. 1 1/2 watt 12 volt
- ★ For 3 to 5 ohm speakers
- ★ 7mV into 1kΩ 30 c/s to 16 kc/s



PRICES BUILT 1 1/2w 65/- P.P. 1/6 5w 79/6 P.P. 1/6

### ● Mono PREAMPLIFIER

Full range of controls, inputs for mics, p-u., tuner, etc. Output 6-10mV. Suitable for any sensitive transistor amplifiers as above. 7 1/2/12/18V operated. Price built/tested incl. panel 79/6 P.P. 2/6. Stereo version 79/6.

NEW, FREE, 12-PAGE TRANSISTOR/CRYSTAL/VALVE CATALOGUE FREE ON REQUEST



### TRANSISTOR PORTABLE TEST EQUIPMENT

All units size 6 1/2" x 4 1/2" x 2 1/2". ★ RF generator, 150 kc/s to 350 mc/s in 8 ranges. RF, Mod. RF, AF outputs.

PRICE **£9.10.0** P.P. 2/6

- ★ Resistance/capacitance bridge. **£8.5.0.** P.P. 2/6.
- ★ Audio generator 10 c/s-100 kc/s. 4 ranges. **£16.15.0.** P.P. 2/6.



### VHF/FM TUNER TO ASSEMBLE

★ Two pre-built plus metal work and front panel. Total Cost **£12.17.6** P.P. 2/6

- ★ Size: 9 1/2" x 3 1/2" x 4"
- ★ 88 to 108 mc/s tuning.
- ★ 100mV to 100kΩ output
- ★ 6-Transistor printed cct. superhet design

### NEW SW/MW/LW PUSH BUTTON PORTABLE TO BUILD. 3 wavebands

TOTAL COST **£8.19.6** P.P. 3/6

The only fully Tunable 3-waveband radio for home construction.



- ★ Push-button coil pack.
- ★ 1 watt push-pull output
- ★ Ferrite aerial/Telex. aerial/special car coils
- ★ Printed circuit 6-transistor design
- ★ SW 17/50m. LW 1100/1900m. MW 195/550m.
- ★ Car aerial and tape sockets
- ★ Attractive sturdy cabinet with handle. Size 11" x 7 1/2" x 3 1/4". Black fabric with chrome fittings.

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

### VHF/FM TRANSISTOR TUNER TO BUILD

TOTAL COST **£6.19.6**

P.P. 2/6 (complete with frontplate) (Gold sprayed cabinet 20/- extra).



- ★ 5-Transistor 4 diodes.
- ★ Printed circuit superhet.
- ★ Geared tuning 87 to 105 Mc/s FM
- ★ RF stage and double tuned IFT's.
- ★ Output up to 1 volt peak up to 100kΩ.
- ★ 9 volt 9mA supply.
- ★ Size in cabinet 4" x 3 1/4" x 2 1/4".
- ★ All parts sold separately.

### HENRY'S RADIO LTD.

303 EDGWARE ROAD, LONDON, W2

PADington 1008/9

Open Mon. to Sat. 9-6. Thurs. 1 p.m. Open all day Saturday