PRACTICAL
# ELECTRONICS

MAY 1968

PRICE 2/6

## ELECTRONIC PERCUSSION EFFECTS


Also IN THIS ISSUE........

INTRUDER ALARM FOR SMALL CRAFT

TRANSISTOR CURVE TRACER

# LIND-AIR (OPTRONICS) LTD.

*London's Leading Component Shops*

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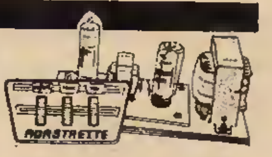
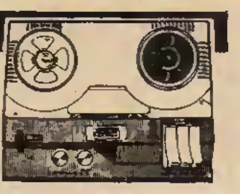
## 2-3 WATT AMPLIFIER




An ideal basis for building your own portable record player. Just add speaker and turntable, and you will have an above-average model for a mere fraction of the cost. 2-3 watt printed circuit with control panel on flying lead. ON/OFF, TONE CONTROL AND VOLUME, colourful escutcheon. Brimar valves: EZ80, ECL82 and composite installation booklet. Price **£4.5.0** P. & P. 3/6.

## MAGNAVOX-COLLARO 363 TAPE DECKS



The very latest 3-speed model—1⅞, 3¾, 7½ i.p.s. available with either 2 track or 4 track head. Features include: Pause control; digital counter; fast forward and rewind; new 4-pole, fully screened induction motor; interlocking keys. Size of top plate 13½ × 11 × 5⅛in deep below unit plate. For 200/250V a.c. mains, 50 c/s operation. New, unused and fully guaranteed.

2 track model **£10.10.0** 4 track model **£13.19.6**

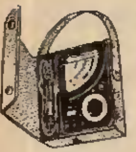
Carriage and Packing 12/6 extra.

## MARTIN TAPE AMPLIFIERS

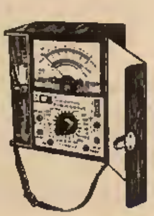
**FOR USE WITH ABOVE DECKS**

2 track model £14.19.6; 4 track model £15.19.6. Carriage and Packing 12/6.

## MULTIMETERS



MODEL TTC.1001. 20,000 O.P.V. with overload protection; d.c. volts, 5, 25, 125, 500, 2,500V; a.c. volts, 10, 50, 250, 100V; d.c. mA 250mA to 50A. With prods and Carrying case ONLY 85/-. P. & P. 3/6.



MODEL TTC. 1030. 50,000 O.P.V.; d.c. volts, 0-3, 12, 60, 120, 300, 600, 1,200V; a.c. volts, 6, 30, 120, 600, 1,200V; d.c. mA 0-03-300. With prods and carrying case ONLY £11.19.6. P. & P. 5/-.

## 9 in 1 ELECTRONIC KIT


Build nine different projects from one basic kit—simple instructions, no technical knowledge required for you to build a Police Siren, Metronome, Morse Code amplifier, Electronic Massager, W/T Transmitter, Radio, Telephone, One-transistor Radio Two-transistor Radio, Electronic Music Kit. Completely safe-operated on 9V PP3 battery. Hours of fun for boys and dads of all ages. Complete with all parts and simple step by step instructions. ONLY 69/6. P. & P. 5/-.

## AUTO TRANSFORMERS

Input 0–200, 220, 240V
Output 110V

| | | | |
|---|---|---|---|
| 50W | £1.7.6 | 1,000W | £9.9.0 |
| 75W | £1.17.0 | 1,500W | £15.15.0 |
| 100W | £2.5.0 | 2,000W | £18.10.0 |
| 150W | £2.15.0 | 3,000W | £26.10.0 |
| 200W | £3.5.0 | 4,000W | £34.18.0 |
| 300W | £4.5.0 | 0-30V, 1A | 30/- |
| 400W | £4.19.6 | 0-30V, ½A | 17/9 |
| 500W | £5.9.6 | 0-30V, 2A | 37/6 |
| 600W | £6.9.6 | 0-30V, 3A | 42/- |

Post extra.

## AERIALS TV UHF VHF STEREO

**Vantena** Table Top V Aerial BBC/ITV, 26/6.
**Cresta** Room Aerial Band I/II/III. Cream or Black, 26/6.
**Yeomaster** Table Top VHF/UHF Tunable Aerial. Chrome or Grey, 78/6.
**YAGI** all Channel Table Top Aerial BBC1/2/ITV/VHF, 65/-.
**HL523 Loft Aerial** HILO V + 5 for vertical Band I/III. With mounting arm and bracket, 58/-.
**New Major** 10 element BBC2 Aerial for loft or outdoor fixing. With roller bracket for up to 2in dia. mast, 45/9.
**H1, Hunter** 13 element BBC2 Aerial as above, 57/-.
**E1, Explorer** 18 element BBC2 Aerial as above, 89/-.
**Loft Six.** 6 element BBC2 Aerial for loft or outdoor fixing. With arm and bracket, 37/6.
**J-Beam** 4 element outdoor Band II VHF/FM Stereo Aerial. With mast, 67/-. Please add 4/- postage.

## MAINS TRANSFORMERS

Input 200–250V 50c/s.

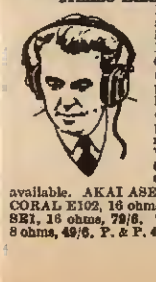
| | | | |
|---|---|---|---|
| 24V 3A | £2.12.6 | 24V 8A | £5.5.0 |
| 24V 6A | £3.15.0 | 24V 12A | £6.15.0 |

Post extra.
Mains and Output Transformer lists available on request.

**GOODMANS SPEAKER BARGAINS!** 5in 3 ohms, 15/6; 6in. 3 ohm, 29/6; 8in. 3 ohm, 32/6; 10in 5 ohm, 65/-; 10 × 6in. 3 ohm, 32/6; Tweeter, 19/6. P. & P. 3/6 per Speaker.


SEE OPPOSITE


## STEREO HEADPHONES



**STEREO HEADPHONES**
Enjoy Stereo Sound as you have never heard it before. MODEL TTC. G1111 as illustrated soft padded earphones. Adjustable headband. Impedance 8 ohms per phone. Frequency range 25–13,000c/s. With 5ft lead. Price 69/6. P. & P. 4/6. Other similar types available. AKAI ASE9S, 8 ohms, £6.5.0; CORAL E102, 16 ohms, £5.19.6; EAGLE SE1, 16 ohms, 79/6. T.T.C. Stethoscope, 8 ohms, 49/6. P. & P. 4/6 each.

## GARRARD DECKS

TEAK FINISH PLINTHS with perspex cover 6½ gns. (for LAB80 8½ gns.). P. & P. 12/6
Agents for Thorens, Dual, Goldring, etc.

| | |
|---|---|
| 3000 with Sonotone 9TAHC Stereo Cartridge .. | £8.19.6 |
| 3000 with Sonotone 9TAHC Diamond Stereo Cartridge .. .. .. .. .. | £9.19.6 |
| AT60 MKI less cartridge .. .. .. | £10.19.6 |
| AT60 MKII less cartridge .. .. .. | £12.19.6 |
| AT60 MKII with Decca Deram Stereo Cartridge | £17.14.0 |
| SP. 25 MKII less cartridge .. .. .. | £10.19.6 |
| SP. 25 MKII with Decca Deram Stereo Cartridge | £15.14.0 |
| AP.75 less cartridge .. .. .. .. | £22.11.6 |
| LAB.80 MKII less cartridge .. .. .. | £24.19.6 |

All plus P. & P. 12/6
Mono Cartridge 17/6 extra.
Stereo Cartridge 22/6 extra.

## TRANSISTOR F.M. TUNER


**SAVE £2.2.0**

6 Transistor FM tuner. Frequency range 88–108Mc/s. Size 6 × 4 × 2½in. Ready built for use with most amplifiers, 9V battery operation. Complete with instructions. LIST PRICE 9 gns.

LIND AIR PRICE **7 gns.** P. & P. 4/-.

Multiplex adaptor for Stereo Radio Reception £5.19.6 extra.

## BARGAIN OFFER! FANTAVOX CASSETTE TAPE PLAYER

Specially designed to replay the well known and popular Musicassettes—prerecorded tape cassette offering a wide choice of all types of music from pop to classical. Up to 40 minutes of quality reproduction through built-in speaker. Simple off/play and volume controls. Fully transistorised operating on six penlight batteries. Modern compact styling with earpiece socket and wrist strap. Size 6½ × 4½ × 2in.

LIND AIR PRICE. **£9.19.6.** Carr., Pkg. and Ins. 5/-.

## COMPLETE HI-FI STEREO SYSTEM

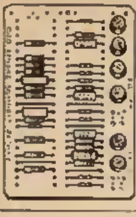
ONLY **59 GNS.** CARR. 20/-

ALL TRANSISTOR 6 WATTS PER CHANNEL STEREO HI-FI SYSTEM OFFERING A PERFORMANCE EQUAL TO IF NOT BETTER THAN SIMILAR SYSTEMS COSTING UP TO DOUBLE THE PRICE. Modern styling plus advanced circuitry using latest silicon transistors throughout.

The famous GARRARD 3000 Record Changer fitted lightweight tubular arm with SONOTONE 9TAHC STEREO/MONO DIAMOND CARTRIDGE will play all sizes of records. (4 speeds 78, 45, 33 1/3, 16 2/3 r.p.m.). Will play up to 9 records automatically, also provision for manual play. Amplifiers and controls are mounted below record player and incorporate Bass, Treble, Volume and Balance controls and On/Off, Gram/Radio, Mono/Stereo slide switches. TWO IDENTICAL LOUDSPEAKER SYSTEMS each incorporating separate bass speakers and high frequency units with crossover network provide full frequency reproduction and are complete with 10ft leads and plugs for connection to amplifier. Will fit easily on to bookshelves, room dividers or existing furniture. BRIEF SPEC. Player/Amplifier unit, Teak finish, size 16½ × 14 × 8¼in 200/250V a.c. operation. Inputs for Radio Tuner/Tape Recorder also outputs for Tape Recorder. Loudspeaker Systems. Teak finish, size (each) 13 × 7 × 8in. Supplied complete with instruction booklet, ready to plug in and play. SEND YOUR ORDER NOW OR CALL AND HEAR THIS MARVELLOUS HI-FI STEREO SYSTEM (Teak finish). Only 59 gns. plus 20/- Carriage and Insurance. (Rosewood 3 gns. extra.) (Clear Perspex Cover 3 gns. extra.)

## LINEAR AMPLIFIERS

**Latest a.c. Mains Models offering highest quality at modest cost.**
**LT66.** All Transistor 12 watts Stereo. Inputs for Tuner, Gram, Mike. Separate Bass, Treble, Balance and Volume Controls £15.15.0. Carr. 7/6. Teak case £3.10.0 extra.
**PTA 15** (as illus.). All Transistor, 15 watts Mono. Inputs for Tuner, Gram, Mike, Guitar, Bass, Treble and two volume controls, £15.15.0. Carr. 7/6. Teak case £3.10.0 extra. **LT45.** 2 Valve 5 watts Mono. Inputs for Tuner, Gram, Bass, Treble and volume controls, £6.19.6. Carr. 7/6. Metal cover 15/- extra. Full details sent on request.



## PRINTED CIRCUITS

Five assorted printed circuit boards with transistors, diodes, resistors, condensers, etc. Guaranteed minimum 20 transistors. Ideal for experimenters. 5 boards for 10/-. P. & P. 2/-.

★ **TRANSISTORISED FM TUNER** ★

6 TRANSISTOR HIGH QUALITY TUNER, SIZE ONLY 6in × 4in × 2½in. 3 I.F. stages. Double tuned discriminator. Ample output to feed most amplifiers. Operates on 9V battery. Coverage 88–108Mc/s. Ready built ready for use. Fantastic value for money. NOW £6/7/6. P. & P. 2/6.

**STEREO MULTIPLEX ADAPTORS 5 gns.**

## F.M. WIRELESS MICROPHONES

94–104Mc/s. Transistorised. Operates from 9V battery. Complete with additional secret tie-clip microphone. List £12.10.0 ONLY £5/15/0. P. & P. 2/6. These cannot be operated in U.K.

## AVOMETERS

Supplied in excellent condition fully tested and checked. Complete with prods, leads and instructions.

Model 47A £9.19.6

Model 8 £18. Model 9 £20. P. & P. 7/6 each.

## MODEL TE.50 20,000 O.P.V. MULTIMETER

0/10/50/100/500/1,000V a.c. 0/5/25/50/250/500/1,000v. d.c. 0–50µA 5/50/500mA. 0/6/60K/600K/6MΩ. £4/17/6. P. & P. 3/-.

## TE22 SINE SQUARE WAVE AUDIO GENERATORS

Sine: 20c/s to 200 kc/s on 4 bands. Square: 20c/s to 30kc/s. Output impedance 5,000 ohms, 200/250V a.c. Supplied brand new and guaranteed with instruction manual and leads, £15. Carr. 7/6.

## NEW MODEL 500

30,000 o.p.v. With overload protection, mirror scale 0·5/1/2·5/10/25/100/250/500/1,000 V d.c. 0/2·5/10/25/100/250/500/1,000V a.c. 0/50µA/5/50/500mA 12A d.c. 0/60kΩ/6MΩ/60MΩ. £8/17/6. Post Paid.

## TE-20RF SIGNAL GENERATOR

Accurate wide range signal generator covering 120kc/s — 260 Mc/s on 6 bands. Directly calibrated. Variable R.F. attenuator. Operation 200/240V a.c. Brand new with instructions. £12/10/0. P. & P. 7/6. S.A.E. for details.

## MODEL ZQM TRANSISTOR CHECKER

It has the fullest capacity for checking on A, B and Ico. Equally adaptable for checking diodes, etc. Spec.: A: 0·7–0·9957. B: 5–200. Ico: 0–50 microamps 0–5mA. Resistance for diode 200Ω–1MΩ. Supplied complete with instructions, battery and leads. £5.19.6. P. & P. 2/6.

## LAFAYETTE TE-46 RESISTANCE CAPACITY ANALYSER

2pf – 2,000 mfd 2 ohms – 200 megohms. Also checks impedance turns ratio, insulation. 200/250V a.c. Brand New £15. Carr. 7/6.

## VARIABLE VOLTAGE TRANSFORMERS

Brand New—fully Shrouded. Input 230V 50/60c/s. Output 0–260V.

| | |
|---|---|
| 1A | £5.10.0 |
| 2·5A | £6.15.0 |
| 5A | £9.15.0 |
| 8A | £14.10.0 |
| 10A | £18.10.0 |
| 12A | £21.0.0 |
| 20A | £37.0.0 |

Post extra.

## ARF-100 COMBINED AF-RF SIGNAL GENERATOR

AF. SINE WAVE 20–200,000 c/s. Square wave 20–30,000 c/s. O/P. HIGH IMP. 21V P/P 600Ω 3·8V P/P. TF. 100kc/s–300 Mc/s. Variable R.F. attenuation int/ext. modulation. Incorporates dual purpose meter to monitor AF. output and % mod. on R.F. 220/240V a.c. £27/10/0. Carr. 7/6.

## SILICON RECTIFIERS

| | |
|---|---|
| 200V P.I.V. 200mA | 2/0 |
| 200V P.I.V. 6A | 5/6 |
| 400V P.I.V. 3A | 7/6 |
| 1,000V P.I.V. 5A | 7/6 |
| 400V P.I.V. 6A | 5/6 |
| 400V P.I.V. 8A | 7/6 |
| 1,000V P.I.V. 650mA | 6/6 |
| 800V P.I.V. 500mA | 5/6 |
| 800V P.I.V. 5A | 7/6 |
| 400V P.I.V. 500mA | 3/6 |
| 70V P.I.V. 1A | 3/6 |
| 150V P.I.V. 165mA | 1/- |
| 150V P.I.V. 25A | 19/6 |
| 700V P.I.V. 100A | 49/6 |
| 400V P.I.V. 3A (S.C.R.) | 7/6 |
| 100V P.I.V. 5A (S.C.R.) | 13/6 |
| 200V P.I.V. 5A (S.C.R.) | 15/6 |
| 400V P.I.V. 5A (S.C.R.) | 17/6 |

Discounts for quantities. Post extra.

## TE-65 VALVE VOLTMETER

High quality instrument with 28 ranges. D.c. volts 1·5–1,500V A.c. volts 1·5–1,500V Resistance up to 1,000 MΩ. 220/240V a.c. operation. Complete with probe and instructions. £15. P. & P. 6/-. Additional Probes available: R.F. 35/- H.V. 42/6.


# CATALOGUE

★ ELECTRONIC COMPONENTS
★ TEST EQUIPMENT
★ COMMUNICATIONS EQUIPMENT
★ HI-FI EQUIPMENT

We are proud to introduce our first comprehensive catalogue of Electronic Components and Equipment. Over 150 pages fully illustrated, listing thousands of items, many at bargain prices. Free discount coupons with every catalogue. Everyone in electronics should have a copy.

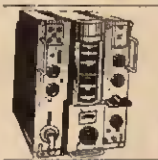
## CLEAR PLASTIC PANEL METERS

First grade quality Moving Coil panel meters available ex-stock. S.A.E. for illustrated leaflet. Discount for quantity. Available as follows: Type MR 38P, 1 21/32in square fronts.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 50µA | 37/6 | 100-0-100µA | 32/6 | 200mA | 25/- | 100V d.c. | 25/- |
| 100µA | 35/- | 500-0-500µA | 25/- | 300mA | 25/- | 150V d.c. | 25/- |
| 200µA | 32/6 | 1-0-1mA | 25/- | 500mA | 25/- | 300V d.c. | 25/- |
| 500µA | 27/6 | 1mA | 25/- | 750mA | 25/- | 500V d.c. | 25/- |
| 50-0-50µA | 35/- | 2mA | 25/- | 1A d.c. | 25/- | 750V d.c. | 25/- |
| | | 5mA | 25/- | 2A d.c. | 25/- | 15V a.c. | 25/- |
| | | 10mA | 25/- | 5A d.c. | 25/- | 50V a.c. | 25/- |
| | | 20mA | 25/- | 3V d.c. | 25/- | 150V a.c. | 25/- |
| | | 50mA | 25/- | 10V d.c. | 25/- | 300V a.c. | 25/- |
| | | 100mA | 25/- | 20V d.c. | 25/- | 500V a.c. | 25/- |
| | | 150mA | 25/- | 50V d.c. | 25/- | 'S' Meter 1mA | 29/6 |

POST EXTRA. Larger sizes available—send for lists.

## ADMIRALTY B.40 RECEIVERS



Just released by the Ministry. High quality 10 valve receiver, manufactured by Murphy. Coverage in 5 bands 650kc/s–30Mc/s. I.F. 500kc/s. Incorporates 2 R.F. and 3 I.F. stages, bandpass filter, noise limiter, crystal controlled B.F.O., calibrator, I.F. output, etc. Built-in speaker, output for phones. Operation 150/230V a.c. Size 19¼in × 13¼in × 16in. Weight 114 lb. Offered in good working condition, £22.10.0. Carr. 30/-. With circuit diagrams. Also available B.41 L.F. version of above, 15kc/s–700kc/s. £17.10.0. carr. 30/-.

## UNR-30. 4-BAND COMMUNICATION RECEIVER

Covering 550 Kc/s — 30 Mc/s. Incorporates variable BFO for CW/SSB reception. Built-in speaker and phone jack. Metal cabinet. Operation 220/240v. A.C. Supplied brand new, guaranteed with instructions. **£12.10.0** Carr. 7/6

**NEW LAFAYETTE MODEL HA-700 AM/CW/SSB AMATEUR COMMUNICATION RECEIVER**

8 Valves, 5 bands incorporating 2 MECHANICAL FILTERS for exceptional selectivity and sensitivity. Frequency coverage on 5 bands 150–400 kc/s 550–1,600kc/s, 1·6–4·0Mc/s, 4·8–14·5Mc/s 10·5–30Mc/s. Circuit incorporates R.F. stage, aerial trimmer, noise limiter, B.F.O. product detector, electrical bandspread, S meter, slide rule dial. Output for phones, low to 2kΩ or speaker 4 or 8Ω. Operation 220/240V a.c. Size 7¾in × 15in × 10in. Supplied brand new and guaranteed with handbook 36 GNS. Carr. 10/-. S.A.E. for leaflet.

**R.C.A. AR88 SPEAKERS**

8in, 3 ohm speakers in metal case. Black crackle finish to match our 88 Receivers. Available Brand New and Boxed with leads. 59/6. Carr. 7/6.

**LAFAYETTE LA-224T TRANSISTOR STEREO AMPLIFIER**

19 transistors, 8 diodes, 1HF music power, 30W at 8Ω. Response 30–20,000 ± 2dB at 1W. Distortion 1% or less. Inputs 3MV and 250MV. Output 3–16Ω. Separate L. and R. volume controls. Treble and bass control. Stereo phone jack. Brushed aluminium, gold anodised extruded front panel with complimentary metal case. Size 10⅛in × 3⅞ × 7⅞in. Operation 115/230V a.c. £25. Carr. 7/6.

## SINCLAIR EQUIPMENT

Z.12 12 watt amplifier, 89/6. PZ4 Power Supply Unit, 99/6. Stereo 25 Preamp., £9.19.6. Q14 Speakers, £6.19.6. Micromatic Radio Kit, 49/6. Built, 59/6. Micro FM Radio Kit, £5.19.6.

ALL POST PAID

**SPECIAL OFFER**

2 Z12 Amps., PZ4 Power Supply, Stereo 25 Preamplifier, £22.

# G.W. SMITH & CO (RADIO) LIMITED

Phone: GERRARD 8204/9155
Cables: SMITHEX LESQUARE
3-34 LISLE STREET, LONDON, W.C.2

## POCKET MULTI-METER

Size 3¾×2⅜×1⅛in. Meter size 2⅛×1⅞in. Sensitivity 1000 O.P.V. on both A.C. and D.C. volts. 0-15, 0-150, 0-1000. D.C. current 0-150mA. Resistance 0-100k Ω. Complete with test prods, battery and full instructions, 42/6. P. & P. 3/6. FREE GIFT for limited period only. 30 watt Electric Soldering Iron value 15/- to every purchaser of the Pocket Multi-Meter.

## 3 to 4 WATT AMPLIFIER

3-4 watt Amplifier built and tested. Chassis size 7 × 3½ × 1 in. Separate bass, treble and volume control. Double wound mains transformer, metal rectifier and output transformer for 3 ohms speaker. Valves ECC81 and 6v6. £2.5.0 plus 5/6 P. & P.

## BSR TAPE DECKS

200/250 v. A.C. mains. Type TD2 Tape speed 3¾ twin track. Type TD10 2-track, 3 speed, plus rev. counter. Type TD10 4-track, 3 speed, plus rev. counter.

Due to 33⅓% Purchase tax which is now applicable on these items, prices will be announced as soon as available.

## *Special offer* ELEGANT SEVEN mk III

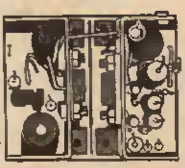
**SPECIAL OFFER. Power supply kit to purchasers of 'Elegant Seven' parts, incorporating mains transformer, rectifier and smoothing condenser, A.C. mains 200/250 volts. Output 9v. 100 mA. 9/6 extra.**

**Buy yourself an easy to build 7 transistor radio and save at least £10.0.0. Now you can build this superb 7 transistor superhet radio for under £4.10.0. No one else can offer such a fantastic radio with so many de luxe star features.**

ONLY **£4.9.6** *Plus 7/6 Post & Packing*

**★ De luxe wooden cabinet size 12½" × 8¼" × 3½". ★ Horizontal easy to read tuning scale printed grey with black letters, size 11½" × 2". ★ High 'Q' ferrite rod aerial. ★ I.F. neutralisation on each separate stage. ★ D.C. coupled push pull output stage with separate A.C. negative feedback. ★ Room filling output 350mW. ★ Ready etched and drilled printed circuit board back printed for foolproof construction. ★ Fully comprehensive instructions and point to point wiring diagrams. ★ Car aerial socket. ★ Fully tunable over medium and long wave, 168-535 metres and 1250-2000 metres. ★ All components, ferrite rod and tuning assembly mount on printed board. ★ 5" P.M. Speaker. ★ Parts list and circuit diagram 2/6, free with parts.**

## X101 10 WATTS (RMS) SOLID-STATE HI-FI AMP. WITH INTEGRAL PRE-AMP



Its great versatility ranges from: a simple intercom. to a modern HI-FI STEREO AMPLIFIER (two are required for Stereo). The X101 is a brilliant new addition to our highly successful range of products. Its professional performance and advanced solid-state circuitry techniques ensures reliability, combined with high fidelity reproduction, at an unbeatable price of 49/6 + 2/6 P. & P.

SPECIFICATIONS: *R.M.S. Power Output:* 13W (music power), 10W (SINE WAVE). *Sensitivity:* for rated output 1mV into 3kΩ load. *Frequency Response:* minus 3dB points are 20Hz and 40kHz. *Total Distortion:* at 1kHz for rated output 1·5%; for 5W output 0·35%. *Output Impedance:* 3 ohms (3–15 ohms may be used). *Supply Voltage:* 24V d.c. at 800mA (6–24V may be used); output at 14V d.c. supply with 3 ohms speaker 7W. *Size:* 2½in × 3in × 1⅛in. The fully comprehensive instruction manual does not only show the basics, such as circuit diagram and connections, but also gives practical easy-to-understand detailed information about the X101. Standard equalisation networks are given for most types of conventional inputs. They include: *Tape head, Mag. P.U., Xtal. P.U., Tuner, Mic,* etc.

CONTROL ASSEMBLY. (including resistors and capacitors): 1. Volume, price 5/-; 2. Treble, price 5/-; 3. Comprehensive bass and treble, price 10/-.

POWER SUPPLIES FOR THE X101: P101/M (for Mono) 35/- P. & P. 2/6. P101/S (for Stereo) 42/6 P. & P. 2/6.

PR101/M: A High Quality, Monoral Pre-amp and Control Unit, particularly suitable for use with the X101 if a ready-built, comprehensive, multi-input system is desired.

CONTROLS: *Selector Switch, Tape Speed Equalisation Switch* (3¾ and 7½ I.P.S.), *Volume, Treble, Bass, three position scratch filter and three position rumble filter.*

SPECIFICATION: *Sensitivities for 200mV output at 1kHz. Tape Head:* 3mV (at 3¾ I.P.S.). *Mag. P.U.:* 2mV. *Cer. P.U.:* 80mV. *Radio:* 100mV. *Aux.:* 100mV. Tape/Rec. Output: 100mV. Equalisation for each input is correct to within ±2dB (RIAA) from 20Hz to 20kHz. Tone Control Range: Bass: ±13dB at 60Hz; Treble: ±14dB at 15kHz. *Total Distortion:* (for 200mV output) <0·02%. *Signal Noise:* > —60dB. *Supply Voltage:* 24V, d.c. 59/6 plus 2/6 P. & P. A STEREO VERSION (PR101/S) WILL BE ANNOUNCED SHORTLY.

THE CLASSIC: High Quality Solid-State Amplifier (Mono). SPECIFICATION: Switched inputs for: *Tape head, Mag. P.U., Cer. P.U., Radio and Aux. Mains Input* 220–250V, a.c., 50Hz. The Classic is the combination of the above described items (X101, P101/M and PR101/M) on one common chassis. Its performance and space age styling makes if the ideal choice for the value-conscious Hi-Fi enthusiast.

Available within 4 weeks. **8 gns.** P. & P. FREE.

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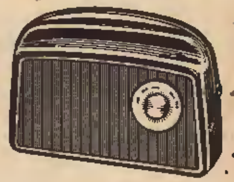
**600 milli-watt solid state 7, transistor plus diode and thermistor**

### Transistor Portable Radio

**plus Baby Alarm Facilities**



Special offer—Power Supply Kit to purchasers of Dorset Portable Radio parts, incorporating mains transformer, rectifier and smoothing condenser, A.C. mains, 200/250v., output 9v., 100mA. 9/6 extra.

Completely modulised high quality portable radio featuring complementary N.P.N. and P.N.P. output stage.

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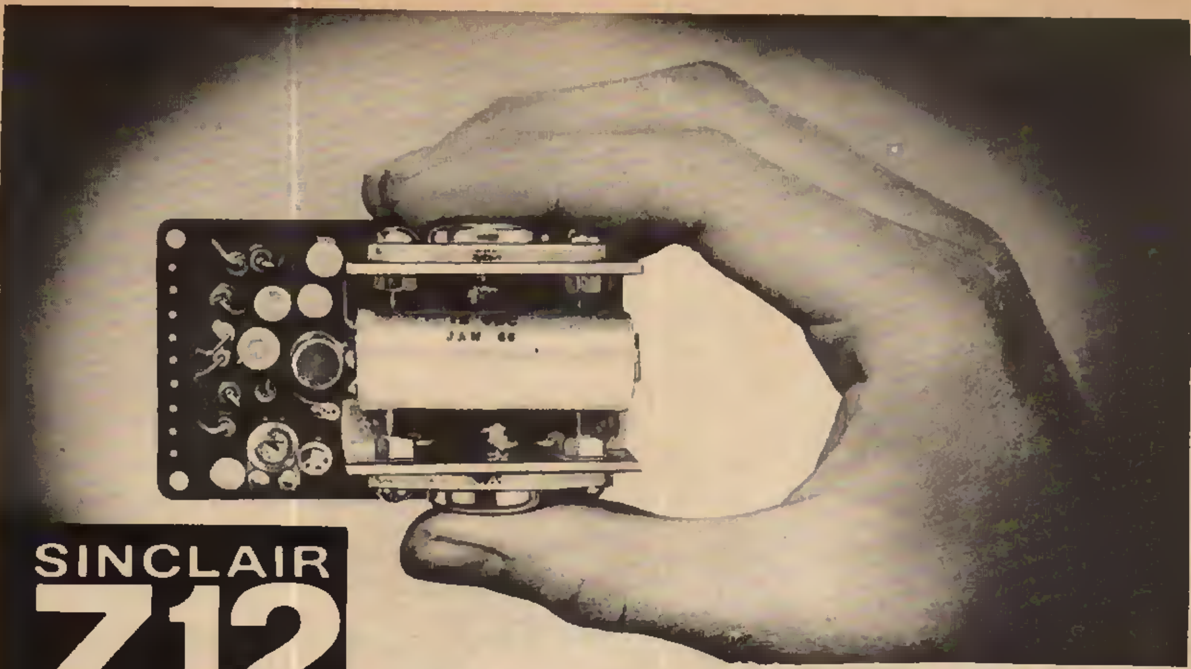

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# Lasky's Radio

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## Lasky's Birthday Draw

**The following 85 numbers have been drawn for prizes in our 35th Birthday Draw. Please refer to Page 12 of our Catalogue for details of entry if your number (on the front page of your Catalogue) is among those listed here:**

| | | | | | | |
|---|---|---|---|---|---|---|
| 000013 | 001415 | 002313 | 012802 | 024444 | 029686 | 034717 |
| 000092 | 001510 | 002414 | 012777 | 024818 | 029875 | 035900 |
| 000828 | 001582 | 002479 | 013626 | 024950 | 029900 | 036000 |
| 000899 | 001711 | 003060 | 013750 | 026515 | 029999 | 037017 |
| 000927 | 001777 | 003166 | 015000 | 027000 | 030166 | 038111 |
| 000929 | 001800 | 005000 | 016001 | 027009 | 030744 | 038212 |
| 000974 | 001900 | 005016 | 019020 | 028010 | 030844 | 039414 |
| 001054 | 001911 | 005161 | 020003 | 028455 | 030982 | 039565 |
| 001274 | 001922 | 005615 | 021414 | 028490 | 031010 | 043472 |
| 001288 | 001991 | 006768 | 021444 | 029030 | 032013 | 046782 |
| 001292 | 002101 | 006900 | 021500 | 029131 | 033417 | 047111 |
| 001333 | 002230 | 011717 | 023466 | 029444 | 034111 | 037388 |
| | | | | | | 048001 |

**The first 10 correct entries to be opened will receive £5 Lasky's Gift Vouchers, the next 25 will receive £1 vouchers and the next 50 will receive 10/6 vouchers.**

*Note: Members of Lasky's Radio staff and relatives are expressly excluded from entry in this competition.*

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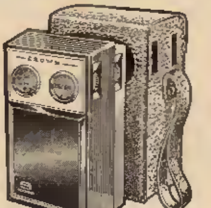
**LASKY'S PRICE £7.9.6** Post 5/-

## CROWN MODEL TRF-6 AM/FM

### 9 TRANSISTOR RADIO



Unbelievably small for an AM/FM receiver—the Crown is only 4½in × 2⅞in × 1⅛in. Super sensitive 9 transistor superhet circuit with directionless stabilised reception. AM cover; MW 535–1,605kc/s. FM cover; 88–108Mc/s. Superb tone reproduction. 2¼in PM speaker. Precision tuning. 6 section (14⅞in) telescopic aerial—clips into side when not in use. Output 280mW max. Beautifully styled and finished cabinet in black plastic with silver metal trim. Operates on one 9V battery. Complete with leather purse, ear-piece and battery. List Price 19½ Gns.

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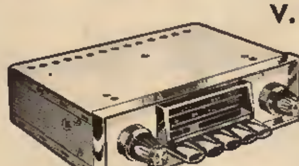
## MOTORING PLEASURE

## "EASI-TUNE" AM/FM MAJOR

### V.H.F. CAR RADIO



A completely new British made AM/FM car radio that brings the HI-FI quality of FM transmissions to your car (ALL the new local stations) PLUS medium waveband cover 185–570m and long waveband cover 1,150–2,000m (FM cover: 88–108Mc/s with automatic A.F.C.). Features five EASI-TUNE push buttons for wave change and instant selection of three of your favourite medium wave stations, plus full manual tuning. Nine transistor and four diode circuit gives immediate reception, powerful 3½W output and superior performance at high speed. Other features include illuminated dial, red "on" indicator, tone control. Strong metal case size 7 × 2 × 5½in (fits all standard cut-outs). Very handsome appearance, silver/black/chrome finish. For 12V positive or negative earth operation. Complete with 7 × 4in speaker, baffle board, universal mounting kit and instruction manual.

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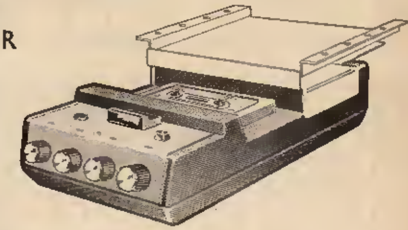
## NEW ANOTHER "EASI-TUNE" CAR ENTERTAINER

### THE STEREO-TONE

### STEREO TAPE CASSETTE CAR PLAYER

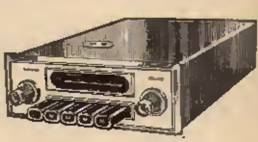


Another British first—right on time, right up-to-date the latest in travelling pleasure. Plays ALL the new great range of PHILIPS Musicassettes with over 250 titles now available—giving YOU the choice of music for your journey (each cassette gives up to 48min continuous play). The Stereo-Tone is compact, easy to fit and styled to enhance any car. Incorporates the well proven Philips tape play mechanism and a specially developed 12 transistor amplifier giving 2¼W output per channel with sharp stereo separation. Controls include on/off with indicator, single control for start/stop, fast forward and rewind, sep. volume, bass, treble and stereo balance controls. Tape loading and change are super easy—the Stereo-Tone slides out from its vibration free mounting for inserting or turning cassette over then pushes back for obstruction free operation. The Stereo-Tone cabinet is made from high quality scratch proof CYCOLAC plastic in dark grey with satin silver control panel with black knobs. Size only 9½ × 5½ × 3½in. Tape speed 1⅞ i.p.s. with transistor motor regulator. Operates on all 12V positive or negative earth systems. Complete with two loudspeakers, baffle boards, leads, etc., simple (four screw fixing) mounting assembly AND one Free Musicassette of your choice.

**LASKY'S PRICE £29.0.0** Post FREE

### TWO BAND TRANSISTOR CAR RADIO BARGAIN!

### MODEL CR-62



A new high quality imported all transistor superhet car radio that really breaks the quality/price barrier. A unique feature of this set are the four M/W band station preselection buttons which you yourself set to your own four favourite stations—this is in addition to full M/W band cover over 535–1,605kc/s and full L/W band cover over 150–300kc/s (IF frequency 455kc/s). Externally adjustable aerial trimmers ensure maximum output. Six transistor (including one drift type) and one diode circuit provides powerful 2W output. The set is adjustable for use on either positive or negative ground 12V systems (external line fuse fitted). Standard mounting size 6½ × 5½ × 2in—front panel ⅛in larger all round—finished in anodised aluminium with black push buttons. Complete with mounting brackets, full installation instructions and two baffle boards (for round or elliptical speaker). Fully guaranteed.

**LASKY'S PRICE £9.19.6** Post 5/-

**6 × 4in elliptical 8Ω dynamic speaker 17/6 extra—Post FREE.**

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VOL. 4 No. 5
May 1968

# PRACTICAL ELECTRONICS

## LABOUR OF LOVE

"THE trouble with certain amateurs" we heard a well known professional recently complain, "is that they make things far too good". This was a mild protest at the fastidious concern for detail and elaboration indulged in by some spare time constructors.

In expressing this opinion, this critic certainly revealed his awareness of amateurs, and indirectly paid tribute to the high standard of craftsmanship often found amongst the non-professionals. This is certainly gratifying. In all walks of life too much distinction is maintained between the amateur and the professional. In general parlance the term professional, when applied to person or product, suggests superiority. Quite commonly it is assumed that the amateur represents merely the second best.

The activities and achievements of individuals in fields outside their normal vocation are often belittled without just cause. Resentment of outsiders poaching upon their exclusive preserves, plus a feeling of insecurity or even of inferiority (unadmitted, of course) may be contributory factors for the patronising manner adopted by some professionals towards their amateur brethren.

So far as our own particular field of interest is concerned, we have occasionally encountered such attitudes from individuals professionally engaged in the electronics industry. Happily such cases are the rare exception. Many of our most esteemed friends and associates are in the industry. Professionals they may be, but also real amateurs at heart. For what does the word really mean but a lover, or devotee. Genuine interest and high proficiency in a subject (whatever it may be) should not be automatically nor exclusively equated with professionalism. Let's face it, there are good and bad workers on both sides of the fence!

Now to answer the above quoted criticism levelled at some amateurs. A project undertaken for enjoyment in one's own time is bound to reflect this in countless little ways. The finalised piece of home-made equipment will carry some marks of the builder's own personality, and not an inspector's rubber stamp applied at the end of a production line. The amateur has no time sheet to fill in, and if the fancy leads him to a little extravagance—it is his own pocket he dips into. Fussy concern for detail is no cause for condemnation, but rather for envy. Many a professional must, on occasion, wished he could have spent more time or used more material on a given project. But in the commercial world things are necessarily rather different. Ay, there's the rub!

F. E. Bennett—*Editor*

## THIS MONTH

### CONSTRUCTIONAL PROJECTS



### SPECIAL SERIES



### GENERAL FEATURES



### BEGINNERS



### NEWS AND COMMENT



***Our June issue will be published on Friday, May 17***

**All correspondence intended for the Editor should be addressed to: The Editor, PRACTICAL ELECTRONICS, George Newnes Ltd., Tower House, Southampton Street, London, W.C.2. Advertisement Offices: PRACTICAL ELECTRONICS, George Newnes Ltd., 15/17 Long Acre, London, W.C.2. Phone: 01-836 4363. Telegrams: Newnes London. Subscription Rates including postage for one year, to any part of the world, 36s.** 

# INTRUDER ALARM FOR SMALL CRAFT

THIS article describes the construction of a simple low cost alarm that will prove effective as a deterrent to vandals or marauders visiting your yacht or motor-boat.

Although primarily designed to prevent unlawful entrance through boat doors and hatches, it may also be employed as a burglar alarm for cars or as a domestic sentinel. Current consumption on standby is exceedingly low, in the order of microamps and the choice of a silicon transistor in the first stage insures against fortuitous switching of the relay through thermal influences.

## CIRCUIT DESCRIPTION

The circuit diagram for the alarm system is given in Fig. 1. In essence the circuit consists of an *npn* emitter follower TR1, the load of which is a 500 ohm 600 type relay RLA, followed by an astable pulse generator (TR2, TR3) switching an alarm at a selected frequency.

In the standby condition the transistor TR1 is held off by the loop of closed microswitches which are fitted to hatches and doors. It was found in practice that the relay would not trip even for a loop resistance of 50 kilohms, so it can be seen that high contact resistance, effected by alternative choice of contact plate switching through poor connection, should not reduce the efficiency of this alarm.

## ACTIVATION OF ALARM

If the loop line is broken through forced entrance, the small quiescent current through R1 is diverted to the base of TR1 which switches on, so energising relay RLA. The normally open contacts RLA1 close. This has the initial effect of providing a latching potential to the relay by way of R2 thus ensuring that any attempt to cut off the alarm by closing doors or hatches and so completing the loop is frustrated since the relay armature is held in effect by its own contacts.

Any attempts by the marauder to rip out the loop wires are equally ineffectual with this latching action.

## ASTABLE MULTIVIBRATOR

The closed relay contact RLA1 also completes the circuit for the complementary astable multivibrator circuit composed of TR2 and TR3. Most readers are probably familiar with the conventional multivibrator, easily recognised by its crossed pair of feedback capacitors. The circuit employed in this boat alarm produces a similar output pulse, but it is very different in its operation.

In the standby condition the electrolytic capacitors C1 and C2 are discharged, but with the closing of RLA1, C1 charges through the point contact diode D1 and RLB coil with a time constant appropriate to this series train. Simultaneously C2 charges by way of RLB coil, VR1, and R3—with a relatively larger time constant.

Since the charging of C2 is exponential from zero, a negative potential will appear at the base of the *npn* silicon transistor TR2, proportional to the values of R3 and the frequency control potentiometer VR1. This negative bias holds off TR2 and consequently TR3, since no collector current is being passed to the base of this transistor. With the charging of C2 the negative hold-off bias is removed and TR2 is switched into conduction with consequent bottoming of TR3.

This means that most of the supply volts now appears across RLB so closing the normally open contacts of RLB1. At this point the diode D1 is reverse biased and does not allow the rapid discharge of C1 through TR3. This capacitor now acts as a temporary supply to maintain the complementary pair in conduction. With the discharge of C1 and C2 by way of the base-emitter junction of TR2, D1, and VR1, the circuit reverts to its original state, with relay contacts opening prior to the next cycle of charging events.

## MARK-SPACE RATIO

Whilst the consumption of the operating unit is a nominal 20mA, the current taken by the alarm audio transducer will be very much greater. A degree of power conservation can be achieved by adjusting VR1 for the smallest mark-to-space ratio.

This setting will of course, be a compromise between an urgent alarm repetition rate, if this is required, and the available capacity of the batteries employed.

If a bank of high power zinc-carbon dry cells, such as Ever Ready HP1's are used with a car horn, the mark-space potentiometer setting should be at its lowest—although it must be stated that these cells would be more suited to a large underdome bell as an alarm.

# COMPONENTS . . .

**Resistors**
R1 100kΩ
R2 330Ω
R3 270kΩ
All 10%, ½ watt carbon

**Capacitors**
C1 100$\mu$F elect. 15V
C2 8$\mu$F elect. 15V

**Potentiometer**
VR1 10kΩ horizontal preset

**Transistors**
TR1 2N2926 (Yellow)
TR2 2N2926 (Yellow)
TR3 OC71

**Diodes**
D1, D2 OA81 (2 off)

**Switches**
S1 Bulgin s.p.s.t. key operated rotary snap switch (Home Radio)
S2 Push-to-break-single pole miniature push button switch (Radiospares)
SW-SZ Alarm switches—miniature button or lever type (Bulgin) (Quantity as required)

**Relays**
RLA 9V 500Ω coil, 1 make light duty contacts 600 Type (Keyswitch)
RLB 9V 500Ω coil, 1 make heavy duty contacts 600 Type (Keyswitch)

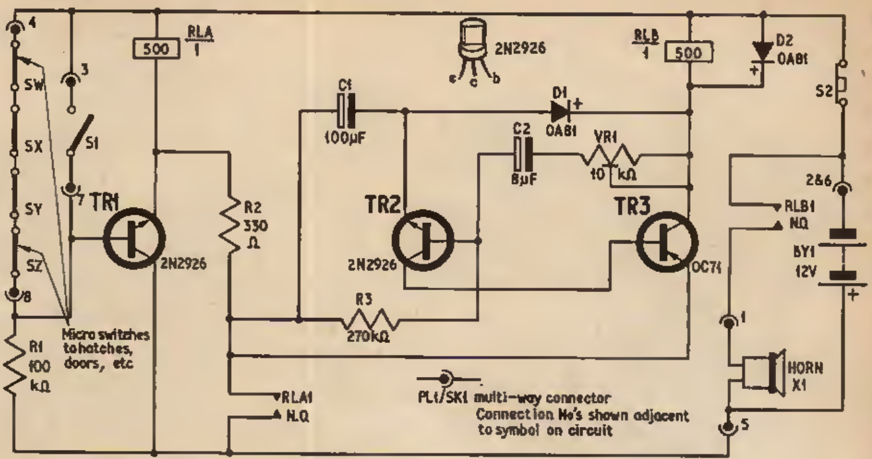



*Fig. 1. Circuit diagram of the boat alarm*

**Connectors**
PL1, SK1 8-way standard multi-pole connector (plug, socket, cover shell and retainer, Radiospares)

**Miscellaneous**
BY1 12V battery (see text)
X1 Car horn (see text)
Diecast Box (S.T.C.) $8\frac{3}{4}$in × $5\frac{3}{4}$in × $2\frac{5}{32}$in (Electroniques)
Miniature p.v.c. wire 7/40 (Radiospares)

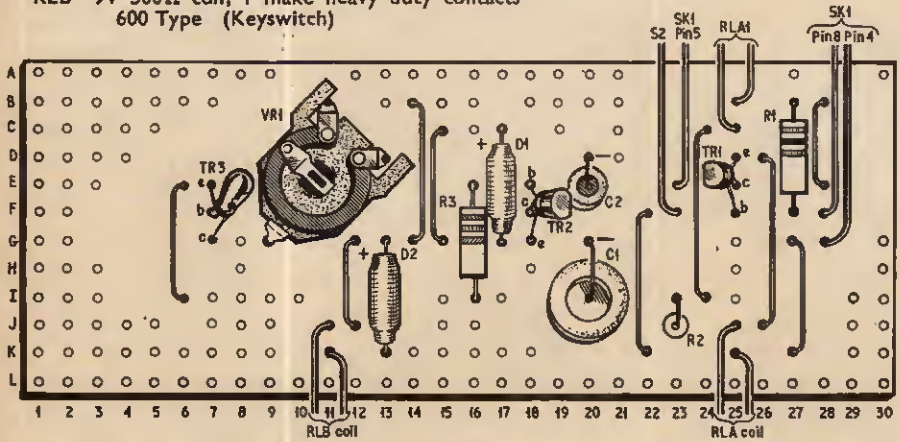
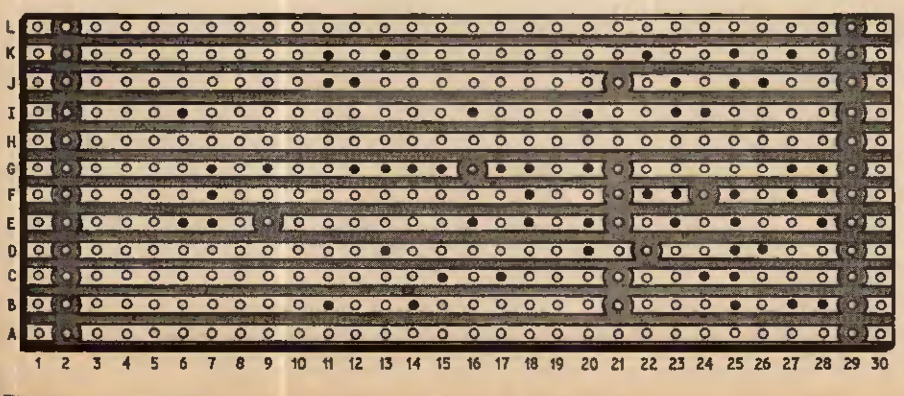
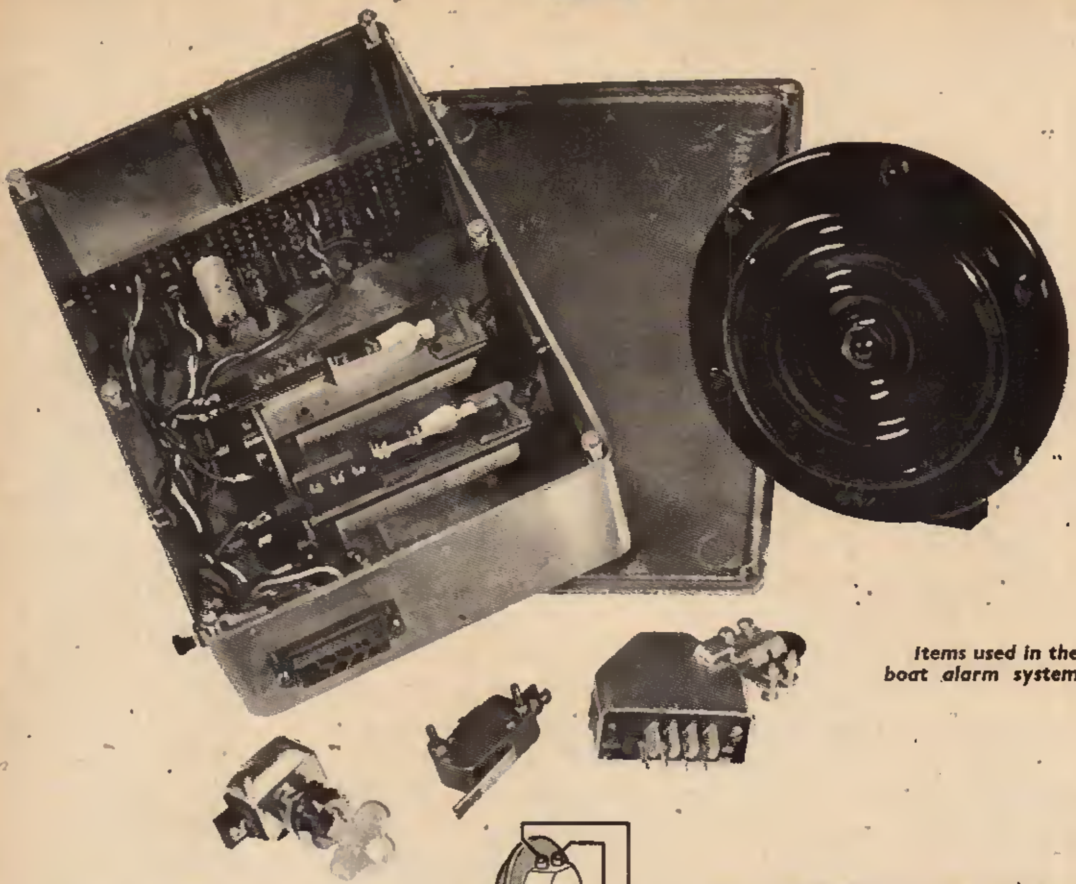



*Fig. 2. The Veroboard sub-assembly*

*(a) top view, showing arrangement of components*



*(b) underside view, showing breaks in conductor strips, and soldered connections*



*Items used in the boat alarm system*

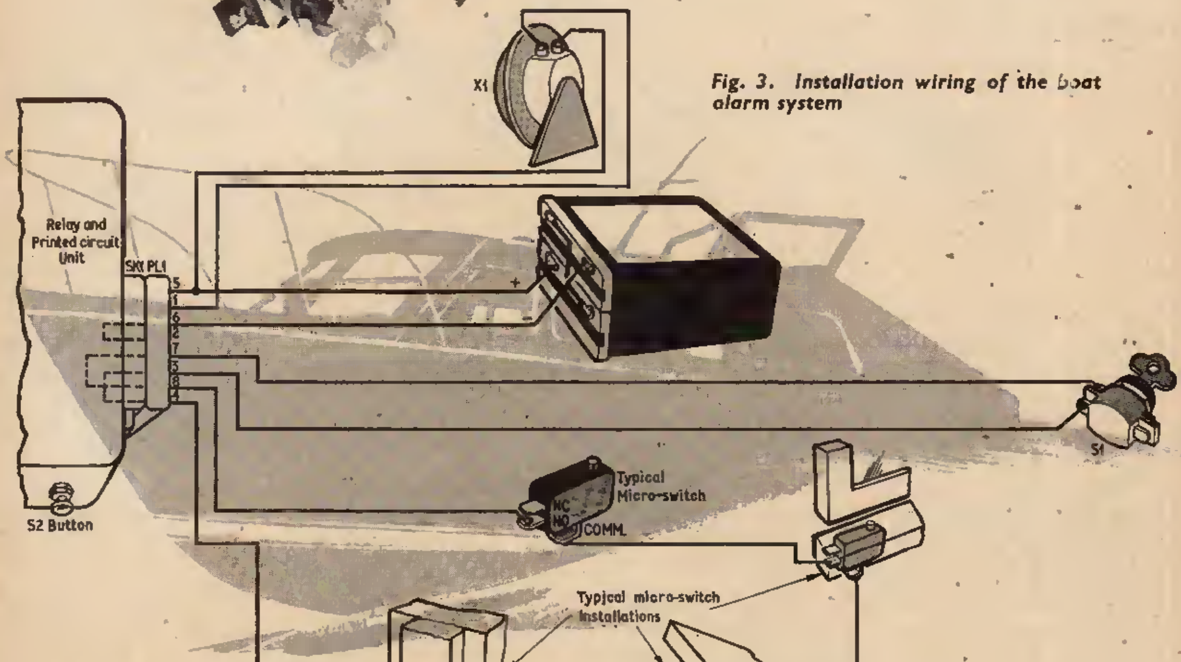



*Fig. 3. Installation wiring of the boat alarm system*

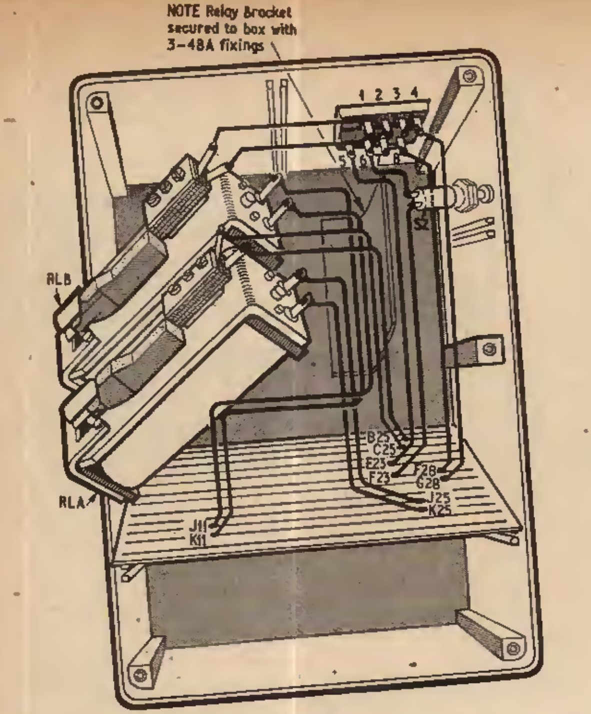



*Fig. 4. Interior view of the main unit. Relays and circuit board have been moved from their normal positions to clarify the wiring details*

Obviously secondary type batteries, i.e. lead acid or nickel cadmium will provide a much larger capacity, and may be preferred. Of the latter kind, the DEAC 5M6 is suitable (two will be required).

## VETO SWITCH

The key operated rotary snap switch S1 is in shunt with the alarm loop and is intended to be installed outside the cabin or other protected enclosure. When S1 is closed the alarm is inoperative and hatches and doors can be opened with impunity.

When the cabin is vacated and the door locked prior to departing from the vessel, the keyswitch is turned and the key pocketed, leaving the system set up. It follows of course, that the siting of this switch should be such as to make it as inconspicuous as possible.

## RESET SWITCH

If an intruder does set off the alarm the deactivation procedure on return would be to close the veto switch S1 with the key, and then press the push-to-break switch S2 which will de-energise relay RL1, so breaking the alarm contacts RLA1. Releasing this switch immediately sets the system to standby again.

## CONSTRUCTIONAL DETAILS

A suitable housing for the electronic assembly is an S.T.C. diecast box slotted to take the Veroboard sub-assembly (see diagrams and photograph).

Since this box is made of an aluminium alloy it is essential to paint this with a waterproof metal primer (as used on boats) to prevent corrosion. This should be done after the unit is sealed so that the paint applied forms a barrier to corrosive influences. Technical data sheets on the choice of primers and paints applicable may be obtained by writing for relevant data sheets to British Paints Ltd., Little Ship Division, Northumberland House, 303–306 High Holborn, London, W.C.1.

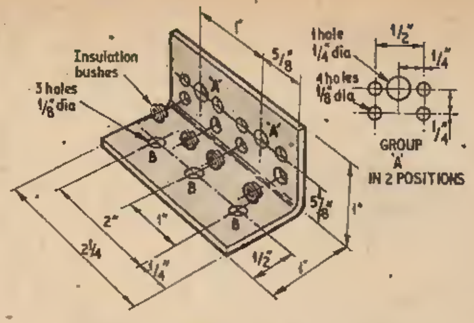



*Fig. 5. Relay mounting bracket*

In the relay sub-assembly, drilling of all holes in the mounting bracket should be done using the template shown as a guide. Since the circuit consists entirely of switching elements there is nothing particularly critical in the construction.

The unit should be given a functional check prior to boxing and particular care should be taken in making the breaks in the copper strip of the Veroboard at the extremes of the board, as one is sometimes inclined to do this extremely fast with a spot fact cutter and leave pieces of swarf to short adjacent strips.

## LOOP CIRCUIT SWITCHES

It is recommended that linear action microswitches be used in the loop circuit as "break-in" detectors. Either the button or lever type microswitches may be used as both types can be suitably recessed for doors and hatches.

Perhaps a more economic system would be the employment of stainless steel shims arranged to operate as contact plates. Wiring to these plates would be by way of eyelet tags, the assembly being both electrically and mechanically joined by brads driven through eyelet tags and shims to the wood backing. As this was not tried in the prototype system it can only be a suggested possible alternative.

Connection to all microswitch detectors should be by miniature p.v.c. 7/40 wire. Although not as inconspicuous as thin enamelled wire, there is less likelihood of abrasion producing false alarms through short circuits if the loop wires are spliced in the run.

Since any attempt to cut wires will trigger the alarm, concealment of these wires by channelling is not really important. Any burglar who is *au fait* with alarm systems would be deterred if he was made aware of some protective guard against his intended pillaging; after all, many motorists display stickers on their windows to the effect that X's proprietary alarm system is installed —which is a daunting first line deterrent.

## ACOUSTIC TRANSDUCER

The audible alarm device suggested is a v.h.f. car horn. However, since the contacts of relay RLB are heavy duty, other types of alarm may be fitted, such as a strident bell—this applies particularly if the system is adopted for home or business protection.

For the larger vessel with its own power supplies, existing hooters, marine horns, or loud hailers can be connected in the external switch circuit.

If the system is used for car protection, horn and headlights can be arranged in series with the RLB contacts. This will necessitate the use of an extra pair of contacts at the multi-pole connector PL1, SK1 for load sharing, as these contacts are only rated at 5 amps. ★

# AUDIO FAIR PREVIEW

Baker "Major" loudspeaker

Garrard SL95 auto transcription turntable

**By M. A. Colwell**

NOW THAT stereophonic broadcasts are in full swing in the U.K. (albeit of insufficient quantity and in a limited number of areas) the manufacturers are jumping on what is now an established bandwagon. The trend to what is termed the "tuner amplifier" is spreading to include stereo.

The problem re-emerges: What is the best unit to buy? This is one question constantly being asked, and it is almost impossible to answer in a few words, because of the many and varied aspects which anyone would look into—not least of these being the capital cost.

Probably the best approach is to take advantage of free entrance facilities offered to that popular event, the Audio Festival and Fair (April 18 to 21). This year the Hotel Russell, Russell Square, London, W.C.1, will open its back doors once again to the hoards of enthusiasts who diligently sort their way through the hotel rooms looking (or should I say listening) for the ultimate in sound reproduction.

Among a plethora of equipment, no doubt, the regular visitor will find his pet subjects and the newcomer will be baffled by what may appear to him to be the old game of hunt the thimble. How best can we help him? First of all, decide before you go whether your visit will be confined to certain types of equipment or a general survey of the whole scene. Stamina could be sucked dry if you attempt to take in every single item and demonstration, so that by the time you reach the fourth floor you will be glad to go down again.

If you are set on a particular branch of the audio scene, get a catalogue—it will save quite a bit of shoe leather. Browse through and make jottings of special interests. See the equipment on the ground floor booths; then after further jottings find your way to the demonstration rooms of your choice. The catalogue will help here again to locate these although, with a little common sense and observation of the direction arrows at strategic points, you should have no difficulty.

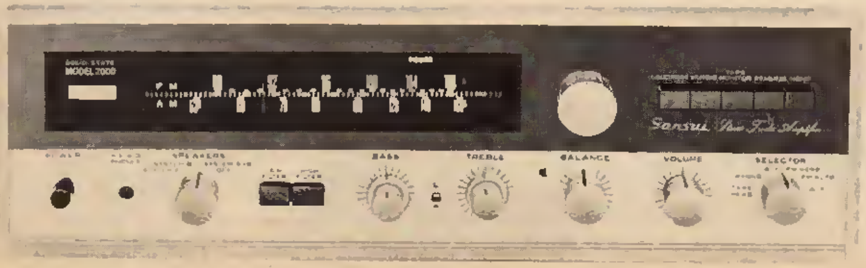
Now for the gear! The following is a preview of some of the equipment to be seen. It is interesting to note, during the current national prestige boosting campaign, that imported products are generally more expensive than the "home grown" varieties.

## TUNER AMPLIFIERS

The "tuner amplifier" mentioned earlier is a term applied in recent years to equipment combining radio tuning and amplification. The addition of a loudspeaker (or in the case of stereo, two loudspeakers) is usually left to the choice of the user, since there is a wide variety of types at different prices according to one's requirements.

Typical examples are shown by the Sansui range. The one illustrated here is the Model 2000 stereo tuner amplifier which overcomes input matching problems by using a field effect transistor at the front end of the amplifier. Inputs are provided for tape head, pick-up, or tuner (internal) for mono or stereo listening.

Later this year the Sansui Model 3000A will be available and offers a higher power output than the current Model 3000. This is also in stereo. The importers are Technical Ceramics Limited.



Sansui Model 2000 stereo tuner amplifier

*Arena stereo tuner amplifier type T1500F with two HT21 speaker units*

Arena of Denmark will be introducing their new stereo tuner amplifier type T1500F through Highgate Acoustics. Modular construction has been used and it offers an output power of 6 watts per channel for input sensitivities of 10$\mu$V for a.m. and 1$\mu$V for f.m. The picture shows the unit with two matching speakers type HT21.

In addition to their current range of tuner amplifiers, the Trio Corporation of Japan are presenting a new solid state amplifier, the TK150E stereo, through their agents B. H. Morris & Co. (Radio) Ltd., a subsidiary of Lasky's Radio. The price compares modestly with the Supreme I—a 64W per channel stereo amplifier, employing separate bass, mid- and high-range amplifiers, expected to retail at £280.

Armstrong will be showing their Series 400 and Series 27 equipment which includes amplifiers, tuners, and stereo decoders.

When selecting f.m. tuners, look for a.f.c. This overcomes many drifting and fading problems often caused by intervening obstructions between transmitter and receiver, or varying atmospheric conditions.

Provisional information obtained from Rogers Developments (Electronics) Ltd., reveals a new f.m. tuner using an f.e.t. front end enabling it to handle large signals without cross modulation, while at the same time being suitable for areas of low signal strength. A.F.C. is incorporated in this model. A multiplex stereo decoder is available as an optional extra. This "Ravensbourne 2" tuner has been designed to match the "Ravensbourne" stereo amplifier.

## SPEAKER UNITS

Many people have different ideas on what is the best speaker. It is largely a matter of personal choice since almost all manufacturers claim the best from their units. Look for a specification with a high flux density magnet and strong rigid frame if going for a moving coil type. Of course, it must have an impedance to match the amplifier. Excellent results are obtained with the established Quad electrostatic unit.

Well known names such as Wharfedale, Whiteley, Celestion, Goodmans, and so on, will no doubt attract the usual audiences for comparative listening. Of course, they all use different records, pick-ups, and amplifiers, which may give slightly differing results. So it is difficult to make direct comparisons, especially when the rooms are packed with steaming bodies under the floodlights. Perhaps you may be athletic enough to dash from one room to another before the memory of what was heard first has faded.

In between the aural bliss of Satchmo and the "1812", take a look at the Titan Minor loudspeaker by Audio & Design. This uses a titanium cone on beryllium copper suspension. It is claimed to reproduce bass more efficiently than conventional types for its size. It is available housed in a cabinet 17½in × 11in × 8¼in. Power handling capacity is 15 watts from 40Hz to 22kHz, ± 4dB.

## DISC EQUIPMENT

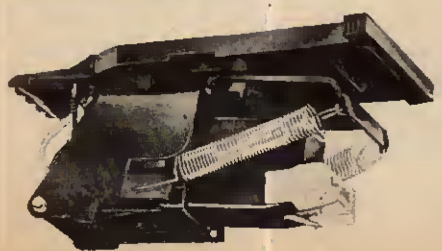
Ancillary equipment can be added at various stages as funds permit, but it is always worth making notes at the Fair for future reference.

Pick-ups have seen some design changes in recent years and it will be interesting to see what is new. Tracking weight is frequently a subject of much confusion. Let it not be assumed automatically that the lighter the stylus pressure, the better the performance. Similarly with record wear, much depends on the design of the pick-up arm and, even more, on the true running of both turntable and disc.

Where these factors are near perfect, then one can entertain the ¾ ounce pressure, otherwise there is the risk of groove jumping on less accurate turntables and discs. Pick-up arms should be *very* free moving both horizontally and vertically.

Of unusual design, the Shure M75E-95G "Gard-a-Matic" Hi-Track cartridge, is designed specifically for the new Garrard SL95 transcription turntable (see later). The performance is equivalent to that of the M75E but with a retractile safety suspension system, claimed to provide scratch-proof, bounce-proof operation where floor vibration is a problem. Shure also

*Shure M75E-95G "Guard-a-Matic" cartridge with suspension system*



*Rogers "Ravensbourne 2" f.m. tuner*

announce new models in the "economy" range of cartridges. The M31E and M32E have elliptical tipped stylii for tracking at 1–2gm and 2½–5gm respectively.

Audio & Design are introducing a stereo "induced field" cartridge with an output of 0·9mV per cm/sec. It uses an elliptical tipped stylus and is intended for feeding into high impedance inputs.

Cosmocord have developed another version of the stereo compatible cartridge announced last year. The Acos GP91SC incorporates a mono crystal for mono or stereo records. The stylus is suspended on a flexible plastics arm so that it will track stereo grooves, while reproducing a mono signal. It is available in three versions with outputs of 200, 350, or 640mV at 1·2cm/sec.

The Goldring Model GL75 transcription unit, with "free field" stereo magnetic cartridge, maintains the tradition of their using variable speed motor units. The new pick-up arm has a sliding counter balance to calibrate stylus pressure, and can be raised or lowered hydraulically on to the disc by operating a simple lever.

Garrard equipment at a more modest price include the AP75 single record player, Models SL95 and SL75 auto transcription turntables and the Model 3500 auto turntable, with a low mass pick-up arm, and cue and pause control.

The Model SL95 features "gimbal-type" pick-up arm pivots; the arm has afromosa wood set into aluminium for low frequency resonance damping. The record platform can be pushed down out of the way for single play operation.

Following some suggestions made to B.S.R. they have now superseded the UA70 with a new Model UA75, which uses a heavy cast alloy machined turntable.

## TAPE RECORDERS

Probably the most interesting news in the tape recording field is from Ferrograph. After 18 years of pounding on their "Tape Deck" (which was originally registered as a trade mark), with very little alteration to the basic design, they have decided to up-date the appearance and construction to the sleek squarish model basic to the new Series 7.

The electronics are similarly up-dated to all solid state silicon devices, including f.e.t. input stages. The machine can be used horizontally or vertically with easy access to the electronic units. A time switch is incorporated for preset starting without the need for it to be previously powered. Several other features are to be found, based on principles in its forerunners. Pre-record facilities for multi-play echo will be found on stereo models, which are supplied with either half- or quarter-track heads.

For another example of a professional studio tape recorder, look out for the BTR4 by E.M.I. Its complementary portable recorder the L4, with film sync facilities is popular for field work among professionals and amateurs.

The latest Brenell deck, Mark 5 Series 3, will be on show; features of this model include a self-compensating braking system, and space for accommodating up to four heads for mono or stereo.

## ACCESSORIES

Microphones for mono or stereo will be in abundance, including the MD409, and MD415 by Sennheiser (through Audio Engineering), specially designed for "pop" group vocalists. Both have anti-feedback properties and the bass response is tailored for close microphone technique.

The same Company is also demonstrating a new pair of stereo headphones, HD414, for those audiophiles who want personal listening while the wife watches the television.

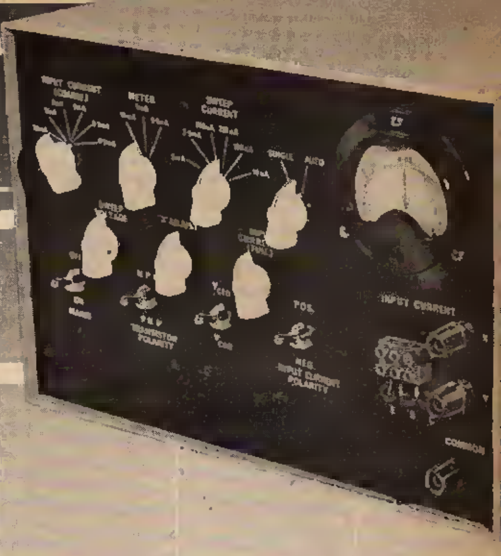
The well known range of Shure microphones is to be supplemented by the Unidyne IV series, Models 548 (mono) and 548s (stereo). These are designed for professional applications and are fitted with Cannon type connectors.

Finally, a word of advice. Don't arrive at the doors without a ticket or you may not get in. Tickets can be obtained free of charge through your local hi fi dealer or from the organisers of the Audio Festival and Fair, 42 Manchester Street, London, W.1. (include a stamped addressed envelope). ★

*Ferrograph Series 7 stereo recorder*

*Goldring GL75 transcription unit with lever operated pick-up arm*

# TRANSISTOR CURVE TRACER




By G.K. FAIRFIELD

THE most useful test for a transistor is to plot its complete range of input/output characteristics. Not only will this show up the transistor limitations but a great deal of useful information can be derived from a study of the curves.

These characteristics can be produced by making measurements point-by-point using meters to indicate the value of currents flowing. However, this "static" method is subject to a number of serious limitations, the most important of which is the overheating and possible destruction of the transistor when measurements are attempted at the higher current end of its characteristics.

A much better method is to allow the transistor to reach its high current values for only a very short period of time. This is called the "dynamic" method and to use it a cathode-ray oscilloscope must be used to display the transistor characteristics.

This article describes a unit which may be connected to almost any conventional oscilloscope in order to display the transistor characteristics. Single curves can be shown and arrangements are included to permit "families" of ten or more curves to be displayed.

## METHOD OF TESTING

The basic technique is shown in Fig. 1. Half sine waves of voltage are applied to the collector of the transistor from a mains transformer via a load resistance $R_L$ and rectifier D1. A constant bias current is fed to the transistor input through switch S1, either to the base or the emitter depending upon whether common-base or common-emitter curves are required.

A voltage proportional to the collector current ($I_C$) is developed across the load resistance $R_L$ and applied to the Y-plates of the oscilloscope. The collector voltage $V_C$ is applied to the X-plates.

Thus as the voltage $V_C$ varies from zero to the peak of the half sine wave, so the current $I_C$ changes due to the non-linear characteristics of the transistor. The $I_C/V_C$ transistor characteristic is plotted on the c.r.o. screen.

Since the transistor is put through this cycle of applied collector voltage change at a rate of 50 times per second (actually 100 times if the reverse change of $V_C$ is also used as in Fig. 1) then a clear trace of this characteristic is maintained on the face of the tube. This curve is, of course, applicable to the particular bias current chosen which depends on $V_B$ and the value of bias resistor $R_b$. To plot a series of such curves it is only necessary to change the value of $R_b$ in steps, allowing one complete curve to be traced for each fixed value of $R_b$.

With the simple arrangement of Fig. 1 it is possible to plot $I_C/V_C$ curves for common-emitter or common-base configurations by suitable settings of S1. Both *pnp* and *npn* transistors can be tested by choosing the correct polarity of half-sine wave obtained by the appropriate setting of a reversing switch S2, connected to the rectifier D1.

In order to convert this circuit into a practical arrangement it is necessary to add a means of changing the

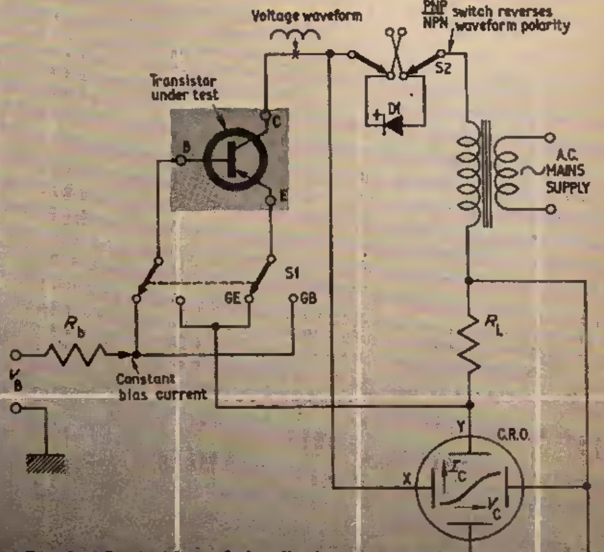



*Fig. 1. Basic idea of the display system*

value of $R_b$ between each curve traced in order that multiple curves can be displayed. It will also be necessary to include a cathode follower (or emitter follower) between the X output of the circuit and the oscilloscope in order to avoid loading the high impedance collector circuit. This is particularly important when common base curves are to be displayed. Several different collector voltage and current ranges will be required to accommodate all the transistors that are likely to be tested.

## PLOTTING FAMILIES OF CURVES

A convenient number of curves to produce a useful "family" is about ten. These curves will be traced one by one and in order to see them all together on the oscilloscope screen it will be necessary to repeat them fairly regularly (or alternatively a cathode-ray tube could be used having a very long persistance phosphor screen). What is required is a rapid single-pole ten-way switch stepping on automatically and continuously to repeat its sequence of ten positions. A Post Office type uniselector switch meets this specification admirably. For those not familiar with this device a brief description will not be out of place. Refer to Fig. 2.

The uniselector switch is operated by applying a pulse through the coil which pulls down an armature carrying a claw to engage on the ratchet wheel. This wheel is attached to the wiper arms of the switch; the fixed contacts are arranged in a semi-circle around the switch arm. Thus each applied pulse rotates the switch arm by one position and engages with the next fixed contact.

Many versions of the uniselector are available and can generally be adapted for our purpose. A number of parallel banks of switch contacts are usually found and three will be required for the Curve Tracer. A standard type of driving coil is one requiring 50 volts to initiate a switch operation. Other types may be found and the driving voltage can be changed or coil rewound to accommodate a different design. The one used in the prototype had a 75 ohm coil.

## FINAL CIRCUIT

The complete circuit is shown in Fig. 3. A stabilised power supply is included which uses two 150V reference tubes V1 and V2. This supplies the constant voltage source for the base current determining network, and also voltage supplies for the cathode follower V3 driving the X-plates of the oscilloscope.

A five-pole, two-way switch S8 enables either a single curve to be traced or a family of characteristics displayed. (S is for a single sweep display; A is for auto-repetition.) It is convenient to commence our description of the curve tracer by considering switch S8 to be in the "single" position.

The appropriate polarity of base current is selected by switch S5 (generally negative for *pnp* and positive for *npn* transistors, although a reverse characteristic may be required sometimes).

The reference voltage is applied to a potentiometer network S6 which allows a selection of input currents covering the range 10mA, 5mA, 2mA, 1mA, 500$\mu$A, and 200$\mu$A, depending on the switch position. Fine control of input current for a single trace is provided by potentiometer VR2, which can be calibrated 0–1, 0–2, and 0–5 if desired, to correspond with the choice of range available.

A meter is also included in the circuit to measure the exact value of current supplied to the base. This has current shunt resistors, wound to give full-scale deflection of 10, 1, and 0·1mA. The current passing

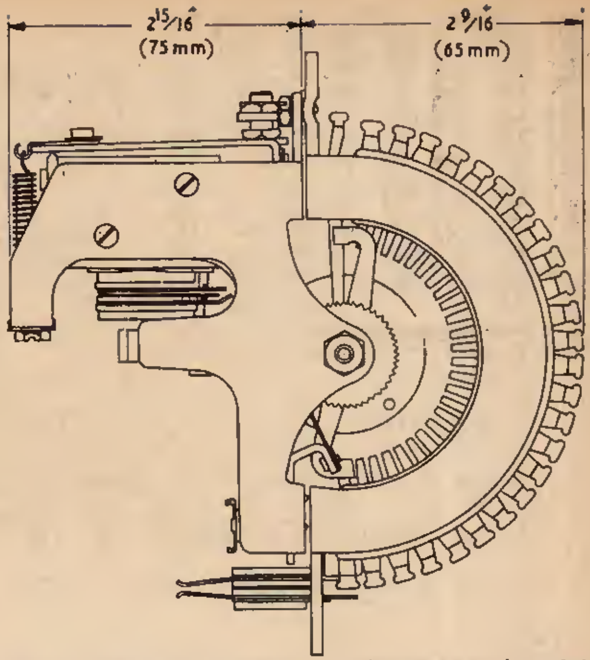



*Fig. 2. Side view of uniselector; the armature is at top left above the coil*

through the meter is direct current; a full-wave bridge rectifier has been included in the circuit. This is to avoid changing connections to the meter when the polarity of the input voltage is reversed by S8. If desired this bridge can be omitted and its place taken by a reversing switch similar to that shown for S2.

The configuration of the transistor undergoing test is selected by means of S4. This permits the current set by VR2 to be applied to the base or emitter depending upon whether it is desired to display the grounded emitter or grounded base characteristic.

The collector voltage is a rectified sine wave supplied via D3 from the 50V secondary of a mains transformer. The maximum amplitude of this sweep voltage is controlled by the setting of potentiometer VR1. The polarity of the sweep voltage is selected by S2 to suit either *pnp* or *npn* transistors.

The sweep voltage is also applied via the cathode follower V3 to the X-plate of the oscilloscope tube. A preset adjustment VR3 is provided in V3 cathode circuit to give zero adjustment.

The current axis voltage, representing the change in collector voltage as the transistor collector potential is swept through its range of values, is taken from across a resistor, selected by S3, and fed to the Y-axis terminal of the oscilloscope tube.

Six current ranges are provided for maximum currents of approximately 5mA, 2·5mA, 500$\mu$A, 250$\mu$A, 100$\mu$A, and 10$\mu$A, depending on the position of S3. Resistor R7 is included to complete the circuit and prevent a surge in current which would otherwise occur each time S3 was moved to a new position.

When switch S8 is moved to the "auto" position, the uniselector is brought into action. Instead of the value of the input current being set by the position of VR2, a set of resistors, R26 to R34, are sequentially brought into circuit as the uniselector is stepped round to each of its contact positions in turn.

A separate curve is displayed during the time that the uniselector is stationary and a particular resistance

# CIRCUIT DIAGRAM

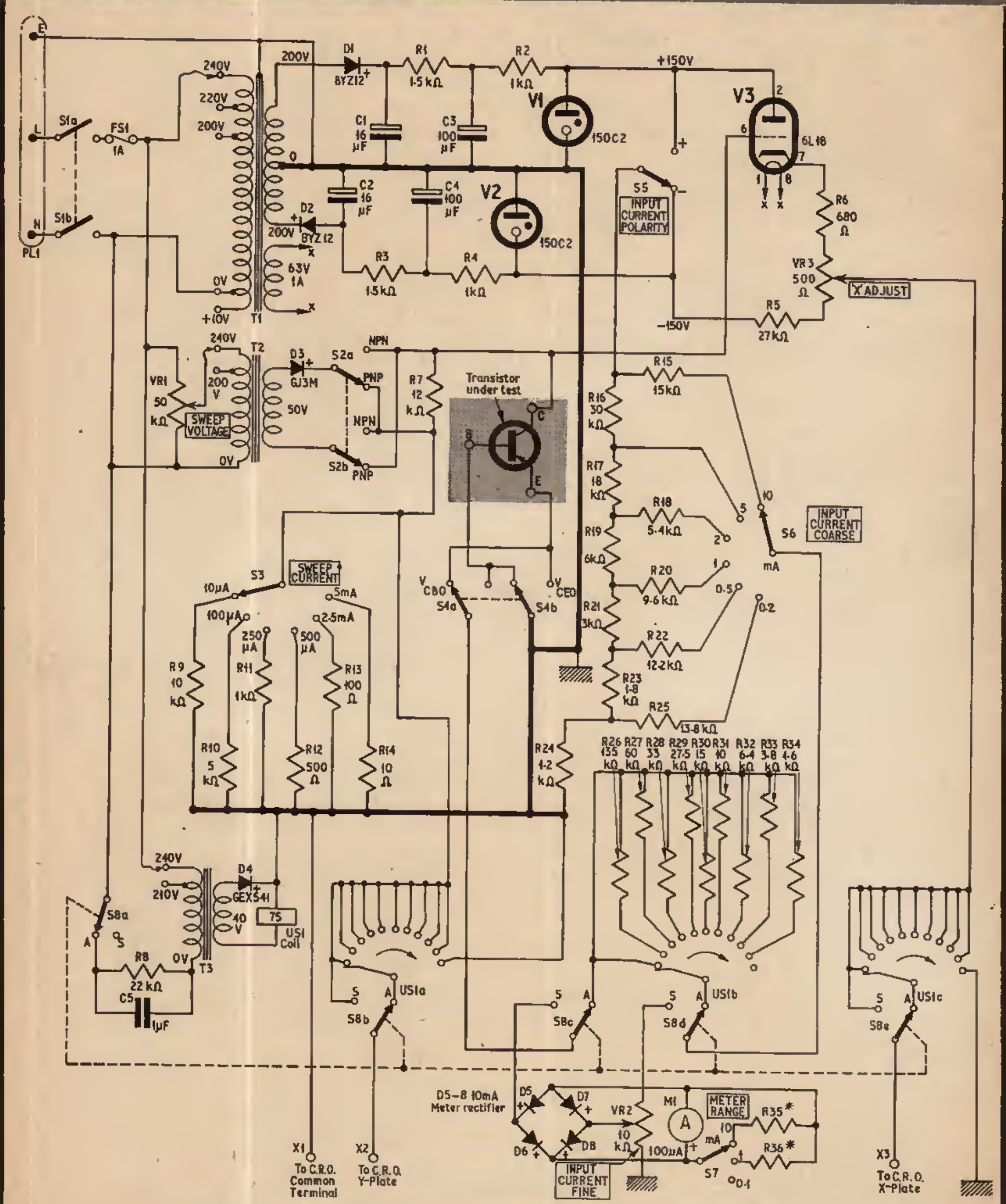
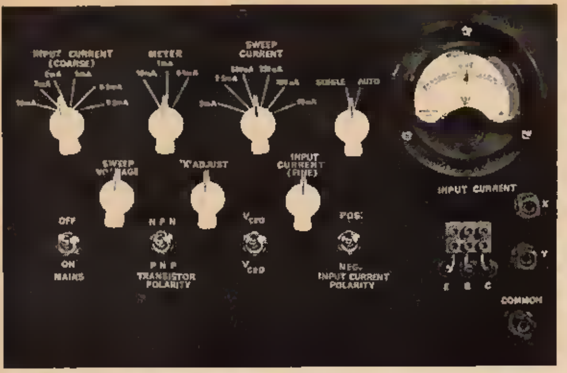



*Fig. 3. The complete circuit of the curve tracer for connection to a d.c. oscilloscope*




is in the circuit. The uniselector is automatically stepped on to the next position and a second curve is displayed. The process then repeats and the whole cycle repeats every 200ms. This is sufficiently rapid to give the illusion of a stationary set of curves being displayed on the screen simultaneously.

The uniselector is energised from the 40V secondary winding of a mains transformer T3 via rectifier D4. The primary of this transformer is connected to the mains supply via one of the arms of the switch S8a. A time-constant (C5, R8) is included in the primary circuit in order to phase the application of an operating pulse to the uniselector to correspond to the half cycle when the collector sweep is inoperative.

### COMPONENTS

It is appropriate to mention some of the components used in the instrument. The majority of them are easily obtained, but it may be necessary to select values of some resistors by measurement of a batch of the nearest preferred nominal types. Others will need to be made up by combinations of suitable values, these being indicated in the components list and in Table 1.

Resistors R35 and R36 are made from resistance wire (eureka or nichrome) to give the required values to indicate 10mA and 1mA f.s.d. on the meter. The thinner the wire used, the shorter its length need be. It can be wound on any insulating former to hand. If the wire obtained is not insulated make sure that adjacent turns do not touch; it is probably a good idea to deposit molten wax on the finished article to keep the wire firmly in place.

As an example, 38 s.w.g. eureka wire has a resistance of 23·8 ohms per yard or 1·5 inches measures one ohm.

# COMPONENTS . . .

**Resistors**

| | | | | | |
|---|---|---|---|---|---|
| R1 | 1·5kΩ | R13 | 100Ω | *R25 | 13·8kΩ |
| R2 | 1kΩ | R14 | 10Ω | *R26 | 135kΩ |
| R3 | 1·5kΩ | R15 | 15kΩ | *R27 | 60kΩ |
| R4 | 1kΩ | *R16 | 30kΩ | R28 | 33kΩ |
| R5 | 27kΩ | R17 | 18kΩ | R29 | 27kΩ |
| R6 | 680Ω | *R18 | 5·4kΩ | R30 | 15kΩ |
| R7 | 12kΩ 5% | *R19 | 6kΩ | R31 | 10kΩ |
| R8 | 22kΩ 1W | *R20 | 9·6kΩ | *R32 | 6·4kΩ |
| R9 | 10kΩ | *R21 | 3kΩ | *R33 | 3·8kΩ |
| *R10 | 5kΩ | *R22 | 12·2kΩ | *R34 | 1·6kΩ |
| R11 | 1kΩ | R23 | 1·8kΩ | R35, 36 (see text) | |
| *R12 | 500Ω | R24 | 1·2kΩ | | |

All 10%, ½ watt except R7, R8, R35 and R36
Resistors marked with an asterisk are not standard preferred values and should be selected from nearest preferred values, or made up from combination of two resistors to give each required value. See Table 1

**Potentiometers**
VR1 50kΩ linear carbon
VR2 10kΩ linear wirewound
VR3 500Ω linear wirewound

**Capacitors**
C1 16μF elect. 450V
C2 16μF elect. 450V
C3 100μF elect. 450V
C4 100μF elect. 450V

**Transformers**
T1 Mains transformer (Parmeko type P2752)
Pri.: +10, 0, 200, 220, 240V;
Sec. 1: 200–0–200V 75mA; Sec. 2: 6·3V 1A;
Sec. 3: 6·3V 2A; Sec. 4: 6·3V 1A
(Sec. 3 and sec. 4 are not used in this circuit)
T2 Mains transformer (Douglas type MT 102AT)
Pri.: 0, 210, 240V
Sec.: 0, 19, 25, 33, 40, 50V 0·5A (Sec. 0–50V used for T2)
T3 Same as T2 but Sec. 0–40V used

**Valves**
V1 Gas filled stabiliser type 150C2
V2 Same as V1
V3 6L18 triode

**Diodes**
D1 BYZ12 *or* SJ403
D2 BYZ12 *or* SJ403
D3 GJ3M
D4 GEX541
D5–8 Meter bridge rectifier 10mA

**Meter**
M1 0–100μA moving coil

**Fuse**
FS1 1A chassis or panel mounting fuseholder

**Switches**
S1 Double-pole, on/off, toggle
S2 Double-pole, changeover, toggle
S3 2-pole, 6-way wafer (only 1 pole is used)
S4 Double-pole, changeover, toggle
S5 Single-pole, changeover, toggle
S6 2-pole, 6-way wafer (only 1 pole is used)
S7 Single-pole, 12-way wafer (only 3 ways are used) *or* 4-pole, 3-way (only 1 pole is used)
S8 6-pole, 2-way (only 5 poles are used)

**Uniselector switch**
US1 3 or 4 banks, each 25 ways, coil resistance 75Ω

**Terminals**
X1, X2, X3 Screw terminals (3 off)

**Plug and socket**
PL1 Mains plug, chassis mounting, type P73

**Miscellaneous**
Chassis 10in × 7in × 2in or made from aluminium sheet 14in × 11in 18 s.w.g.
Plywood or aluminium sheet for case 12in × 8in × 8in internal dimensions
Clamps and insulation for C3 and C4 (2 off)
Valveholders, B7G (2 off); B8A (1 off)
Tags boards, double, 18-way, 12-way, and 7-way
Tag strip, single, 5-way
Brackets for 18-way tag board
Pillars, 2¾in long, for 12-way tag board
Grommets; 3-way terminal block
Seven knobs, nuts and bolts, wire

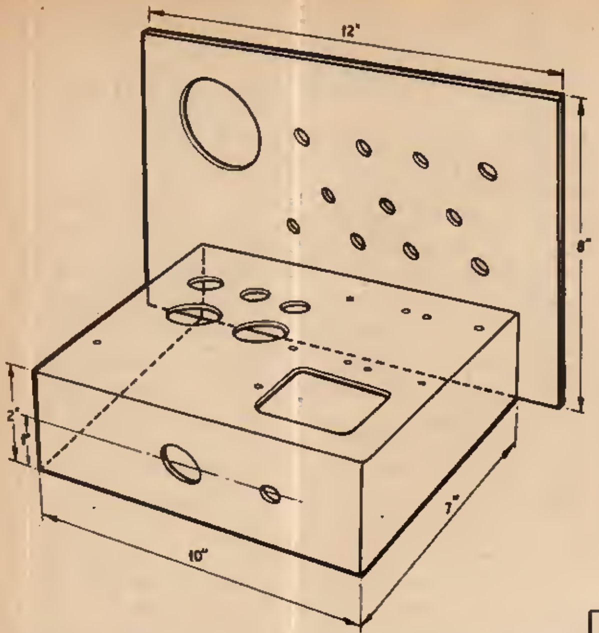



*Fig. 4. Front panel and chassis assembled. Hole sizes and positions will depend on the components actually obtained, but the wiring diagrams in Figs. 5, 6, and 7 appear half scale and give a reasonable guide to positions*

**Table 1: NON-STANDARD RESISTOR COMBINATIONS**

| Resistor | Required value | Combination |
|---|---|---|
| R10 | 5kΩ | 10kΩ + 10kΩ in parallel |
| R12 | 500Ω | 1kΩ + 1kΩ in parallel |
| R16 | 30kΩ | 15kΩ + 15kΩ in series |
| R18 | 5·4kΩ | 2·7kΩ + 2·7kΩ in series |
| R19 | 6kΩ | 12kΩ + 12kΩ in parallel |
| R20 | 9·6kΩ | 6·8kΩ + 2·7kΩ in series |
| R21 | 3kΩ | 1·5kΩ + 1·5kΩ in series |
| R22 | 12·2kΩ | 12kΩ nominal selected by measurement |
| R25 | 13·8kΩ | 56kΩ + 18kΩ in parallel |
| R26 | 135kΩ | 560kΩ + 180kΩ in parallel |
| R27 | 60kΩ | 120kΩ + 120kΩ in parallel |
| R32 | 6·4kΩ | 33kΩ + 8·2kΩ in parallel |
| R33 | 3·8kΩ | 8·2kΩ + 6·8kΩ in parallel |
| R34 | 1·6kΩ | 5·6kΩ + 2·2kΩ in parallel |

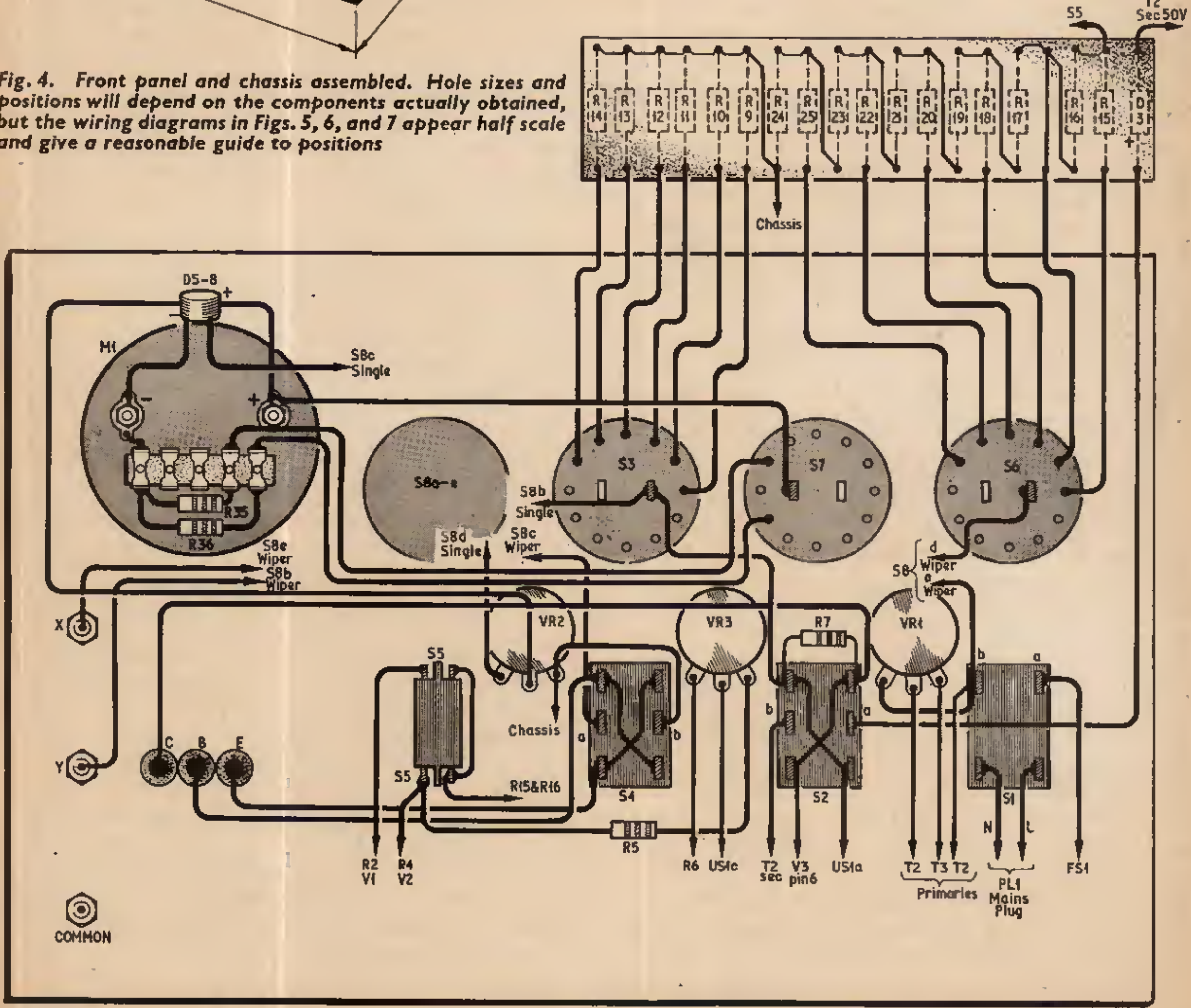



*Fig. 5. Wiring the components on the front panel. The component group board is tilted up to show connections, but is in fact fitted to brackets on the front panel. This drawing appears approximately half scale*

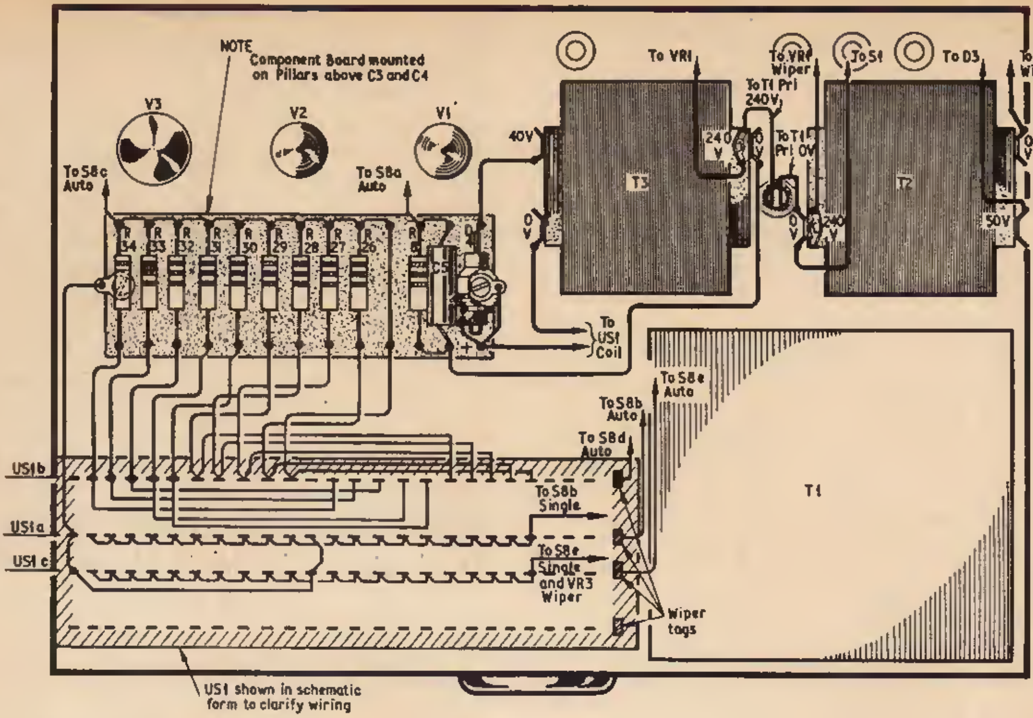


*Fig. 6. Top side wiring of the chassis. Each dash on the uniselector represents an outlet tag; the wiper is at the right hand end and coil connections underneath (not visible here). The uniselector is mounted on pillars above the chassis. C3 and C4 are underneath the group board. This drawing appears half scale*

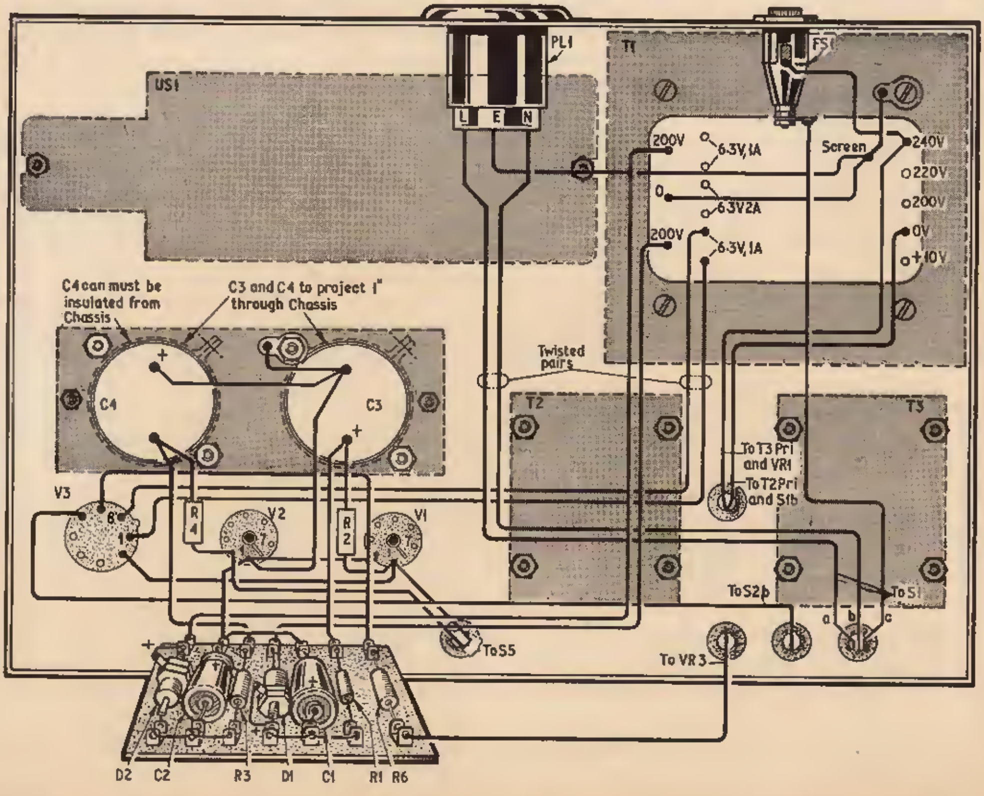


*Fig. 7. Underside wiring of the chassis. The group board is tilted to show the component wiring clearly*

Do not allow the wire to become stretched or the resistance will increase per unit length. The values of resistance needed for R35 and R36 will depend on the d.c. resistance of the meter coil. These can be calculated from the formula:

$$R_S = \frac{R_M \times I_M}{I_S - I_M}$$

where $R_S$ is the shunt resistance required,
$R_M$ is the meter resistance,
$I_S$ is the current scale required,
$I_M$ is the nominal current rating of the meter (in this case $100\mu A$).

When making the calculation, resistances are in ohms and currents in amperes, so allowance must be made for the multiple and sub-multiple signs.

Capacitors C1 and C2 are tubular types and usually insulated. In any case the can of C2 must not be connected to chassis. C3 and C4 are the kind that have to be mounted vertically on the chassis, but here again the can of C4 must not be connected to chassis. It can be wrapped with plastics insulating tape.

The transformers have been selected as being readily available types. T1 has three 6·3V windings but only one is used for V3 heater. If desired, one of the other 6·3V windings can be used to supply a panel bulb, although this is not shown.

The diodes originally used were AEI types SJ403 but it may be easier to obtain the Mullard BYZ12, which has a substantially higher current rating.

The wafer switches are pre-assembled types that can be bought for a reasonable sum, but S8 may have to be a slightly more expensive "Yaxley" or "Maka-switch" type.

The uniselector switch is obtainable at many surplus stores. At least three banks are required and a 75Ω coil. Check the action of this component before buying to make sure that the wipers ride smoothly through the arc of contacts. This can be done by pressing the armature several times. No parts should be damaged otherwise operation may be intermittent. The uniselector has 25 ways; two series of 11 contacts on each bank are paralleled.

## FRONT PANEL

Front panel mounting position is given in Fig. 4 with the wiring below it (Fig. 5). The wiring to S8 has been abbreviated in the interests of clarity, but it should not be difficult to ascertain the appropriate tags if wiring to them is followed in alphabetical sequence, from a predetermined starting pole, in counter-clockwise fashion.

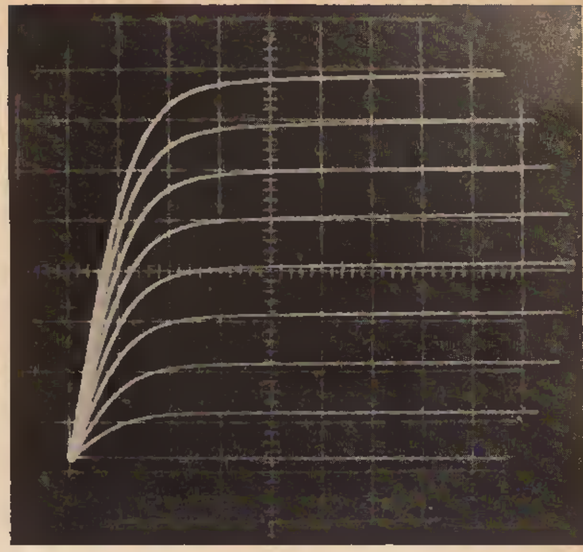
The "common" terminal on the front panel must make either direct connection to the panel (if metallic), or wired to a chassis connection.

Resistors for connection to S3 and S6 are mounted on an 18-way group tag board, which is fitted to the top of the front panel by right-angle brackets. If the resistors are uppermost, minor alterations to their values can be achieved *in situ* while the instrument is operating.

## CHASSIS CONSTRUCTION

Drilling details of the chassis are not given because some adjustment may be necessary according to the components acquired. However, the top and underside wiring diagrams of the prototype (Figs. 6 and 7) are drawn to scale to give reasonable indication of the positions of the components.

Transformer T1 is mounted so that the turret tags project through the chassis for connection underneath.



***Photograph of a family of $I_C/V_C$ curves displayed on an oscilloscope***

If there are "screen" tags on the transformers these must be connected to chassis.

The main power supply components are mounted on a group tag board under the chassis, while C3 and C4 are fitted (as mentioned previously) to clamps on the chassis. It may prove to be helpful to make the holes for these large enough so that they can project through to about one inch below the chassis top.

A 12-way group board is mounted on pillars above these two capacitors to take the resistors for US1b. Here again, easy access is achieved for alteration of component values.

*Finally, before going on to the operation, a word of warning: if it is necessary to make alterations while the instrument is switched on, be careful where you put your fingers and soldering iron. Components on the front panel, as well as T2 and T3 carry exposed live mains.*

## OPERATION

The curve tracer must be used in conjunction with a directly coupled (d.c.) oscilloscope. The time base must be capable of being switched out of circuit and a d.c. amplifier substituted in its place. Not all oscilloscopes have this facility and it may be necessary to add an amplifier to the design of the unit. It need only have a modest gain of about a hundred times and quite a small bandwidth and could derive its power from the supply incorporated within the unit.

The type of display obtained is shown in the photograph. The illuminated graticule shown in the photograph was made from ⅛in perspex placed immediately in front of the oscilloscope screen. Edge lighting through one edge of the perspex by means of a low power bulb will light up the scribed scale lines. This graticule was found useful in calibrating the curves displayed on the screen.

The photograph shows the $I_C/V_C$ characteristic of a low gain *pnp* transistor having increasing values of reverse base bias. The ninth and tenth bias values bring the transistor into its cut-off region and consequently only a single straight line is traced for both steps. ★

# ELECTRONIC CYMBALS

## PERCUSSION EFFECTS

By A.J. BASSETT

**THERE ARE two kinds of electronic music effects circuit: one can be considered as self-contained and self-generating; the other is dependent on a sound source from a musical instrument.**

**Sounds made by real cymbals or drums can be modified electronically to produce unusual effects. This is where the *Drummer's Whoosh Unit* comes in; this will be based on a modified version of the purely *Electronic Cymbals* described in the present article.**

THE electronic cymbals unit uses the white noise generator (described in January) and a power supply (described in December) with a new filter circuit. The circuits of the white noise generator and power supply are reprinted in Fig. 1 so that the whole extent of the circuit involved is realised from the outset.

The power supply is not shown in the photographs as it was external to unit, but there is plenty of room to incorporate it in the box if required. Alternatively, the performer may prefer to use dry batteries, so making the unit entirely self-contained and portable.

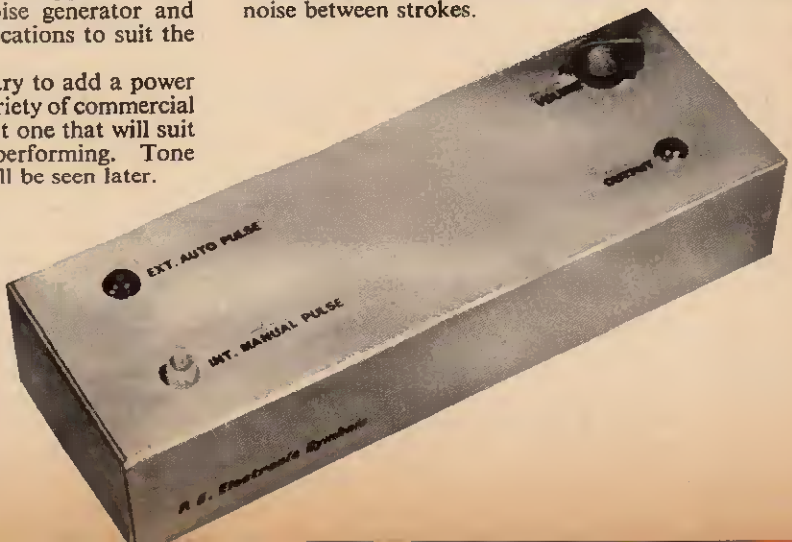
If required to be housed in the same box as the Drummer's Whoosh amplifier, this can still be done, but we would recommend the constructor to exercise some patience until next month's article appears. The same box can house one white noise generator and filter for both purposes, with modifications to suit the Drummer's Whoosh.

With all these circuits it is necessary to add a power amplifier and, since there is a wide variety of commercial types available, the user should select one that will suit the environment in which he is performing. Tone controls are a desirable facility as will be seen later.

### SWITCHED FILTER

One white noise generator will provide sufficient output to operate a set of cymbal effects circuits of different pitches and qualities, giving a set of transistorised "cymbals" of relatively small size, and at reasonable cost. The cymbals effect circuit is enclosed in the dotted line box in Fig. 1a.

The 100 kilohm potentiometer VR1 controls the level of the white noise signal fed to the filter circuit. The white noise is filtered and deliberately "coloured" by transformer T1 and capacitor C5, then passes by way of C6 to the base of TR1. This transistor is normally biased into non-conduction by a negative supply applied through R10. A 1·5V or 3V battery will usually suffice here, and serves to prevent a hissing noise between strokes.



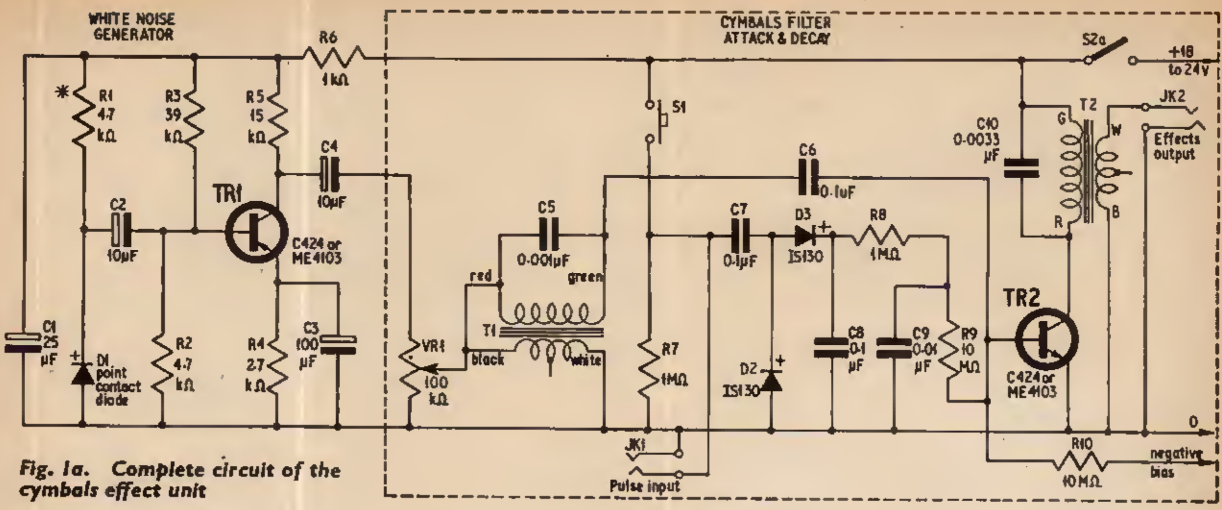



*Fig. 1a. Complete circuit of the cymbals effect unit*

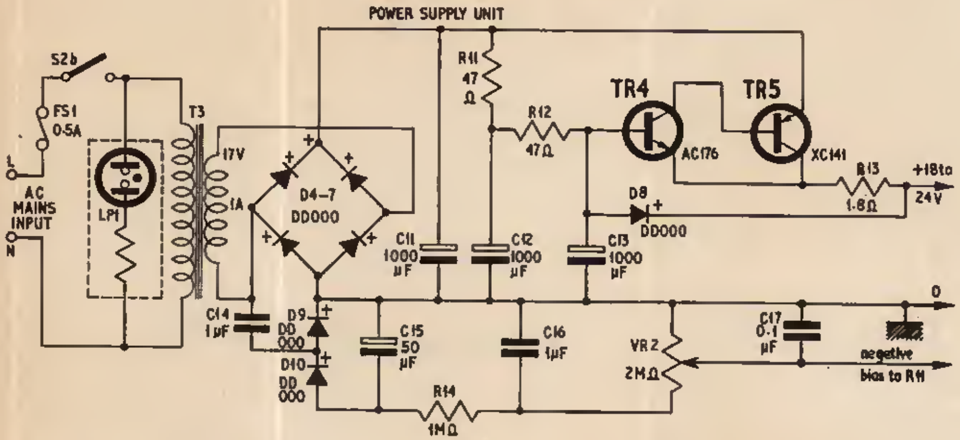



*Fig. 1b. Modified power unit to supply negative bias*

In order to simulate a cymbal stroke, a positive pulse must be applied to the circuit via C7, and must be of sufficient magnitude to overcome the negative bias with ease, and cause TR1 to conduct. To obtain a realistic result, this calls for a pulse of at least 6 volts, and indeed any voltage up to about 50 volts may be used.

A simple way to test the circuit would be to connect a 1 megohm resistor from C7 to the negative supply (common) line, and a Morse key or a push button switch from this input to the 18V to 24V positive supply line. A quick jab on the push button will charge up C8 via diode pump D2 and D3. C8 will then discharge by way of R8, R9, and TR1.

R8 and C9 act as a filter to reduce "thump" effects. As long as C8 holds sufficient charge, the potential maintained at the base of TR2 will cause TR2 to conduct, and to amplify the signal fed to its base via C6. As C8 discharges, the output from TR1 will die away. This output is fed through a further filter-circuit (T2 and C10) to the effects output jack JK2.

It is worth mentioning that a 1½V or a 3V battery connected between chassis and the negative bias line in this circuit will suffer negligible drain, and can be wired in permanently without any need for an on/off switch. A new leakproof battery would be likely to last for a number of years (well beyond normal shelf life), until corrosion sets in.

Better results may be obtained from the circuit by using an adjustable negative bias. The power supply circuit in Fig. 1b incorporates a negative bias supply suitable for the purpose. Bias adjustment may be used to control the decay time of the cymbal stroke.

## ASSEMBLY AND TESTING

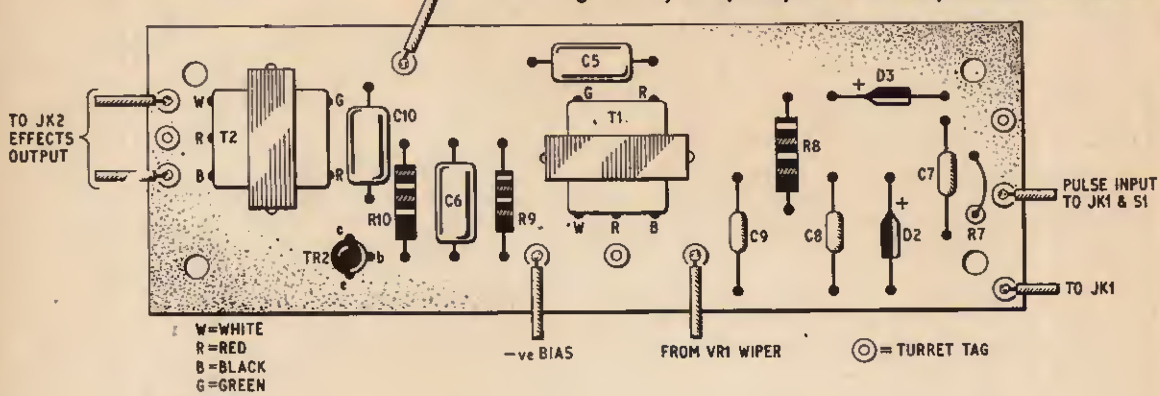
Prepare the printed circuit board according to the design shown (Fig. 2) and assemble parts on it as shown in Fig. 3. Fig. 2 shows the hole-spacing to suit a TO5 transistor encapsulation, and this spacing will suit type C424. If type ME4103 is used, the hole spacing may be made closer to suit the TO18 leadout arrangement of this transistor.

When assembly of the components on the cymbal-effects circuit-board is complete, wire it up to a white noise generator, d.c. power supply of 18V to 24V and an audio amplifier or mixer unit. Temporarily connect the positive supply line to the junction of D2 and D3. Switch on and adjust VR1 and the controls on the amplifier so that the sound of the white noise generator comes from the loudspeaker as a loud hiss.

Disconnect the positive line from D2 and D3. The sound should die away fairly rapidly. With some transistors, the sound will fade to a very low level without the need for a negative bias supply; others may need the application of a negative base bias via R10,

*Fig. 2. Printed circuit pattern for cymbals filter (full size)*

*Fig. 3. Layout of components on the printed circuit board*




# COMPONENTS ....

## CYMBALS FILTER

**Resistors**
R7 1MΩ
R8 1MΩ
R9 10MΩ
R10 10MΩ
All 10%, ¼ watt carbon

**Potentiometer**
VR1 100kΩ log. carbon

**Capacitors**
C5 0·001μF
C6 0·1μF
C7 0·1μF
C8 0·1μF
C9 0·01μF
C10 0·0033μF
} All low voltage polyester or paper

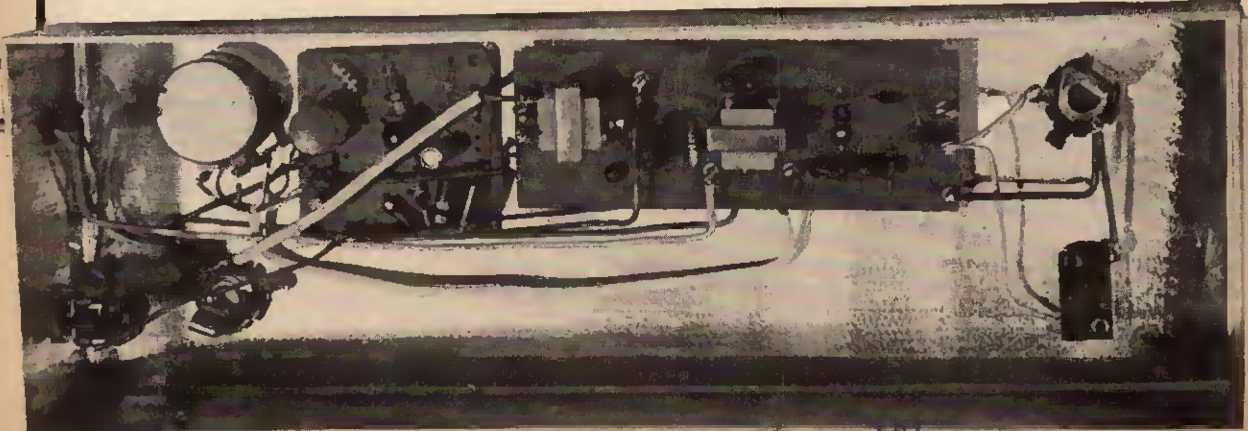
**Transformers**
T1, 2 Transistor transformers type LT44 (2 off)

**Transistor and Diodes**
TR2 ME4103 or C424 (S.G.S. Fairchild)
D2 and D3 1S130 (2 off)

**Jacks (with Plugs)**
JK1, JK2 Standard ¼in jack sockets (2 off)

**Switches**
S1 Single pole push on, release off push button
S2 Double pole on/off toggle switch (S2a in low voltage line; S2b mains input to power unit if used)

**Miscellaneous**
Printed circuit board
Single core screened cable
Chassis 12in × 4in × 2½in
Knob
*Component layout shown in Figs. 2 and 3*



# COMPONENTS . . .

### POWER SUPPLY UNIT

**Resistors**
R11 47Ω R13 1·8Ω
R12 47Ω R14 1MΩ 10% ½W
All 5% 3W, wirewound except R14

**Potentiometer**
VR2 2MΩ linear carbon

**Capacitors**
C11 1,000μF elect. 25V
C12 1,000μF elect. 25V
C13 1,000μF elect. 25V
C14 1μF polyester 160V
C15 50μF elect. 25V
C16 1μF polyester 160V
C17 0·1μF polyester 160V

**Transformer**
T3 Mains transformer, charger type. Pri. 240V mains; sec. 0–17V 1A

**Transistors**
TR3 XC141 TR4 AC176

**Diodes**
D4 to D10 DD000 (Lucas) (7 off) or 1S130

**Switch**
S2b (see under *Cymbals Filter*)

**Miscellaneous**
FS1 Fuse 0·5A with holder
LP1 Neon panel indicator with resistor
Printed circuit board 6in × 2½in
Heat sink for XC141
Knob
*Component layout given in December 1967 issue*

### WHITE NOISE GENERATOR

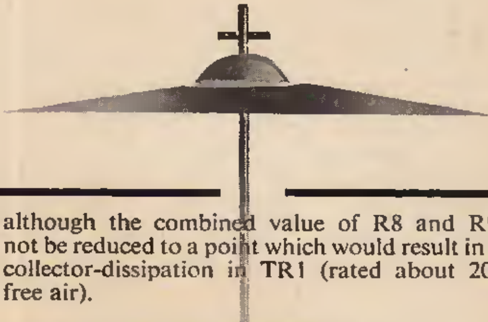
**Resistors**
R1 4·7kΩ R4 2·7kΩ
R2 4·7kΩ R5 15kΩ
R3 39kΩ R6 1kΩ
All 10%, ¼ watt carbon

**Capacitors**
C1 25μF elect. 25V
C2 10μF elect. 25V
C3 100μF elect. 12V
C4 10μF elect. 25V

**Transistor and Diode**
TR1 C424 (S.G.S. Fairchild) or ME4013
D1 Point contact diode, any noisy type, such as sold for crystal receivers

**Miscellaneous**
Printed circuit board 2in × 2in (Bonanza Board)
Connecting pins and wire
*Component layout given in January 1967 issue*

*Components for cymbals filter given on previous page*



in order to achieve a quiet background in between strokes, and a 1½V battery is usually quite sufficient.

If the positive line is quickly touched on to the junction of D2 and D3 a few times in succession, a sound similar to a cymbal stroke may be heard, but may not be very realistic at this stage, as adjustment of VR1 and the tone controls of your amplifier will have a considerable effect on the output qualities.

VR1 must not be set too high, or the effect will result in a continuous roaring or crackling sound. This is because the white noise is fed to the base of TR1 at a high level to overcome the negative bias. Turn down VR1 to a level somewhat below that at which the roar occurs. If, now, the cymbal strokes tend to have a somewhat crackly ending, VR1 must be set to an even lower level to give a smooth finish to each stroke.

## VARIATIONS

The circuit is not by any means restricted to the component values given. By changing the values of C5 and C10 the cymbals pitch may be altered; the use of different transformers will give yet further ranges of effects. A choke or other inductor could be used in place of T2, and the output taken from the collector of TR1 by way of an 0·1μF capacitor.

Changing the values of C7, C9, and R9 will affect the "attack" and "decay" characteristics of the circuit, although the combined value of R8 and R9 should not be reduced to a point which would result in excessive collector-dissipation in TR1 (rated about 200mW in free air).

## METHODS OF OPERATION

For manual operation, the simplest method is to connect a 1 megohm resistor (R7) from C7 to the negative (common) supply wire, and apply pulses to this input from the 18V to 24V positive supply point by use of a Morse key or a push button switch. The final circuit shown in Fig. 1 performs the same function.

The circuit may also be operated electronically by connecting C7 directly to an electronic switching circuit (via JK1) such as a slow running multivibrator (for automatic "repeat" effects); a ring counter (for rhythm effects) or an electronic keying circuit. In all these circuits the pulse may be supplied from the collector of the switching transistor concerned. If using the multivibrator described in the article on a *Simple Rhythmic Control Unit* (February issue) JK1 would be connected to the collector of either TR1 or TR2 in that circuit.

The "Cymbals" circuit may be used very successfully with an electronic rhythm machine or a rhythm generator. An adaptation of the circuit may be used for beat group sound effects; this will be described next month in the *Drummer's Whoosh Unit*.

# BOOK REVIEWS

### BEGINNER'S GUIDE TO ELECTRICITY

**By Clement Brown**
**Published by George Newnes Limited**
**185 pages, 7½in. × 5in. Price 15s**

ANYONE starting a career or hobby in *electronics* might be put off by the title of this book when looking for an elementary guide. In order to understand and appreciate the technicalities of even the most simple of electronic circuits, one should have, or be able to grasp, the fundamentals of basic electricity. It comes at a time when more and more schools and training colleges are giving courses in the subject, and is therefore suitable for almost any beginner from 14 to 40 years of age.

It is written in an intelligently straightforward style that will complement course lectures and lab. experiments. Of necessity it is not by any means exhaustive but will certainly cover in adequate terms the theory to be found in advanced level G.C.E. and O.N.C. courses. Electronics is not strictly introduced until Chapter 7, and even then in only basic form.

Technical terms tend to baffle many beginners, but here they will find explanations easily understood, and related to everyday electrical appliances and electronic circuits. Valve and transistor theory is included. The relationship between theory and domestic and industrial applications provides a suitable balance to a book that could otherwise have been rather dry reading.

The final chapter gives some guidance for those wishing to make a career in this fascinating activity.

M.A.C.

### ABC's OF TRANSISTORS

**By George B. Mann**
**112 pages. Price 20s**

### F.E.T. CIRCUITS

**By Rufus P. Turner**
**160 pages. Price 25s**

### ABC's OF VACUUM TUBES

**By Donald A. Smith**
**128 pages. Price 20s**

### BRIDGES AND OTHER NULL DEVICES

**By Rufus P. Turner**
**143 pages. Price 26s**
**Published by W. Foulsham & Co. Ltd.**
**All 8¾in × 5½ in**

ANOTHER four titles in the impressive catalogue of Foulsham Sams educational primers in an expanding technology. All four of the books present their subjects with a minimum of mathematics apart from the last title which sets out the necessary bridge equations happily, without qualification. Treatment of the subject matter is succinct and well illustrated and all four volumes are recommended as beginning texts for those anxious to be taught the rudiments of electronics.

**ABC's of Transistors** deals simply with the basic physical and electronic features of these devices and analyses their action in oscillators and amplifiers. Practical servicing and testing procedure of these circuits are also discussed.

**F.E.T. Circuits** is an excellent book for those readers who like their electronics practical. From a brief introductory chapter on structure and performance you are launched into the whole gamut of circuit applications of this versatile high impedance device: transmitters, receivers, test gear, control circuit, each one in effect a potted constructional project as all component and performance details are given.

**ABC's of Vacuum Tubes.** Dealing in the main with the construction and action, both dynamic and passive, of valves from the diode to the multigrid family. Biasing and classes of operation are covered and the final two chapters deal with miscellaneous and special purpose valves. Altogether a painless introduction to valve technology.

**Bridges and Other Null Devices.** Measurement is fundamental to all sciences. In electronics the bridge type circuit predominates in this application and this book sets out to explore its various forms for specific measurement purposes. From basic bridge circuit theory the reader is introduced to most of the equipment found in a test gear laboratory. Although the illustrations are of American equipment, the principles and measurement capabilities are universal.

G.G.

### COLD CATHODE TUBES

**By J. B. Dance, M.Sc.**
**Published by Iliffe Books Ltd.**
**125 pages, 8¾in × 5½in. Price 35s**

IN A world largely dominated by the semiconductor, glass enveloped devices are becoming increasingly rare. But one group of tubes seems to have gained a new lease of life due, indeed, to the general expansion of electronic techniques brought about by solid state devices. For visual displays of data, or indication of the operational condition of circuitry, there is no real substitute for the cold cathode tube. This can be a simple neon lamp (which may double as a voltage regular), or a rather more complex numerical or character indicator tube. The orange-red glow of neon is the outward manifestation of electronic sophistry, as we well know.

But the cold cathode tube family includes the well known G.M. tube for nuclear radiation detection, stepping tubes for counting circuits, and other important specialised types, besides.

The electronics enthusiast who is "genned up" on solid state may be lacking in knowledge about cold cathode tubes. He can now find the basic facts of gas discharges and straightforward descriptions of those tubes he is most likely to encounter in modern electronic apparatus in this book. Some experiments with neon diodes and trigger tubes are described and there are many practical circuits which show typical applications of the various devices. A good practical introduction to the subject, with a minimum of maths.

D.D.R.

# Transistor Amplifier DESIGN

## 4 NEGATIVE FEEDBACK

By A. Foord

NEGATIVE feedback occurs when a proportion of the output voltage of an amplifier is fed back to the input in such a way as to reduce the overall gain, so that the gain with feedback is less than the gain without feedback. Feedback can be used to:

(1) Give a predictable mid-band gain, the greater the amount of feedback the less sensitive the amplifier is to changes of transistor characteristics.

(2) Increase bandwidth or to give a shaped frequency response curve which depends almost solely on the passive components forming the feedback network, and does not depend on an accurate knowledge of transistor parameters (which may vary between one specimen and the next of the same type).

(3) Increase or decrease input or output impedances; by using different feedback arrangements it is possible to obtain input or output impedances higher (or lower) than those normally associated with transistor stages. In particular it is possible to arrange for a high input impedance and a low output impedance, so that amplifier stages can be cascaded without interaction.

(4) Reduce the distortion which normally occurs in the final stages of an amplifier, where current and voltage swings are highest.

### BASIC PRINCIPLE

Any study of negative feedback begins with a functional block diagram, Fig. 4.1.

The circuit has two signal paths: the forward path, which is usually an amplifier and contains all the active devices, is marked with its voltage gain $A$; the feedback path $B$ which has a gain less than unity. The bar above the symbol $A$ indicates that there is a phase reversal in the amplifier, while $B$ represents the fraction of the output voltage fed back to the input.

The phase reversal to obtain negative feedback occurs in the amplifier; the arrows in the block diagram reassure us that the feedback is in fact negative. In a simple case this is obvious, but for more complicated arrangements a check will ensure that we do not accidentally use positive rather than negative feedback.

Take a simple example, Fig. 4.2. Without feedback we require an input of 0·1V to the amplifier for an output of −10V. If negative feedback is added making $B$ equal to 0·1 times, 0·1V is still required at the input of the amplifier itself to obtain an output of −10V.

The input to the addition point needs to be 1·1V, so that when the −1·0V is added to the input we are left with 0·1V to give an output of 10V. The overall gain with feedback is now

$$G' = \frac{-10}{1{\cdot}1} = -9{\cdot}1 \text{ times}$$

The negative feedback has reduced the gain from its open loop value of 100 times to a closed loop gain of 9·1 times, therefore the closed loop gain is approximately $1/B$ times ($1/B = 10$).

A more detailed examination will show that the gain with feedback is approximately $1/B$ provided the closed loop gain is much less than the open loop gain, Fig. 4.3.

Starting at the input to the amplifier (call this $V$) then the output of the amplifier is $\bar{A}V$, the voltage fed back is $\bar{A}VB$, and the input is $V + AVB$. Then the overall gain with feedback is given by

$$G' = \frac{V_o}{V_i} = \frac{\bar{A}V}{V + AVB} = \frac{\bar{A}}{1 + AB} = \frac{-1}{\dfrac{1}{A} + B}.$$

If $B$ is much greater than $1/A$ (i.e. $A$ is much greater than $1/B$) then $G = 1/B$.

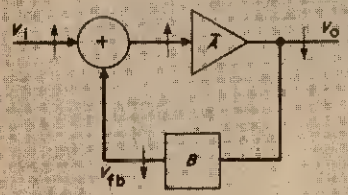


*Fig. 4.1. Functional diagram of an amplifier with negative feedback path*

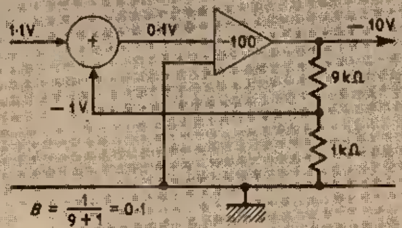


*Fig. 4.2. A simple example of negative feedback*

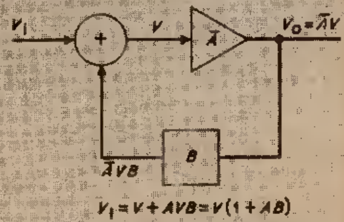


*Fig. 4.3. Voltage relationships between the amplifier and the feedback circuit*

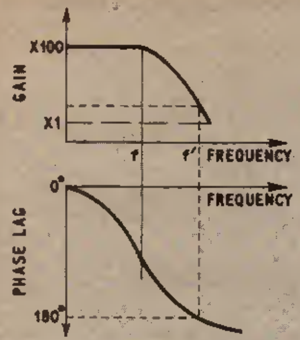



*Fig. 4.4. Gain and phase characteristics which would cause instability*

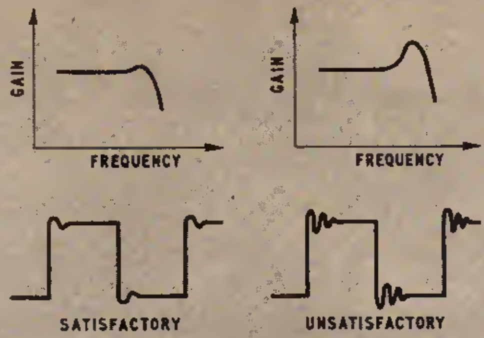



*Fig. 4.5. Instability shown by "ringing" cycles*

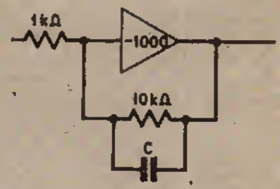



*Fig. 4.6. The practical example of a high gain amplifier with feedback resistor and "anti-ringing" capacitor C*

Therefore, the ideal gain with feedback ($G'$) is equal to $1/B$, if the gain without feedback ($A$) is much greater than $1/B$.

To confirm this, compare the results using the accurate formula and the approximate formula; drop the minus phase sign since we are interested in magnitudes rather than the phase reversal we know occurs in the amplifier.

Actual closed loop gain $\quad G' = \dfrac{A}{1 + AB}$

Ideal closed loop gain $\quad G = \dfrac{1}{B}$

Calculation will show that, if the required gain with feedback is one tenth of the gain without feedback, then we do not need to use the accurate formula, since errors in assuming $G$ equal to $1/B$ are small enough to be discounted.

## STABILITY

Having assumed that the design of the amplifier is such that the feedback will always tend to reduce the gain, but unfortunately this will not always be so, any practical amplifier will contain reactive elements which will introduce a phase shift in the signal as it passes through the amplifier (quite apart from the 180 degree mid-band phase shift required to obtain mid-band negative feedback). The gain and phase characteristics of the amplifier might appear as Fig. 4.4.

Above a certain frequency $f$, gain falls and an extra phase lag is introduced. If we applied 100 per cent negative feedback to an amplifier with this characteristic, to give an overall gain of unity, the amplifier would oscillate.

While there is still greater than unity voltage gain around the loop, there is an extra 180 degrees of phase shift to cause the feedback (which was negative below $f$) to become positive at $f'$. The system would therefore oscillate at the frequency $f'$.

Designing for stability is complicated when a considerable amount of feedback is applied. Instability in a feedback amplifier is shown by a peak in the frequency response curve and ringing on a square wave signal (see Fig. 4.5).

Feedback over one or two stages is normally safe, although later on, when considering the use of 100 per cent feedback to raise input impedance, a non-mathematical approach will be applied to the stability problem. For most purposes, it is in order to see that the frequency response curve does not have a peak of more than a couple of decibels in it, and that the square wave response is satisfactory, i.e. free from ringing effects.

The photographs show results obtained with a high gain amplifier, this had a gain of 1,000 times (60dB) without feedback, and a gain of 10 times (20dB) with feedback (see Fig. 4.6).

Photo A shows the leading edge of the 1kHz square wave input; photo B shows the ringing on the output waveform without the capacitor C, and this was considered unsatisfactory. The capacitor was adjusted in value to obtain the acceptable response of photo C. Since for clarity the photographs only show the leading edge of the square wave, the time scale was extended to show the leading edge more clearly. The capacitor was increased to reduce the bandwidth to 20kHz which increased the rise time to that shown in photo D.

Feedback around one stage only is called local feedback, and since only the common emitter stage provides a phase reversal of its output signal with respect to its input, it follows that local feedback can only be applied around the common emitter stage.

There are two basic ways of applying feedback to the common emitter stage; one arrangement is considered next, and the other is dealt with later, in the section on virtual earth amplifiers.

## SERIES LOCAL FEEDBACK

Referring to Fig. 4.7, the resistor $R_E$ in series with the emitter accounts for the applied feedback, this resistor enables a feedback voltage $V_f$ proportional to load current, to be fed back in series with the input voltage $V_i$. The base-emitter voltage of the transistor is reduced by the feedback so that $V_{BE}$ is less than $V_i$.

If $R_E$ is small and of the same order of value as the internal emitter impedance $r_E$ (say 100 ohms or so), then the amount of feedback is small. Distortion is slightly reduced and bandwidth is increased very slightly, at the expense of a small decrease in gain. If $R_E$ is large then the gain is given by

$$G = \frac{V_o}{V_i} = \frac{R_L}{R_E}$$

The input impedance is given by

$$Z_i = h_{fe}R_E$$

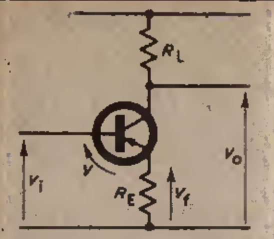



*Fig. 4.7. Series local feedback by the unbypassed emitter resistor*

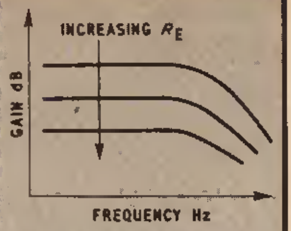



*Fig. 4.8. The effect of $R_E$ on gain and frequency response*

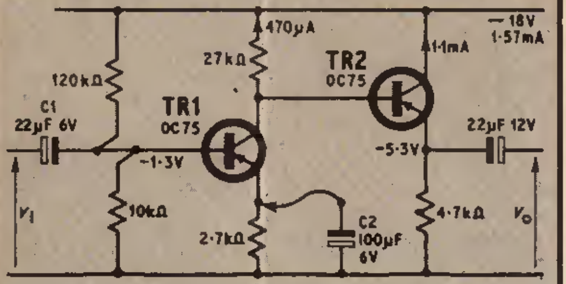



*Fig. 4.9. Emitter follower output to prevent undue loading on the amplifier stage*

In practice for a single stage amplifier biased in the normal way with a divider chain on the base, this increase in input impedance is masked to some extent by the shunting effect of the chain. The effect of $R_E$ on gain and frequency response is as shown in Fig. 4.8.

To avoid loading $R_L$ and to maintain a high gain without feedback, the output can be taken via an emitter follower, a practical circuit is shown in Fig. 4.9.

Since the transistor is used in common emitter we must work out approximately the bandwidth we would expect. For TR1 the collector current is of the order of 0·5mA. Suppose the transistor current gain is typically 50 at 0·5mA. The 3dB down point in common emitter is given by

$$f = \frac{f_T}{h_{fe}} = \frac{1{,}000}{50}$$

$$f = 20\text{kHz}.$$

One would expect the response to roll off somewhere at this frequency, the exact point depending on $h_{fe}$ and $f_T$ for the particular specimen of transistor. Since TR2 acts as an emitter follower the overall frequency response is limited by TR1 since an emitter follower has a frequency response far better than that of a common emitter stage.

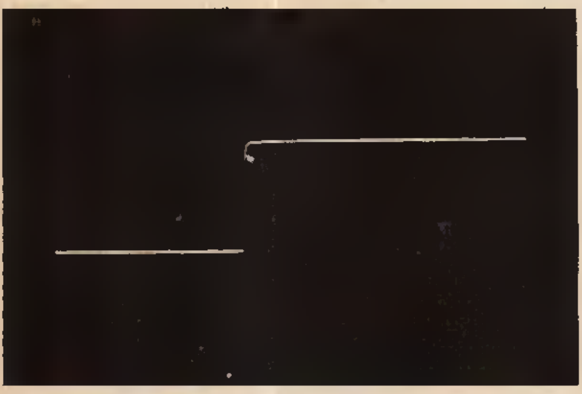


*Photo A. Leading edge of the 1kHz square wave*

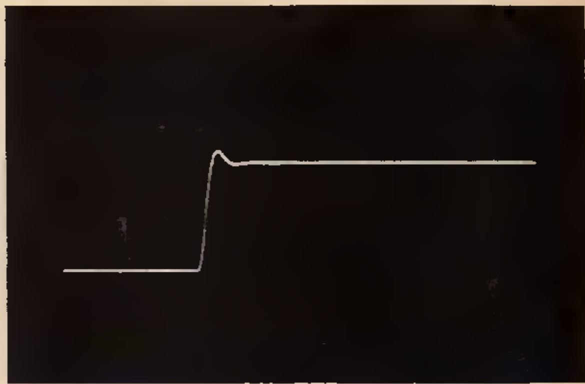


*Photo C. Ringing is brought down to an acceptable level by selection of a parallel capacitor across the feedback resistor*

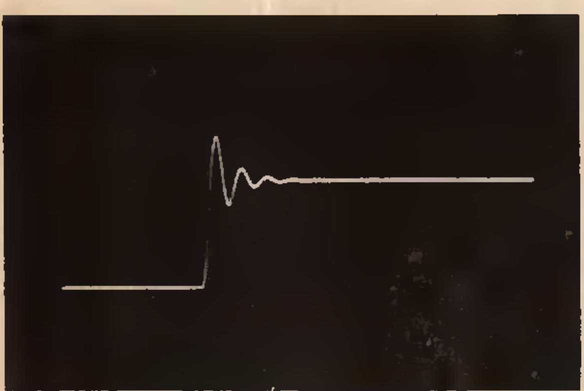


*Photo B. Ringing caused by non-selective feedback*

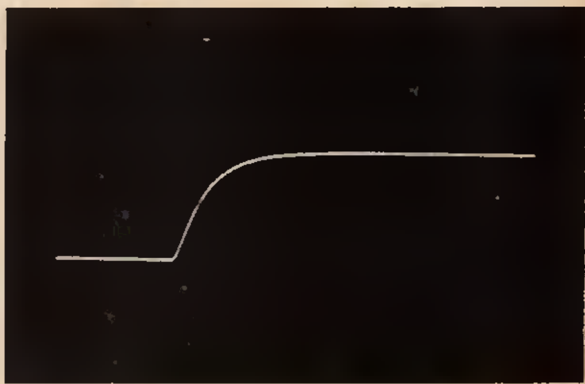


*Photo D. Larger value of capacitance increases the rise time*

The results without feedback (C2 connected) and with feedback are:

| | | |
|---|---|---|
| Gain without feedback | = | 310 times = 50dB |
| Bandwidth | = | 30kHz |
| Input impedance | = | 1kΩ |
| Output impedance | = | 300Ω |
| Maximum output | = | 1·5V r.m.s. no load |
| | = | 500mV r.m.s. into 1kΩ |

The frequency response was measured under no load conditions at 100mV r.m.s. Up to 50kHz or so, the amplifier will provide 500mV r.m.s. into 1 kilohm, but above this frequency the emitter follower current gain starts to drop and the waveform distorts, so that 500mV would only be obtained without distortion into a load greater than 1 kilohm.

The gain without feedback appears high until we remember that the collector load is 27 kilohms rather than the 1 kilohm or so we would expect for another common emitter stage and a high gain transistor is being used.

| | | |
|---|---|---|
| Gain with feedback | = | $\frac{27}{2{\cdot}7}$ = 10 times = 20dB |
| Bandwidth | = | 68kHz |
| Input impedance | = | 7kΩ |
| Output impedance | = | 300Ω |
| Maximum output | = | 500mV r.m.s. into 1kΩ (up to 50kHz) |

The actual measured gain was 19·5dB, which is probably an error in measurement or tolerances on the collector and emitter resistors. Since the open loop gain is 30 times the closed loop gain, one might expect the gain of 20dB to be independent of variations in characteristics between one OC75 and the next, although the bandwidth might alter slightly.

Although the gain has been reduced by a factor of 30 times, bandwidth has only increased twice. Series local feedback is often used inside another overall feedback loop, where a predictable stage gain is required rather than an unpredictable (though higher) gain.

With an input impedance of 7 kilohms and an output impedance of 300 ohms, these amplifiers can be cascaded without interaction. Bandwidth is also extended at the low frequency end, but since this is within our control (coupling and decoupling capacitors) the main benefit of this type of negative feedback is the predictability of mid-band gain rather than the small extension of bandwidth.

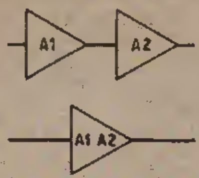



*Fig. 4.10. Combining two identical amplifiers*

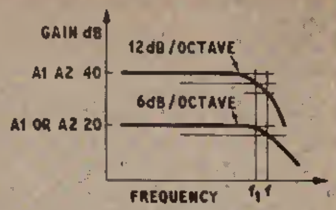



*Fig. 4.11. The response of each amplifier is added to give overall response*

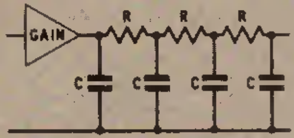



*Fig. 4.12. Equivalent circuit of a transistor looks like that of a transmission line at high frequencies*

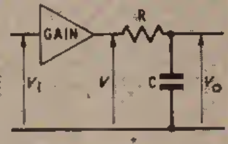



*Fig. 4.13. A single CR conversion of Fig. 4.12*

## TRANSFER FUNCTIONS

The amplifier can be represented as a block, so that two amplifiers in series could be represented by adding the two separate gains in decibels (see Fig. 4.10).

$A_1$ = 10 times = 20dB $\quad$ $A_1 A_2$ = 100 times

$A_2$ = 10 times = 20dB $\quad\quad\quad\quad$ = 40dB

Working on the frequency response curve and adding decibels this would result in the response shown in Fig. 4.11.

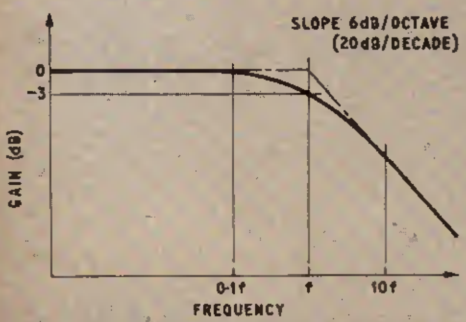



*Fig. 4.14. Approximating the frequency response, then deriving the accurate response (solid line)*

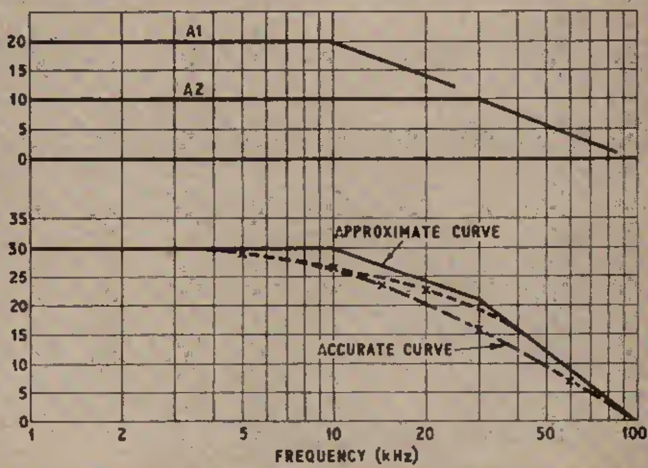



*Fig. 4.15. Summing the response of two amplifiers in cascade*

Where each amplifier was 3dB down (at $f$), the response is now 6dB down (for two identical amplifiers), and the new 3dB down point is lower down at $f_1$, as one would expect. The slope of the curve for a single amplifier is approximately 6dB per octave, and for two amplifiers in series this will be 12dB per octave.

In the equivalent circuit of a transistor (Fig. 4.12) it appears as a transmission line for high frequencies, but as a first approximation it can be considered as a single CR network, Fig. 4.13.

Taking the CR network or single time constant on its own, at low frequencies C has a high impedance and $V_0 = V$. At a frequency when C has a reactive impedance equal to $R$, $V_0$ is 3dB down with respect to $V$, and continues to fall at 6dB per octave (20dB per decade) with increasing frequency, as in Fig. 4.14.

The solid line curve is the accurate frequency response, while the dotted line is the straight line approximation. The point $f$ where the impedance of the capacitor is equal to the resistor is called the "turnover" or break point. The maximum error between the accurate and straight line approximation is 3dB which occurs at the break point. In practice the approximate curve is drawn; $f$ is 3dB down, $0{\cdot}5f$ and $2f$ are 1dB below the approximate curve; the accurate curve is drawn from this information.

For two amplifiers in cascade the procedure just outlined is shown in Fig. 4.15. The bandwidth of the two amplifiers in series is almost identical, but the ultimate slope is now 12dB per octave rather than the 6dB per octave for a single common emitter stage.

### RELATION OF RISE TIME AND BANDWIDTH

A square wave can be considered as the sum of a number of harmonically related sine waves; these include a fundamental sine wave at the basic repetition frequency and frequencies of three, five, seven times, and so on (odd harmonics of the basic frequency).

If a square wave of 1kHz is fed into an amplifier with a sharp cut off at 1·5kHz all the harmonics are filtered out, leaving only the 1kHz fundamental, Fig. 4.16.

If the response of the amplifier is extended to 20kHz the output would consist of the fundamental and harmonics up to 19kHz. Harmonics at 21kHz, 23kHz upwards would be attenuated according to the roll-off of the amplifier response curve. The square wave would hardly be degraded at all, since the amplitudes of these harmonics (relative to the fundamental) are small. The loss in harmonics increases the rise time of the square wave, Fig. 4.17.

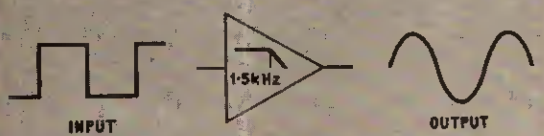



*Fig. 4.16. A square wave signal can be filtered to give the fundamental frequency only*

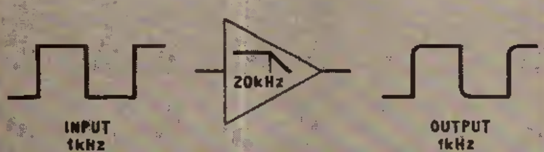



*Fig. 4.17. Increase in the rise time of the square wave by loss of harmonics*

To determine the bandwidth of an amplifier we would feed in a square wave with a rise time better than we would expect the amplifier to handle, and measure the degradation on the output.

Suppose our square wave had a rise time of 5µs and after passing through the amplifier this was degraded to 25µs, then our amplifier has a rise time of $\sqrt{(25^2 - 5^2)}$ or 24·5µs and its bandwidth is given by:

$$f = \frac{0{\cdot}35}{\text{rise time}} = \frac{0{\cdot}35}{24{\cdot}5} \times 10^6 = 14{\cdot}3\text{kHz}$$

This method is only an approximate means of determining bandwidth, it would tell us if our amplifier had a bandwidth of 20kHz or 10kHz, but we could not rely on discriminating between bandwidths of 20kHz and 17kHz.

However the edges of the square wave do represent the type of signals present in a transient, which simple sinewave testing cannot do, so that we can see immediately any instability or excessive overshoot or ringing in the amplifier. The disadvantages are that we do need a square wave of good rise time, and an oscilloscope capable of showing it.

**Next month: Negative feedback applied to practical circuits.**

## BETTER SOUND

THE BBC announces that four programmes in a new series "Better Sound" will be broadcast on Fridays at 7.00–7.30 p.m. in Study Session, Radio 3 from May 3 to 24. Listeners will be invited to send questions of general interest, or requests for more information on particular topics covered in the series and these will be dealt with in two extra programmes which will follow the repeat of the series later in the year.

The series will be repeated on Radio 4 on Saturday mornings at 11.00–11.30 a.m. from August 17 to September 14. There will be no programme on August 31 (Bank Holiday weekend), but there will be two additional programmes on Saturdays, September 21 and 28.

Each programme will focus attention on one area of this wide field. A number of topics (e.g. microphones, loudspeakers, stereo) will therefore be treated in more than one programme. Advice on particular makes cannot be given and the construction and repair of equipment will not be dealt with.

Programme 1: Transmission and reception of radio, including stereophonic broadcasting. Explanation of AM and FM, etc.

Programme 2: The nature of sound, and room acoustics, with demonstrations of the effect of different placings of microphones and loudspeakers.

Programme 3: The reproduction of music in mono and stereo; hi fi equipment.

Programme 4: Tape-recording for the amateur.

The diagrams in the Study Notes (BBC Publications, 2/6 plus 5d postage) will be helpful in following the broadcasts and the explanations in the text of the basic principles of the transmission, recording and reproduction of sound in mono and stereo will be useful for reference, particularly for the less knowledgeable listener.

# nucleonics for the EXPERIMENTER

By M.L. Michaelis M.A.

## 7—RADIOACTIVITY MEASUREMENT; STRACE RADIATION METER

PREVIOUS articles in this series have discussed nuclear radiation, atomic structure, and the practical applications of nucleonic measurements; measuring methods and various kinds of detectors have been considered in a general way. A distinction has been made between activity measurements and energy measurements, and electronic methods for sorting electrical pulses from a spectroscopic, i.e. energy-distinguishing, nuclear radiation detector explained.

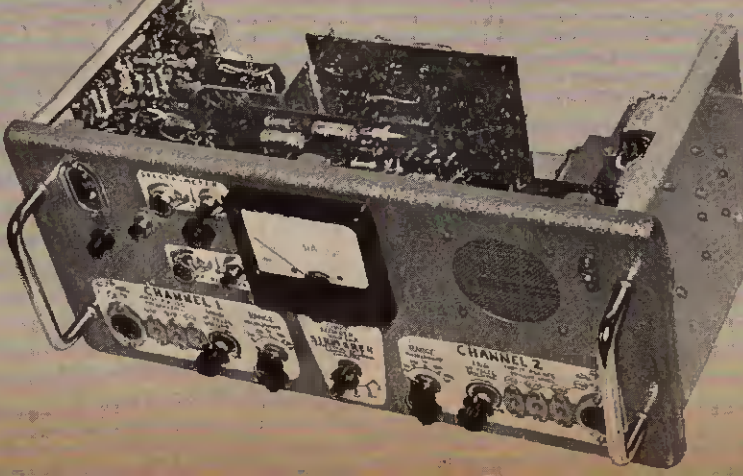
Now the point is reached where we have sequences of pulses, ready for activity determination, i.e. for counting the numbers arriving per unit time, corresponding to the numbers of radioactive atoms distintegrating per unit time. This counting process is the function of the actual *radiation meter* unit in any nucleonic equipment. This month, we will discuss the basic requirements and electronic circuit techniques which are involved. It is quite immaterial whether the pulses originate from a non-spectroscopic detector like a G.M. counter, or from a spectroscopic detector such as a scintillation detector with kick-sorter amplifier.

In the former case, the mean pulse frequencies may correspond to the gross activity of a mixture of different kinds of radioactive atoms, whereas in the latter case, the activity of a particular species of radioactive atoms can be observed selectively, to the exclusion of others which may be present at the same time in the radioactive sample. However, the principles of making activity measurements, and the structure of the radiation meter used for the purpose, are the same in both cases.

### ACTIVITY AND DETECTION EFFICIENCY

The activity of a radioactive sample is the number of atoms distintegrating in it in unit time, irrespective of the type of disintegration or the energy of the emitted nuclear radiation. We have already seen (in Part 3) that the unit of activity is the *curie* (Ci), corresponding to $2{\cdot}2 \times 10^{12}$ distintegrating atoms per minute. This is the activity of 1 gram of pure radium, by definition. Convenient practical units for amateur measurements are the pico-curie (pCi), corresponding to 2·2 disintegrating atoms per minute in the given sample, and the nano-curie (nCi), corresponding to 2,200 distintegrating atoms per minute in the given sample.

It is customary to take one minute as the time unit for radiation meters, so that their essential function is to determine the pulse counts per minute. The abbreviation c.p.m. is conventionally used for "counts per minute."




**STRACE RADIATION METER**

It is not possible to calibrate a radiation meter directly in pCi or nCi, but only in c.p.m. This is because the ratio of c.p.m. to pCi depends on the numerical detection efficiency of the radiation detector employed. The ratio is 2·2 only if every distintegrating atom in the radioactive sample produces an electrical response pulse in the detector. This is rarely the case in practice; a greater or smaller proportion of the radiations will miss the detector, so that the ratio c.p.m./pCi is practically always considerably less than 2·2. Of course, it is the aim of any detector and sample arrangement to achieve as high a numerical detection efficiency as possible. This is also referred to as the *geometry factor*.

## TWO EXAMPLES

Two examples will make this point clear.

In the first case, consider a radioactive sample lying on a large flat radiation detector, i.e. G.M. counter. The nuclear radiations may be emitted in any direction by chance. Thus, on the average one half of them will fly upwards or obliquely upwards, and miss the detector. The other half will travel downwards or obliquely downwards, and enter the detector to produce a pulse. The ratio c.p.m./pCi would be 1·1 in this case.

In the second case, consider the sodium iodide crystal of our scintillation detector (see Part 5), with the radioactive sample placed at the bottom of the axial sample well. Nuclear radiation emitted in almost any direction will then strike the crystal, so that we would expect very nearly the ideal value of 2·2 for the ratio c.p.m./pCi.

In practice, we actually find values considerably smaller than 1·1 and 2·2 for the respective cases, because two further factors reduce the detection efficiency. Firstly, some quanta of radiation may be absorbed within the sample, or other insensitive material, before reaching the sensitive detector region. Secondly, some quanta may pass straight through the detector without getting absorbed to produce a pulse. Thus the ratio c.p.m./pCi is only about 0·1 for a liquid sample in the Mullard MX124/01 G.M. counter tube specified for our equipment (see Part 4). The scintillation detector possesses a considerably greater detection efficiency, under some conditions approaching closely to the ideal value of 2·2 for the ratio c.p.m./pCi.

## RADIOACTIVE DECAY

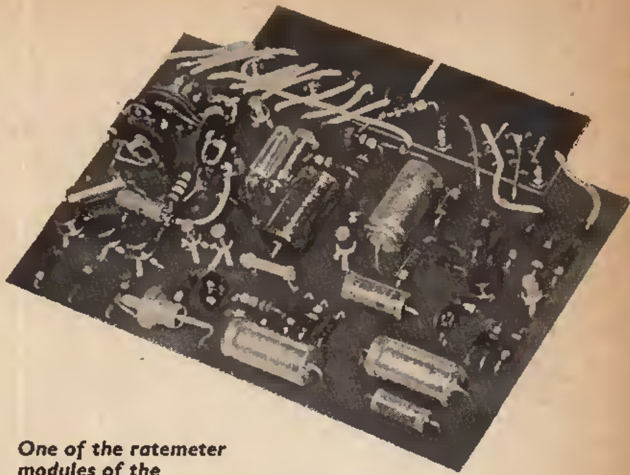
Since the activity of a given radioactive sample is a statement of the number of atoms disintegrating per unit time in that sample, this activity must necessarily diminish with the progress of time, because the number of atoms left over is continuously decreasing. For any given species of radioactive atoms, the activity is strictly proportional to the number of atoms of that species which are present in the sample, i.e. the rate of decay is directly proportional to the amount present.

This is the basic characteristic of any exponential process (the rate of fall of the voltage across a capacitor discharging through a resistor is always proportional to the actual voltage left across the capacitor at the instant considered, or the rate of growth of a sum of money on compound interest is at all times proportional to the accumulated capital). Thus the activity of a simple radioactive sample decreases exponentially with time. This is a very important principle, known as the *radioactive decay law*.

Different species of radioactive atoms decay at different rates, which are specifically characteristic of the respective species, just as different capacitor/resistor combinations discharge at different rates according to the produce of capacitance and resistance (time constant) of the circuit.

## DECAY HALF-LIFE

For radioactive samples, we specify a *decay half-life*. This is the time taken for one half of a large initial number of atoms to disintegrate. If we wait a further equal period of time, one half of the remainder will have disintegrated, i.e. the number of atoms still left over is halved during each successive half-life period. The process theoretically never goes to completion. The smaller the number left over becomes, the greater the random departures from smooth exponential decay. Ultimately, when only one atom is left over, it is inherently impossible to predict how long it will continue to remain intact.



*One of the ratemeter modules of the STRACE Radiation Meter*

A similar indeterminacy prevails already at the outset, when we had a very large number of atoms. If we were to single out any particular atom for close observation, there is no way of predicting, in which successive half-life period it will meet its fate. This is subject to pure chance. Thus whilst we can be pretty sure that almost exactly one half of a large number of atoms will disintegrate in a half-life period, we are unable to determine in advance which particular atoms will belong to the decaying half.

## STATISTICAL FLUCTUATIONS

The inherent unpredictability of the lifetime of any single radioactive atom introduces random fluctuations in the predictable mean behaviour of a large number of similar atoms. If the smooth exponential decay law would ideally demand that $n$ atoms should disintegrate in a given sample within a certain time of observation, then the *actual* number of atoms observed to decay within that time will in all probability differ from $n$. It may be smaller or larger. If we repeat the experiment numerous times under identical conditions, the average of all observations will approach ever more closely to $n$. Regarding the discrepancies of individual results, we will find that these average to $\pm\sqrt{n}$. This is called the *mean uncertainty* of the count $n$.

As far as practical measurements are concerned, this means that if we want our activity reading to be reliable to within 1 part in $n$, we must count at least $n^2$ pulses before we stop the counter and divide by the total time taken. Otherwise random fluctuations will exceed our tolerance limit and the readings are meaningless to the envisaged accuracy.

It is common practice to specify four accuracy classes, namely 1, 5, 10, and 20 per cent. These correspond to desired reliabilities of 1 part in 100, 20, 10 and 5, so that we must respectively count at least 10,000, 400, 100 or 25 pulses.

Note carefully that it is solely the *total pulse count* which determines the statistical accuracy, quite irrespective of the time taken for clocking-up this count. The radiation meter must simply be left running until the required number of pulses have arrived, and if this takes a very long time in the case of low activities, the circuits must be designed with adequate long-term stability.

## RADIATION METER TIMING

The relationships explained in the previous section dominate the design of practical radiation meters. In the case of digital counting, there are few basic problems as far as long-term stability is concerned. Professional equipment often adopts count timing here. In other

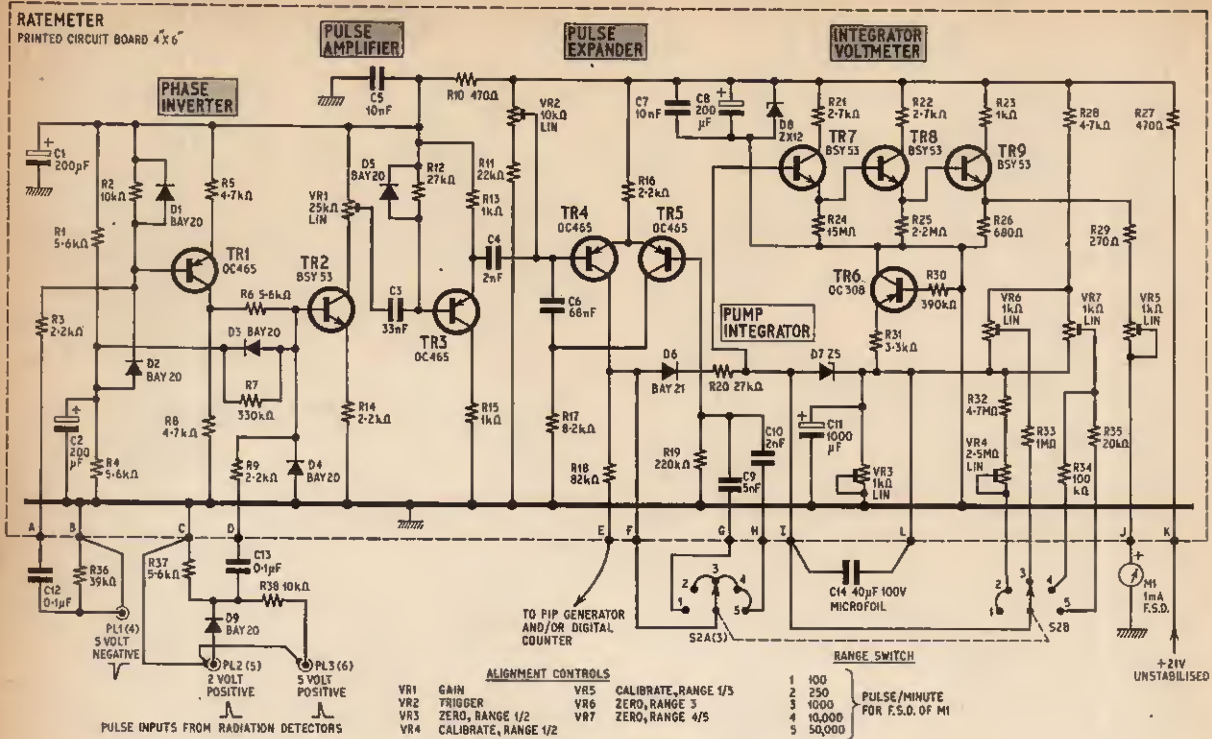



*Fig. 7.1.* **STRACE RADIATION METER: Circuit diagram of the ratemeter module**

words, the time taken to achieve a predetermined count is measured. Suppose we desire a statistical accuracy of 1 per cent. The clock will then be zeroed and the counter set to 10,000. The clock is then set running forwards and the counter backwards. When the counter reaches zero, it stops the clock automatically.

In the case of analogue counting, more special considerations are required. We remember that analogue counting establishes the activity reading as the voltage developed across a capacitor. Each pulse pumps a definite small electric charge into the capacitor, whilst the capacitor at the same time discharges through a precision resistor. The resulting voltage across the capacitor is directly proportional to the rate of arrival of the pulses. This voltage will fluctuate in a random manner, due to the random fluctuations of the pulse rate. The meter reading thus fluctuates over a certain range of the scale, instead of being steady.

## RATEMETER TIME-CONSTANT

Consider the lowest range of the ratemeter in our STRACE equipment, which is 100 c.p.m. for full-scale deflection. The design figure is the 5 per cent statistical accuracy class, which calls for 400 pulses in the "counting time". These take four minutes to arrive at 100 c.p.m., so that the product of the integrating capacitor value ($\mu$F) and its discharge resistor (megohms) should be 240 seconds.

If the value of the capacitor is kept constant, but the value of the discharge resistor halved, then a given pulse rate will produce only half as great a meter deflection. The full-scale deflection c.p.m. value is thus doubled. But the statistical accuracy is unchanged, because although the time constant has been halved, the rate of arrival of the pulses for full-scale deflection has been doubled, so that the same number of pulses arrive within the time-constant period.

In general, this leads to a simple rule. The various desired c.p.m. ranges are obtained by switching corresponding different discharge resistors across the *same* integrating capacitor, whereby the same statistical accuracy is then obtained on all ranges. This is most fortunate, since only one capacitor is thus required. The capacitor must be of immaculate quality, above all, it must have very low leakage and excellent long-term capacitance stability, so that it is rather expensive. Precision resistors are much cheaper, and only these are required in quantity according to the desired number of ranges.

## STRACE RATEMETER MODULE

Fig. 7.1 shows the complete circuit of the ratemeter module for the STRACE radiation meter unit.*

The components within the broken-line rectangle are accommodated on a 4in × 6in printed circuit board. Layout is in no way critical.

Almost any silicon *npn* transistors are suitable for TR2, 7, 8, 9, and almost any silicon *pnp* types for TR1, 3, 4, 5, provided collector voltage ratings are at least 12V working in all cases. TR6 may be any small germanium *pnp* audio power transistor, e.g. OC72 is also suitable. The small diodes may be any *silicon* type with small self-capacitance and at least 100V p.i.v. rating. D7 is a 5V miniature Zener diode, D8 is a 500mW dissipation (at least) 12V power Zener diode. Resistors should be ±10 per cent, except those connected to S2B, which must be ±5 per cent, or better still ±1 per cent. The specified prototype semiconductors are all S.T.C./Intermetal types, but in no way imperative.

TR1 is a polarity inverter for those radiation detector types feeding negative pulses to PL1. D1 suppresses positive pulses or components while D2 prevents overload of TR1 on excessive negative pulse amplitudes at PL1. TR2 is the main pulse amplifier stage. It is fed at the base with the positive output pulses from TR1 collector, as well as with the inputs of positive-pulse radiation detectors connected to PL2 and/or PL3. D9 is included here to prevent short-out of PL3 input by the low-impedance output stage of a detector connected to PL2, thus it is not necessary to disconnect the cables of switched off detectors.

* (Ref to Fig. 2.1 for block diagram of STRACE Radiation Meter Unit.)

### THRESHOLD LEVELS

VR1 is the collector load of the main pulse amplifier. It is preset to give the response threshold levels marked against PL1 to PL3. D4 suppresses negative pulses or components at TR2 base, and D3 prevents overload of TR2 if excessive positive pulse amplitudes are applied to PL2 or PL3. The diodes D1 to D4 associated with TR1 and TR2 thus make the circuit very tolerant of large differences in input pulse amplitudes. The performance is still perfect even if the pulses fed to PL1, PL2 or PL3 are ten times larger than the specified threshold values. Gain controls are thus not necessary on the front panel.

### PULSE EXPANDER

TR3 is a driver emitter follower, to feed the pulse expander from the necessary low source impedance. The pulse expander TR4/TR5 is a transistorised equivalent of the valve-operated pulse expanders already introduced last month in the gamma ray spectrometer kick-sorter amplifier.

TR4 normally rests cut-off, and TR5 conducting. When a trigger pulse arrives via C4, the roles of the two transistors change over for a time determined by C9 or C10 in conjunction with R19. Thereafter, the transistors revert to the resting state of their own accord. The duration of conduction of TR4 in response to each trigger pulse from TR3 is independent of the form or duration of that trigger pulse, being determined solely by C9, C10 and R19.

### PUMP INTEGRATOR

During each conduction pulse of TR4, a definite quantity of positive charge is pumped via D6 and R20 into the integrating capacitor C14. S2B switches the appropriate discharge resistor across C14, to establish the different c.p.m. ranges as discussed previously. The other wafer, S2A, of the range switch selects C9 or C10 for determining the pump pulse duration. On the lowest range (f.s.d. = 100 c.p.m.), C9 is in circuit and gives a long pump pulse, whereas the short pump pulse with C10 is used for all other ranges.

The value of the integrating capacitor C14 is 40$\mu$F, and the net value of the discharge resistance (R32, VR4 and the input impedance of the read-off voltmeter TR7, 8, 9) is 4 megohms for both range 1 and range 2. Due to the different pump pulse duration, range 1 is 100 c.p.m. and range 2 is 250 c.p.m. for full-scale deflection, so that the statistical accuracy is in fact somewhat poorer than 5 per cent on range 1 but somewhat better than 5 per cent on range 2 and all other ranges. This is a compromise made to avoid unduly high values for C14, or unmanageably high circuit resistances.

### READ-OFF VOLTMETER

The read-off voltmeter for the integrator capacitor C14 comprises the remainder of the circuit on the right of Fig. 7.1. The design figure is for a 1mA fsd meter and/or chart recorder connected to the output.

TR7, 8, 9 are cascaded current amplifiers to reduce the current drain on the integrator capacitor C14 for the voltage read-off process. VR3 sets a d.c. bias voltage in series with C14 on ranges 1 and 2, to overcome the silicon threshold of TR7, 8, 9. TR6 is in parallel with VR3 and possesses a compensating temperature coefficient to cancel thermal drift of the threshold level of TR7, 8, 9. TR6 must be positioned close to TR7, 8, 9 to sense the same temperature as the latter components.

VR6 and VR7 fulfil the same function as VR3 for the other ranges. VR5 sets the meter sensitivity for all ranges. D8 stabilises the supply voltage for all stages. D7 limits the maximum voltage developed across C14, to prevent damage to the meter M1 or TR7, 8, 9 if the range switch is set to a range too low in relation to the input pulse rate.

**Next month: The remaining circuitry for the STRACE radiation meter; this includes the pip generator, audio amplifier, and power unit.**

# SEMICONDUCTOR BASICS

By G. J. KING

## 6—OTHER SEMICONDUCTORS

THIS series has so far dealt with the more commonly used members of the semiconductor family, and in this concluding article the aim is to consider briefly some of the more recent developments using semiconductor materials.

### TUNNEL DIODE

The tunnel diode action differs considerably from the conventional diode. The main difference concerns the reverse current characteristic which reveals that the diode is highly conductive for all values of reverse voltage (see Fig. 6.1); the forward current changes with increasing forward voltage.

Initially, the forward current increases with forward voltage in the normal way up to current $I_p$ due to forward voltage $V_p$. As the voltage is further increased the current starts to fall, and subsequently falls into a deep valley before it starts rising again to follow the normal diode forward characteristic. This is called a negative resistance characteristic because it is opposite to ordinary resistive current flow.

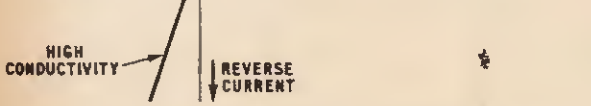



*Fig. 6.1. Characteristics of tunnel diode. Note the negative resistance zone and that high conductivity occurs in the reverse direction*

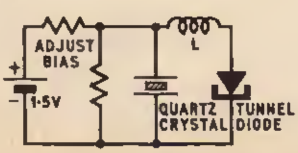



*Fig. 6.2. Simple crystal-controlled oscillator using tunnel diode*

The depletion layer (potential barrier or "space charge" region) is much narrower than in conventional junction diodes due to a very high concentration of *p*- and *n*-type impurities in the basic crystal. Hence, electrical charges are encouraged to traverse the junction by an action called tunnelling.

In most applications the tunnel diode is biased so that the operating point is established in the negative resistance region, and it is suitable for use as an amplifier, detector, oscillator, high-speed switch and rectifier. This latter aspect may seem strange in view of the high reverse conductivity.

Conventional rectifiers are arranged for substantial current flow in the forward direction, but extremely small in the reverse direction. Tunnel rectifiers, on the other hand, are arranged for substantial reverse current flow at very low voltages and much smaller forward current due to the negative resistance effect. This means that tunnel diodes can provide efficient rectification at much smaller signal voltages than conventional rectifiers, but note the reversed polarity requirements (for which reason they are sometimes called "back diodes").

Their amplifying attributes are particularly valuable at microwave frequencies (above 300MHz) due to low noise operation and low current demands.

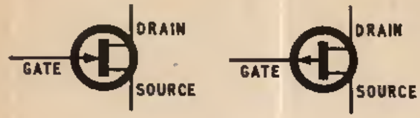
Stabilisation assumes great importance when the device is arranged as an amplifier, for it has a great tendency to oscillate more freely than to amplify without oscillating. This results from the wideband negative resistance characteristic which, when the amplifier is really well designed, can yield gain over a bandwidth in excess of an octave without variable tuning.

There is no trouble at all in getting a tunnel diode to oscillate, even with only a fraction of a volt bias. A basic oscillator circuit using a quartz crystal as control is given in Fig. 6.2. This yields a high range of harmonics because as the diode oscillates it swings continuously from the low voltage state, through the unstable negative resistance region to the high voltage state.

### INTEGRATED SCREEN TRANSISTORS

Early transistors were troubled with a high output/input feedback capacitance which called for neutralising techniques in high gain amplifying applications to prevent the amplifier from changing into an oscillator.

In ordinary transistors the unwanted feedback capacitance stems from the comparatively large bonding areas required for the emitter and base leadouts. The




*(a) n-channel type* *(b) p-channel type*

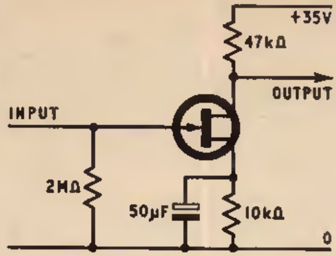




***Fig. 6.3. F.E.T. symbols***

***Fig. 6.4 F.E.T. audio amplifier circuit***

***Fig. 6.5. Make-up of silicon controlled rectifier (see text)***

effect of this causes a portion of the output signal to get back to the input of the transistor in phase with the real input signal, thereby creating conditions for positive feedback. Even though oscillation may not actually occur the effect can distort the response characteristics of the amplifier.

The "integrated screen" is a section of diffused semiconductor beneath the base bonding area. Feedback capacitance is considerably reduced making them suitable for intermediate-frequency amplifiers in particular. Their use ensures that the response characteristics retain a close tolerance even when the equipment is mass produced.

## FIELD EFFECT TRANSISTORS

The field effect transistor differs from the type of transistor that we have looked at so far, in that it is a voltage amplifier (as is the thermionic valve) rather than a current amplifier. It has a very high input impedance (millions rather than thousands of ohms) stemming from reverse biasing of the input junction required for normal operation. It will be recalled that the ordinary transistor is biased on the emitter/base junction for forward conduction, and it is this which endows it with the relatively low input impedance.

Basically, the f.e.t. consists of a slice of high resistance semiconductor sandwiched between two wafers of low resistance semiconductor having either *p*- or *n*-type characteristics. One end of the high resistance slice is called the source and the other end the drain. The two wafers are connected together to form what is called the gate.

The f.e.t. also differs from the ordinary transistor in that its action is governed only by one type of current carrier—either the electron or the hole—and for this reason it is sometimes termed "unipolar". Its symbol, too, is different, as shown in Fig. 6.3, where (a) is an *n*-channel type and (b) a *p*-channel type, the carriers being electrons and holes respectively.

***Sectional view through a typical Texas f.e.t.***

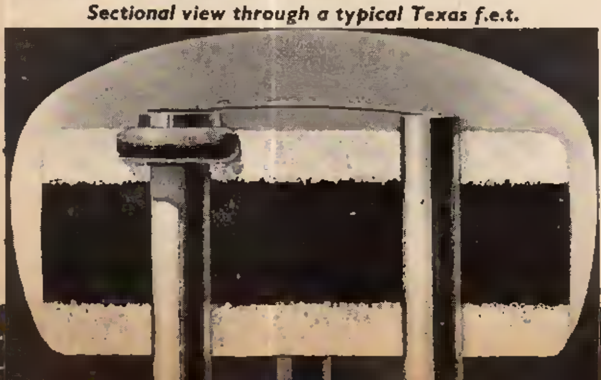


Fig. 6.4 shows basic f.e.t. amplifier stage, using an *n*-channel device. While the drain polarity is positive on the *n*-channel type, it is negative on a *p*-channel device, and the latter often incorporates a resistive potential divider across the supply, with the junction connected to the gate.

## THYRISTOR

The thyristor (or silicon controlled rectifier) is a junction diode with four semiconductor layers in *npnp* formation, as shown in Fig. 6.5. The end *p*-type is called the "anode" and the end *n*-type the "cathode". The sandwiched *p*-type is the "gate" or triggering electrode.

Owing to the four-layer make-up, current will not flow from cathode to anode (or vice versa) under ordinary conditions. However, when a pulse is applied to the gate, current is allowed to flow in the forward direction from anode to cathode.

When the polarity of the applied source is reversed the thyristor, like an ordinary diode, only passes a small leakage current. Unlike an ordinary diode, it will not pass forward current again when the polarity changes back, that is, not until it is once more gated or triggered.

The gating pulse controls the instant during a forward input pulse at which diode conduction starts. Once triggered, conduction is maintained as long as the supply polarity is correct and until the forward current falls below a small holding value. In this way, the thyristor is considered as the semiconductor version of the thyratron trigger valve.

## STRAIN GAUGE PRINCIPLE

Finally, a word or two about the semiconductor strain gauge principle. While the inherent resistivity of a piece of semiconductor like silicon depends on the various factors that we have already discussed, like the addition of impurities, heat and light, it also depends on mechanical strain. That is, by twisting, bending, or straining a small chip of semiconductor the crystal lattice is "distorted" and a change in resistivity occurs. This is the basic strain gauge principle, currently employed in various commercial and domestic devices.

A very interesting and fairly recent application of the principle is adopted in the strain gauge pick-up cartridge. The well-known crystal cartridge employs the strain gauge principle, but more recently has been replaced by the ceramic type. Very recent strain gauge pick-ups use a very small chip of silicon, less than 0·01in long and less than 0·0001in in cross section.

★

# Multivibrator

## AN ELECTRONIC SWITCH

LAST month's beginners project explored the light dependent resistor (l.d.r.) and its use as a "light-operated switch". This month's project demonstrates another "electronic" switch, namely the multivibrator.

The multivibrator is basically a two transistor circuit in which one transistor is switched on and the other off, i.e. the circuit has two distinct "states", and may be regarded as an electronic two-pole on/off switch, sometimes referred to as a "Flip-Flop".

To demonstrate the action of the multivibrator, two lamps have been inserted in the circuit and these flash on and off as first one transistor is switched on and then the other.

### CIRCUIT

The circuit diagram (Fig. 1) has numbered circles, which represent the terminal strip connections; these are also indicated on the wiring diagram in Fig. 2.

The two transistors TR1 and TR2 employed in this circuit are inexpensive *npn* types 2N2926 readily available from most components shops, and advertised elsewhere in the magazine.

The collector of TR1 is capacitively coupled to the base of TR2 by C1, and the collector of TR2 is coupled to the base of TR1 by C2. These capacitors are electrolytic types and the polarities must be adhered to, see Figs. 1 and 2.

The cross-coupling of the multivibrator circuit produces what, in effect, is an oscillator, due to the feedback action of the capacitors. Oscillation is started by the unbalance in each half of the circuit due to component tolerances. The output waveform at the collector of each transistor is almost square.

### THE OPERATION

When power is first applied to the circuit from the battery the unbalance between each half of the circuit pushes one transistor towards current cut-off and the other towards full conduction.

Let us assume at the start that TR1 and LP1 is switched on and TR2 is off; the voltage at TR1 collector charges C1 because the collector end of C1 is less negative than the base of TR2. At the same time, the base of TR2 becomes negative bringing it into conduction from its off state and switches LP2 on.

The capacitor C1 discharges through VR1 and C2 starts charging, making the base of TR1 go negative.

The result is alternative conduction through TR1 and TR2.

The flow of current in the base of the transistors causes a larger flow of current in the collectors and it is this larger current which drives the lamps.

The timing of the switch-over is determined by the values of the capacitors, the amount of charge on them, and the value of resistors R1, R2, and VR1, through which the charge leaks away.

### SWITCHING TIME ADJUSTMENT

By adjusting the setting of the potentiometer VR1, the value of the resistance affecting the discharge of each capacitor can be altered to change the switching time, so that one bulb will be on for a different period of time compared with the other. In fact, as one bulb comes on for a longer time, the other does so for a shorter time. This is called altering the mark-to-space ratio of the generated waveform.

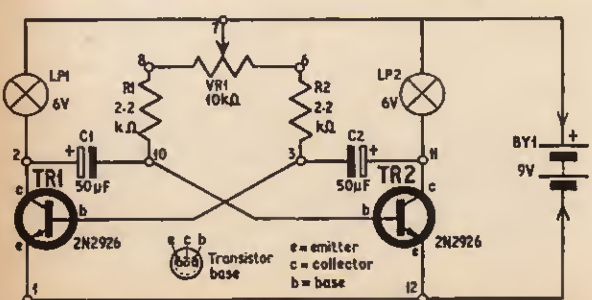



*Fig. 1. Circuit diagram of the multivibrator. The numbered circles represent the terminal strip connections*

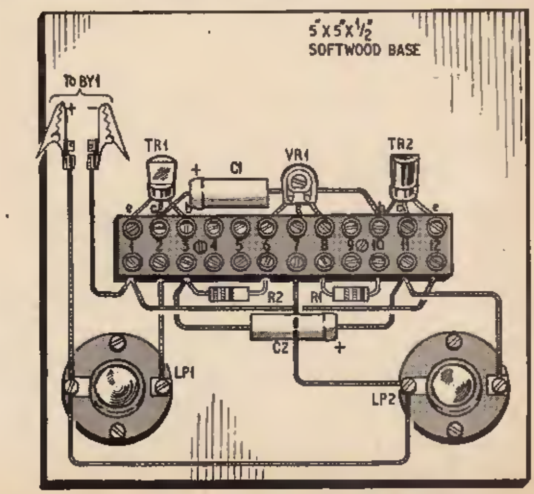



*Fig. 2 Constructional and wiring details. Note the transistor and capacitor connections*

Low consumption 6V lamps are used with a current rating of 0·06A (60mA), but lamps rated at 0·1A (100mA) will work just as well. Higher ratings should not to be used unless the transistors are changed for higher current types.

### USING *PNP* TRANSISTORS

If the reader wishes to use *pnp* transistors the capacitor polarities must be changed round, i.e. the positive ends are connected to the bases of the transistors. Also, the battery connections will have to be reversed, i.e. negative terminal connected to the lamps.

### CONSTRUCTION

Commence the construction by cutting a softwood baseboard 5in × 5in × ½in. The next stage is to wire the 12-way terminal strip before mounting this in position on the baseboard. A plastics sleeved link wire should be inserted between terminals 1 and 12. The two resistors R1 and R2 should be positioned between terminals 3 and 6; 8 and 10.

The outer leads of the subminiature potentiometer VR1 should be carefully bent so that they can be inserted in terminals 6, 7, and 8, see Fig. 2. The electrolytic capacitors C1 and C2 are positioned in terminals 2 and 10, 3 and 11. It is important that C1 and C2 are wired to the correct terminals; reference should be made to Fig. 2.

Finally, before mounting the terminal strip on the baseboard, the transistors should be mounted on the strip, see Fig. 2. Particular care should be taken to ensure that the transistor leads are wired to the correct terminals, as they can be damaged if wired incorrectly.

### FINAL ASSEMBLY

The terminal strip and m.e.s. bulb holders can now be screwed to the baseboard, see wiring diagram for relative positions. The terminal strip should be checked against the wiring diagram and screwed to the baseboard with two ¾in No. 4 countersunk woodscrews. The m.e.s. bulb holders are screwed to the baseboard with four ¾in No. 4 countersunk wood screws.

## COMPONENTS . . .

**Resistors**
R1 2·2kΩ R2 2·2kΩ
10%, ¼ watt carbon

**Potentiometer**
VR1 10kΩ linear subminiature preset

**Capacitors**
C1, 2 50μF electrolytic, 12V (2 off)

**Transistors**
TR1, 2 2N2926 (2 off)

**Lamps**
LP1, 2 6V 0·06A (60mA) (2 off)

**Miscellaneous**
BY1 9V type PP9 battery
One 12-way plastics terminal block
Two m.e.s. bulb holders, batten mounting
Wooden baseboard 5in × 5in × ½in
Two miniature crocodile clips or battery connectors
Six ¾in No. 4 countersunk wood screws
Plastic covered, single core copper wire

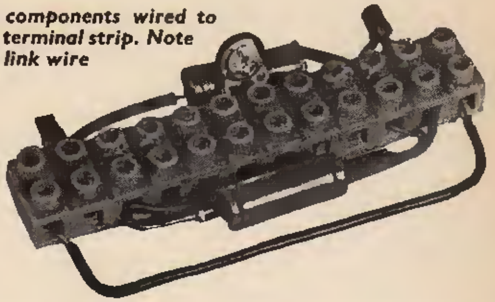
**Total cost £1 approx.**

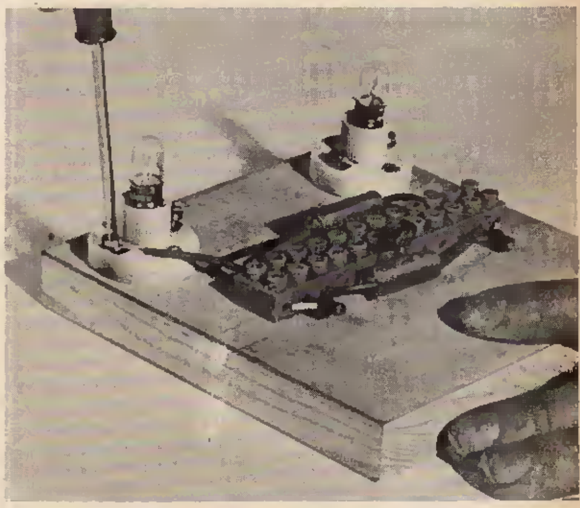
A lead from terminal 11 is taken to LP2 bulb holder. Two leads are taken from the other connecting screw and wired to terminal 8 and LP1 bulb holder, see Fig. 2. The other connecting screw of LP1 should be wired to terminal 2.

Finally, the battery leads should be wired in circuit. The negative lead is taken from terminal 1 and clipped on the battery negative connector by a miniature crocodile clip. The battery positive lead is taken from terminal connecting both lamps together.

The crocodile clip acts as a simple switch if removed when not used. All the wiring should be given a final check before making the final battery connection. The multivibrator lamps will start flashing or switching on and off as soon as the supply is connected.

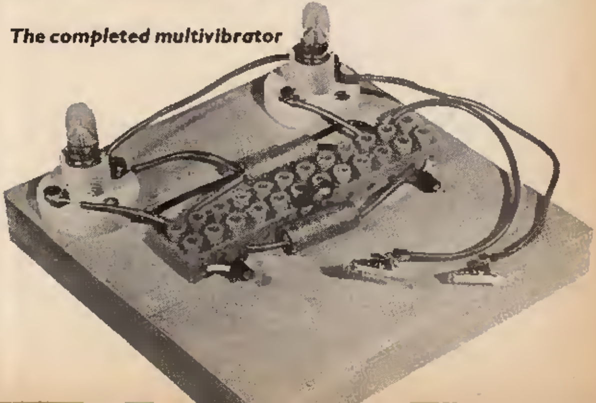
*All components wired to the terminal strip. Note the link wire*





*Fixing a connecting lead to one of the m.e.s. bulb holders*

*The completed multivibrator*



The detailed explanation concerning the operation of UNIT "A" is continued in this month's article, with further practical examples.

We resume by considering the use of the operational amplifier as an integrator.

An operational amplifier will be handling time as well as voltage when acting as an integrator, so some means must be found of inserting intervals of time onto the computer. One method is to employ external oscillators to provide known functions of time in terms of frequency. An input to an integrator might consist of a steady d.c. voltage which is switched on for a time $t$ (step function or square wave), or alternatively, a sinusoidal voltage of frequency $f$ and period $1/f$.

If a graph is drawn of the resulting integrator output function, and this is the form that answers to problems involving change or motion will usually take, the X axis of the graph will be calibrated in intervals of time, with voltage on the Y axis. It follows that an oscilloscope, which also uses time on the X axis and voltage on the Y axis, can provide a convenient form of output display, especially when an integrator is operating at high speed.

The operational amplifier is converted to an integrator when a capacitor $C_f$ is inserted, in place of a resistor, in the feedback path; see Fig. 5.1. When an input voltage $-E_{in}$ is applied to the integrator by means of a simple switch S for a time $t$, the output $E_o$ will take the form of an increasing ramp voltage proportional to $t$ with slope

$$-E_{in}\,\frac{1}{R_{in}C_f}$$

Note that the operational amplifier will continue to invert an input voltage even when used as an integrator.

## THE INTEGRATOR IN EQUATION SOLVING

The electronic analogue computer does provide a powerful technique for obtaining rapid solutions to problems involving calculus, which cannot be equalled either by numerical methods or by a digital computer.

If differentiation and integration are regarded as straightforward mathematical operations, it will be found that the terms of, say, a second order differential equation can be manipulated on the computer in much the same way as the terms of a "steady state" algebraic equation.

For example, when an equation term $y$ is differentiated against time its derivative $dy/dt$ is obtained, and a second differentiation yields the second derivative $d^2y/dt^2$. The reverse process is where integration of the second derivative $d^2y/dt^2$ produces the first derivative $dy/dt$, and another integration gives $y$ as the result.

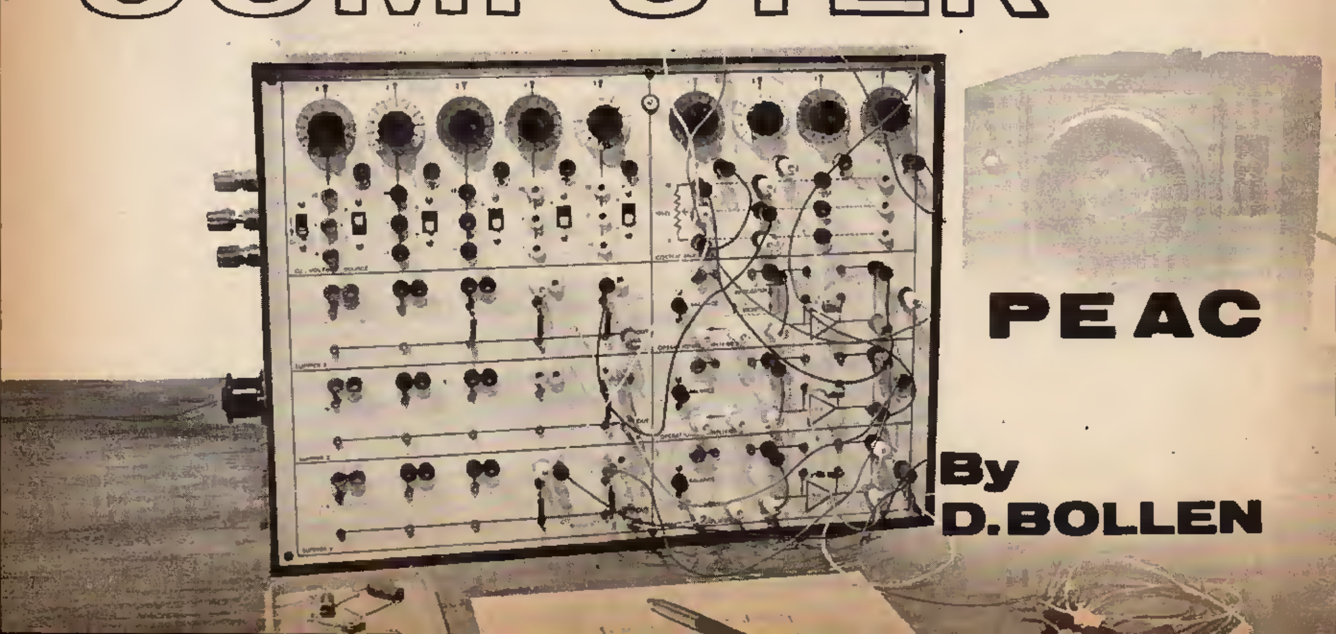
Fig. 5.2 shows how a simple integrator can handle equation terms. Combined operations are made possible by cascading integrators, while using coefficient potentiometers and computing component ratios for summation, multiplication, and division (Fig. 4.1).

The process of differentiation, although feasible if care is taken, is generally avoided on analogue computers because it gives rise to unstable operational amplifier configurations, but this imposes only a slight limitation since integration can be employed—in the majority of cases—in place of differentiation.

## INTEGRATOR ACCURACY

The transfer accuracy of an operational amplifier, when it is used as an integrator, will be theoretically limited by its finite value of open-loop gain. However,

# ANALOGUE COMPUTER



# PEAC

By D. BOLLEN

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| 64μF | 275 volts | 1/3 | 8 + 16 | 450 volts | 1/9 |
| 800μF | 15 volts | 1/2 | 50 + 50 | 275 volts | 2/– |
| 500μF | 25 volts | 10d | 40 + 40 + 20 | 275 volts | 2/1 |

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|---|---|---|---|---|---|
| 16/16/16, 350V | 2/2 | 100/100, 50V | 3/2 | 12,500μF, 30V | 16/– |
| 50/50/50, 350V | 2/7 | 150/350, 300V | 4/– | 30,000μF, 30V | 25/– |
| 1,000μF, 70V | 3/2 | 250/250, 325V | 4/– | 1,000μF, 15V | 1/6 |
| 100/200, 275V | 3/2 | 2,000/2,000, 25V | 4/6 | 1,000μF, 18V | 1/– |
| 100/200/200/50, 275V | 4/– | 250μF, 50V | 10d | 500μF, 15V | 10d |
| 3,000μF, 35V | 3/9 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 0·25μF | 3 volt | 8μF | 3 volt | 64μF | 2·5 volt |
| 1μF | 50 volt | 8μF | 6 volt | 64μF | 9 volt |
| 1μF | 350 volt | 8μF | 50 volt | 100μF | 3 volt |
| 1·25μF | 16 volt | 8μF | 275 volt | 100μF | 6 volt |
| 2μF | 3 volt | 10μF | 25 volt | 100μF | 9 volt |
| 2μF | 9 volt | 16μF | 150 volt | 150μF | 12 volt |
| 2μF | 70 volt | 20μF | 3 volt | 200μF | 3 volt |
| 2μF | 150 volt | 20μF | 6 volt | 200μF | 4 volt |
| 2μF | 350 volt | 20μF | 9 volt | 200μF | 16 volt |
| 2·5μF | 16 volt | 20μF | 15 volt | 250μF | 2·5 volt |
| 2·5μF | 25 volt | 25μF | 6 volt | 250μF | 9 volt |
| 3μF | 3 volt | 25μF | 12 volt | 320μF | 2·5 volt |
| 3μF | 25 volt | 25μF | 15 volt | 350μF | 9 volt |
| 3·2μF | 6·4 volt | 25μF | 25 volt | 350μF | 10 volt |
| 4μF | 4 volt | 30μF | 6 volt | 400μF | 2·5 volt |
| 4μF | 12 volt | 30μF | 10 volt | 400μF | 15 volt |
| 4μF | 25 volt | 40μF | 3 volt | 500μF | 4 volt |
| 4μF | 100 volt | 40μF | 6·4 volt | 500μF | 6 volt |
| 5μF | 6 volt | 50μF | 9 volt | 640μF | 2·5 volt |
| 5μF | 25 volt | 50μF | 12 volt | 750μF | 12 volt |
| 6μF | 3 volt | | | | |

All at 1/– each, 9/– per dozen. Mixed Packets of 20 (our selection) 10/–.

**PAPER CONDENSERS**

| | | | | | |
|---|---|---|---|---|---|
| 0·001μF | 500 volt | 0·02μF | 600 a.c. | 0·25μF | 350 volt |
| 0·001μF | 1000 volt | 0·02μF | 350 volt | 0·5μF | 350 volt |
| 0·002μF | 500 volt | 0·1μF | 350 volt | 0·5μF | 500 volt |
| 0·005μF | 750 volt | | | | |

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|---|---|---|---|---|---|
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| 0·0018μF | 400 volts | 4d | 0·22μF | 160 volts | 7d |
| 0·0015μF | 400 volts | 4d | 0·27μF | 160 volts | 8d |
| 0·001μF | 400 volts | 4d | 0·056μF | 125 volts | 7d |
| 0·01μF | 160 volts | 4d | 1μF | 125 volts | 1/6 |
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| ECC82 | 7/4 | PABC80 | 7/1 | PL36 | 10/1 |
| ECC83 | 7/4 | PC97 | 10/6 | PL81 | 8/5 |
| ECL80 | 7/1 | PCC84 | 7/4 | PL83 | 8/5 |
| ECL86 | 8/5 | PCC89 | 10/6 | PL84 | 6/6 |
| EF80 | 7/1 | PCF80 | 8/5 | PL500 | 12/5 |
| EF85 | 7/1 | PCF86 | 10/1 | PY32 | 9/– |
| EF183 | 9/5 | PCL82 | 8/5 | PY81 | 6/9 |
| EF184 | 8/5 | PCL83 | 9/10 | PY82 | 4/9 |
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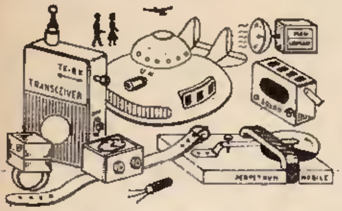

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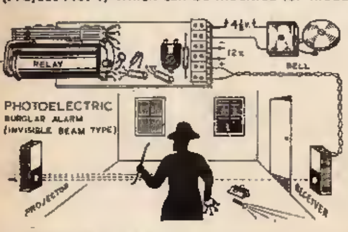


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**TABLE 5.1**

| $C_f$ | $R_{in}$ | t |
|---|---|---|
| $1\mu F$ | $100k\Omega$ | 2·8sec |
| | $10k\Omega$ | 800ms |
| $0{\cdot}1\mu F$ | $100k\Omega$ | 280ms |
| | $10k\Omega$ | 80ms |
| $0{\cdot}01\mu F$ | $100k\Omega$ | 28ms |

Maximum value of t for an error of 1%

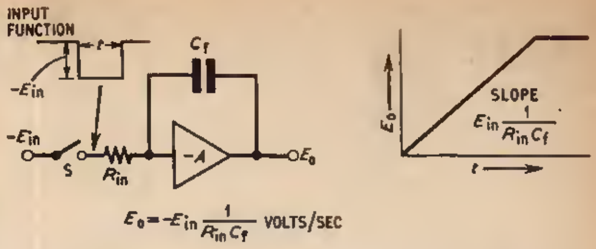


*Fig. 5.1. The operational amplifier as an integrator*

the situation is much more complicated than with, for example, a summing amplifier (Fig. 3.8) since the amplifier error can no longer be defined in terms of the simple relationship between closed-loop and open-loop gains.

As a guiding principle, integrating amplifiers may have very large values of closed-loop gain provided that the time $t$ of an input function remains small. Closed-loop integrator gains of 1,000 or more are not uncommon in transistor computers, since low voltages and low impedances discourage the use of computing resistors of more than 100 kilohm, and capacitors of more than $1\mu F$ are too bulky. Table 5.1 is calculated for UNIT "A" amplifiers, and sets out the maximum allowable interval $t$ for selected values of $C_f$ and $R_{in}$, where the amplifier transfer error must not exceed one per cent.

Errors due to unwanted drift voltages also become significant when $t$ is long and $C_f$ is small. The greatest care must be exercised when zero-setting integrators to eliminate offset voltages, for good accuracy at long time intervals. Also, the computer should not be subjected to fluctuations of ambient temperature when computations cover several hours of integrator use.

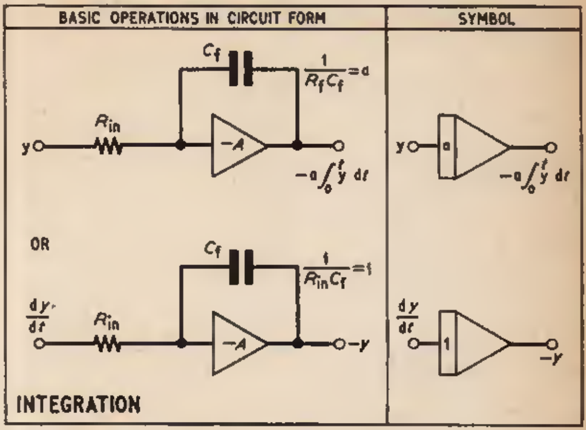


*Fig. 5.2. The handling of equation terms by a simple integrator*

## COMPUTING CAPACITORS

The computing capacitors used for PEAC will normally lie within the range $0{\cdot}01$–$1\mu F$, and the three values most commonly employed are $0{\cdot}01\mu F$, $0{\cdot}1\mu F$, and $1\mu F$. Polystyrene is the preferred capacitor dielectric, for high insulation resistance, but polyester makes an acceptable second best. Mica, paper, and ceramic capacitors should be avoided.

Small value polystyrene capacitors of $\pm 1$ per cent and $\pm 2$ per cent tolerance are easily obtained, but $0{\cdot}1\mu F$ and $1\mu F$ precision components are rare and expensive. To get around this difficulty, the bridge circuit of Fig. 5.3 was devised to allow computing capacitors to be made up from specially selected low cost $\pm 20$ per cent capacitors.

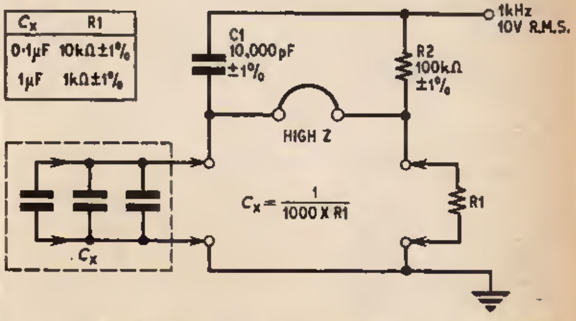


*Fig. 5.3. Bridge circuit used for making up computing capacitors*

The circuit of Fig. 5.3 can be constructed in breadboard form on Veroboard or s.r.b.p., with miniature sockets to take $C_x$ and R1. If an audio signal generator is not available to supply the bridge with about 10V r.m.s. at 1kHz, a signal could be obtained from a transistor multivibrator powered by the 25V computer power supply. Headphones serve to detect the null point when the bridge is in balance, and should have an impedance of about 2 kilohms.

The method of making up a computing capacitor of, say, $1\mu F$ is as follows. A capacitor panel of plain or perforated s.r.b.p. is fitted with small turret tags as in Fig. 5.4. A $\pm 20$ per cent capacitor of about $0{\cdot}68\mu F$ is wired into position on the capacitor panel before it is plugged into the bridge $C_x$ sockets, and a 1 kilohm

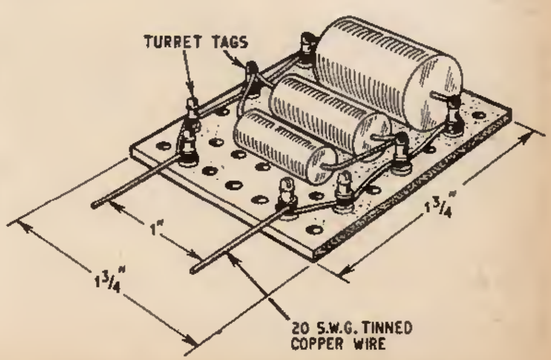


*Fig. 5.4. Computing capacitor plug-in panel*

resistor is inserted for R1. Assorted polystyrene or good quality polyester capacitors of lower value are then temporarily connected across the capacitor panel to increase $C_x$ by small increments, while listening on the headphones for a drop in the level of the 1kHz tone as $C_x$ approaches 1$\mu$F.

A typical computing capacitor might finally consist of a parallel combination of the following values, 0·68$\mu$F, 0·22$\mu$F, 0·02$\mu$F, and 0·005$\mu$F.

If the required value of $C_x$ is exceeded, the note in the headphones will increase in volume when the null point is passed. Allow capacitors to cool off after soldering, and before making a measurement, as heat can cause a temporary or permanent change in capacitance. With the Fig. 5.3 bridge circuit it is possible to detect increments of less than 0·01$\mu$F in a nominal 1$\mu$F capacitor.

## DIFFERENTIAL ANALYSIS WITH UNIT "A"

A second order linear differential equation with constant coefficients has become firmly established as the "classic" introduction to differential analysis on the analogue computer.

The equation describes an oscillatory system with variable damping which can be used to simulate indirectly many physical systems, such as the spring pendulum, a tuned *LC* circuit, or a servomechanism. Also, the equation is easy to set up on the computer, and does not necessarily demand the use of integrator mode switching.

In general form the equation is,

$$a\frac{d^2y}{dt^2} + b\frac{dy}{dt} + cy = f(t) \qquad \text{(Eq. 5.1)}$$

where $a$, $b$, and $c$ are the constant coefficients, $y$ is unknown, and $f(t)$ represents some function of time. Equation 5.1 can be rewritten to suit a particular system by substituting appropriate terms.

***Spring pendulum***

$$m\frac{d^2y}{dt^2} + \mu\frac{dy}{dt} + ky = f(t) \qquad \text{(Eq. 5.2)}$$

where $m$ is the mass of a weight suspended on a spring of constant $k$, which is damped by friction $\mu$. The weight is displaced by an amount $y$ when subjected to a force dependent on $f(t)$.

***Tuned LC circuit***

$$L\frac{d^2Q}{dt^2} + R\frac{dQ}{dt} + \frac{1}{C}Q = f(t) \qquad \text{(Eq. 5.3)}$$

where $L$ is an inductance tuned by a capacitance $C$, and damped by a series resistance $R$. $Q$ is the charge in coulombs on $C$ at any instant of time. The current flowing in the tuned circuit is given by $dQ/dt$, and $f(t)$ represents an input function.

***Servomechanism***

$$\frac{d^2\theta_o}{dt^2} + 2\zeta\omega\frac{d\theta_o}{dt} + \omega^2\theta_o = \omega^2\theta_i \qquad \text{(Eq. 5.4)}$$

where $\theta_o$ is the angular displacement of the output shaft, $\zeta$ the damping factor, $\omega$ the angular velocity, and $\theta_i$ the angular displacement of the input shaft.

The obvious similarity between the above equations is emphasised when, in Fig. 5.5, it is seen that they all have virtually the same problem layout on the computer. Furthermore, as the computer will allow operation at almost any fraction or multiple of real time, a spring pendulum and a tuned *LC* circuit can be simulated simultaneously, and interesting electro-mechanical parallels can be seen to exist between the properties of inductance and mass, resistance and friction, and capacitance and elasticity.

The only real difference between the analogous behaviour of a weight on a spring, a servo shaft, and a tuned *LC* circuit is that the *LC* combination will normally resonate at a much higher frequency.

## PROBLEM EXAMPLE 3. TUNED CIRCUIT ANALYSIS

UNIT "A" will simulate any series tuned circuit by solving Equation 5.2, and will give answers in the form of a.c. meter readings or oscillograms. Tuned circuits resonating in the MHz region are catered for by slowing down the problem to some convenient decadal fraction of real time, so that a simulated circuit on the computer which is, for example, resonating at 300Hz, will serve as a model for a real circuit resonating at 30MHz, with suitable rescaling of $L$, $C$, and $t$.

To initially determine the relative values of $L$, $C$, $R$, voltage $V$, and current $I$, without too much paperwork, it is helpful to start with a representative tuned circuit which allows computer operation in real time, at frequencies convenient for display by an a.c. voltmeter or an oscilloscope. 50Hz is a good frequency to employ as a datum because it can be readily obtained from the mains supply; and rounded values of $L = 1$H and $C = 10\mu$F will also offer resonance at 50Hz.

Taking the circuit of Fig. 5.6a as a starting point, from the knowledge that a series tuned circuit will exhibit an impedance equal to $R$ at resonance, the r.m.s. current flow at 50Hz will be $E_i/R$, or 20mA when $E_i = 2$V r.m.s. and $R = 100$ ohms.

It is necessary to rearrange the basic equation, Equation 5.2, for the computer by dividing through by $L$, and solving for the second derivative.

$$\frac{d^2Q}{dt^2} = -\frac{R}{L}\frac{dQ}{dt} - \frac{1}{LC} + \frac{f(t)}{L} \qquad \text{(Eq. 5.5)}$$

Substituting known values from Fig. 5.6a,

$$\frac{d^2Q}{dt^2} = \frac{100R}{1\text{H}}\frac{dQ}{dt} - \frac{1}{1\text{H} \times 10^{-5}C}Q + \frac{f(t)}{1\text{H}} \qquad \text{(Eq. 5.6)}$$

$f(t)$ in the present case represents a sine wave input of 2V r.m.s. In other circumstances the input function could be a square wave of amplitude $E_{in}$ and period $2t$.

Equation 5.6 is solved on the computer by successive integration. Looking at the symbolised diagram of Fig. 5.6b, it can be seen that there are two closed-loops, one linking the output of OA1 via CP1 to OA1/Input 1, and the other passing through OA1, OA2, and OA3, via CP2, and thence back to OA1/Input 3. The coefficient of CP1 will be multiplied by the gain factor associated with OA1/Input 1. CP2 coefficient is multiplied by the product of gains OA1/Input 3, OA2, and OA3, i.e. $1{,}000 \times 100 \times 1 = 100{,}000$.

$d^2Q/dt^2$, obtained from the sum of the voltages present at the inputs of OA1, is initially assumed to be present. After one integration OA1 provides an output $dQ/dt$, and from this all the terms on the right hand side of Equation 5.6 are assembled. So, $dQ/dt$ is multiplied by $R/L = 100$, using CP1 set for a coefficient of 0·1, and is taken back to OA1/Input 1 where it is then added to $f(t)/L = 2$V r.m.s.

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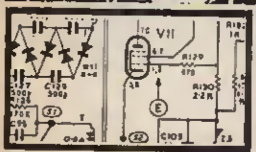
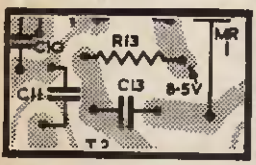


Circuit diagrams

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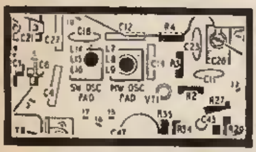
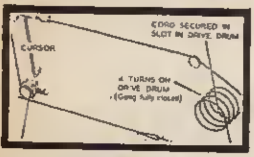


Component layout diagrams

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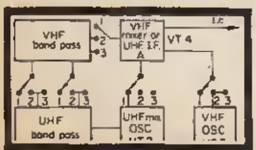


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Moving in the other direction on the symbolised diagram of Fig. 5.6b, $dQ/dt$ is integrated by OA2 to obtain $+Q$. Inverting amplifier OA3 changes the sign of $Q$ before passing it on for multiplication by $1/LC = 100{,}000$ (CP2 coefficient of 1). $-(1/LC)Q$ is then added, at OA1/Input 3, to

$$-\frac{R}{L}\frac{dQ}{dt}+\frac{f(t)}{L}$$

and the sum of all OA1 input voltages yields the required $d^2Q/dt^2$. Because there are two closed-loops in the computer set-up the equation will be self-enforcing.

**Routine.** Switch on UNIT "A" power supply and allow a warm-up time of at least 15 minutes. Ensure that the three operational amplifiers are disconnected from their summer networks, and have no feedback components. Apply 10V d.c. voltmeter leads to OA1/SK13 and an earth socket, and zero-set OA1 for an output voltage of less than $\pm 1$V from the back of the UNIT "A" box, by means of VR1 (Fig. 3.7). Repeat for OA2 and OA3.

Set up the problem according to the patching circuit of Fig. 5.6b, but omit the feedback capacitors and the patching link between OA3/SK13 and CP2/SK1. Set CP1 dial to approximately "1". Connect the voltmeter to miniature socket OA1/SK6 (Fig. 2.9) and zero-set OA1 again, but this time using the front panel control VR15.

Next, zero-set OA2 using VR16, and OA3 using VR17. Insert 0·1$\mu$F computing capacitors into OA1/SK11 and SK12, and OA2/SK11 and SK12, and make good the link between OA3 output and CP2. Set CP2 for a dial reading of "10". Apply the voltmeter to OA2/SK7 and zero-set the complete assembly of amplifiers by adjustment of VR15(OA1) only.

The problem layout will now be ready for dynamic checks and should not need to be re-zeroed for several hours if UNIT "A" is being operated in stable ambient temperature conditions.

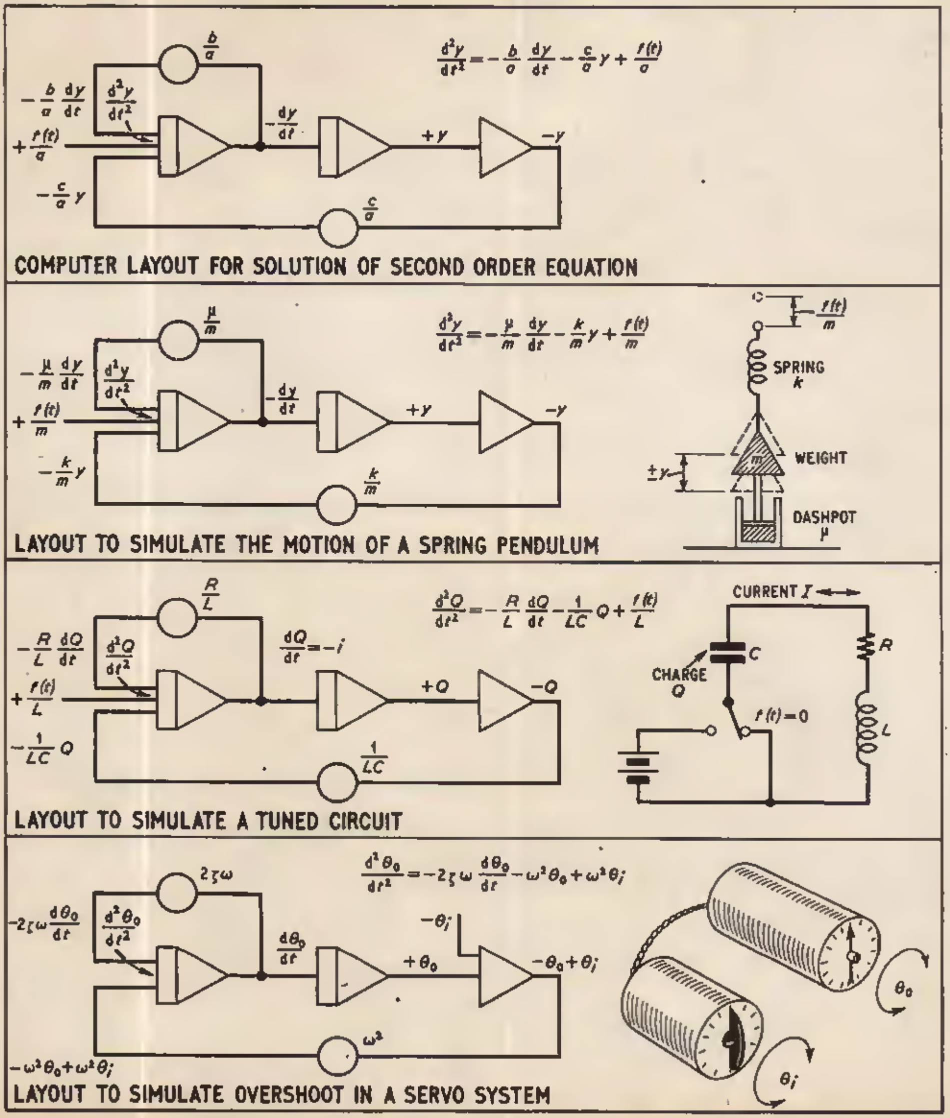


*Fig. 5.5. A second order differential equation applied to physical systems*

## TABLE 5.2

SHOWING HOW COMPUTER OPERATING FREQUENCIES ARE RELATED TO CP2 SETTING AND AMPLIFIER CLOSED-LOOP GAINS

| Resonant Frequency $f$ | Typical Values $L$ | $C$ | CP2 Coefficient | $\frac{1}{LC}$ | Amplifier Gains OA1 Input 3 | OA2 | OA3 |
|---|---|---|---|---|---|---|---|
| 0·05Hz | 1,000H | 10,000$\mu$F | 0·1 | 0·1 | 10 | 10 | 0·1 |
| to | | | | | | | |
| 0·5Hz | 100H | 1,000$\mu$F | 1·0 | 10 | 10 | 10 | 0·1 |
| 5Hz | 10H | 100$\mu$F | 0·01 | $10^3$ | 1,000 | 100 | 1·0 |
| to | | | | | | | |
| 50Hz | 1H | 10$\mu$F | 1·0 | $10^5$ | 1,000 | 100 | 1·0 |
| 500Hz | 100mH | 1$\mu$F | 1·0 | $10^7$ | 1,000 | 1,000 | 10 |
| 1kHz | 100mH | 0·2$\mu$F | 1·0 | $5\times10^7$ | 1,000 | 1,000 | 50 |

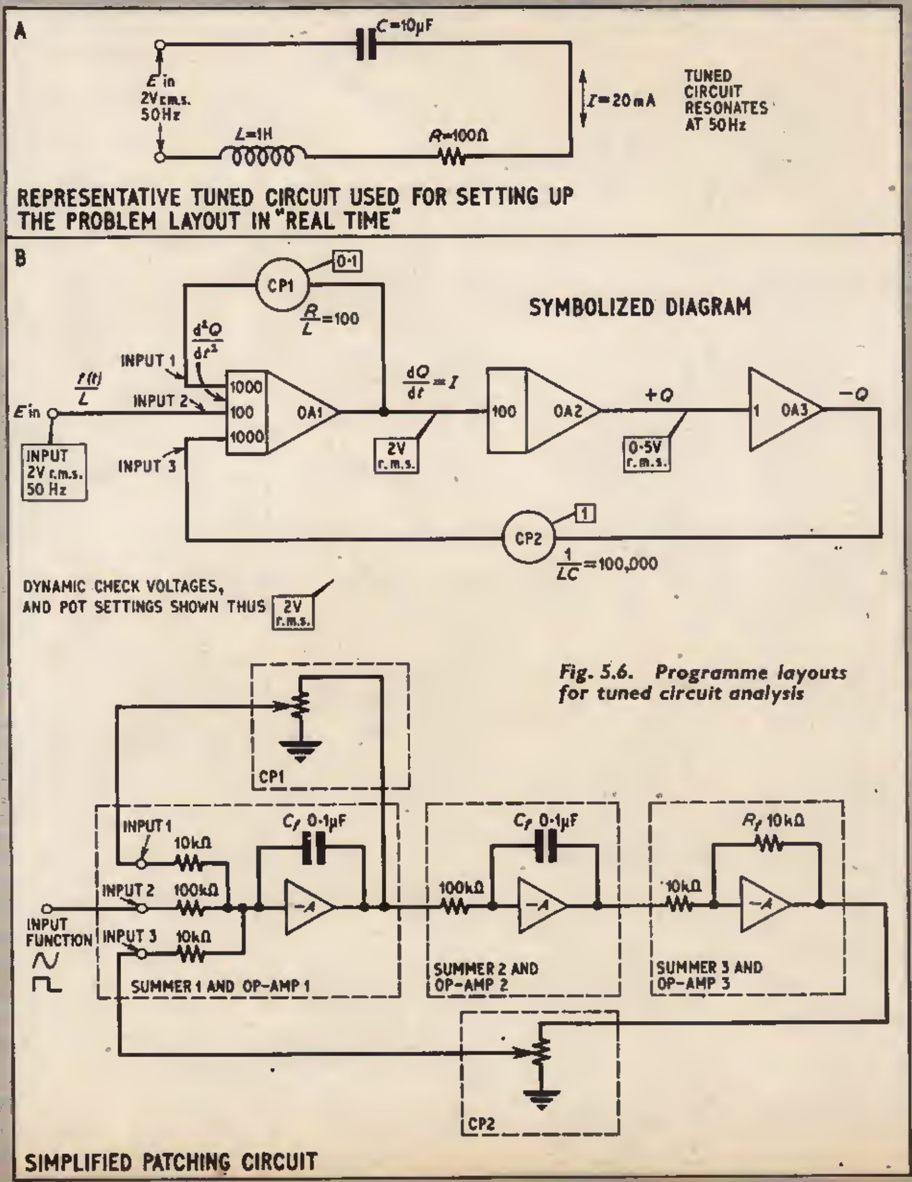


*Fig. 5.6. Programme layouts for tuned circuit analysis*

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**Pre-Set 100K** by Welwyn with intrical bakelite knob, 1/- each; 9/- per dozen.
**100K Pot-Meter.** Miniature type with double pole switch and standard ¼in spindle, by Morganite. 2/- each; 18/- per dozen.
**Blanketstat Glass.** Enclosed, normally closed circuit, will open should blanket overheat, 4/6 each.
**Thermal Relay.** Can be used to delay the supply of HT while heaters warm up, or will enable 15A loads to be controlled by miniature switches or relays. Regular list price over £2, price 7/6 each.
**Siemens High Speed Relay.** Twin 1,000 ohm coils. Platinum points changeover contacts—Ex equipment 6/6 each.
**Toggle Switch Bargain.** 10A 250V normal one hole fitting 2/9 each; or 30/- per doz.
**Electric Lock.** 24V coil, but rewindable to other voltages, 4/6 each.
**Compression Trimmers.** Twin 100pF, 1/- each; 9/- per dozen.
**Precision Wheatstone Bridge.** Opportunity to build cheaply. 100K wire wound pot. 15W rating, only 5/-.
**Sheet Paxolin.** Ideal for transistor projects. 12 panels each 5in × 8in, 5/-.
**3in PM Loudspeaker.** 3 ohm, 12/6; 80 ohm, 13/6.
**Transistor Ferrite Slab Aerial** with medium and long wave coils, 7/6 each.
**Slide Switch.** Sub miniature double pole changeover, 2/- each; 18/- per dozen.
**Vacuum Cleaner Flex.** Non-kinkable ribbed rubber, most pliable but very tough. 24/36 Cores. Normally, 1/9 per yard, offered at £3 per 100 yard coil, post and insurance 5/6.
**Sub-Miniature Silicon Diodes.** General purpose type with gold-plated leads, 1/- each or 7/6 per dozen.
**Message Tapes.** 225ft Tape on 3in spools, normally 4/6 each, we offer 4 tapes for 12/6.
**White Circular Flex.** Ideal for lighting drops, twin made by BICC. Usually 8d yd, 100 yd coil for 30/-, plus 6/- postage.
**Edgewise Control.** Morganite, as fitted many transistor radios, 2K or 5K with switch, 2/6 each or 24/- per dozen.
**12V Inverter.** Full transistorised for operating a 20-watt fluorescent tube, size 6in long × 1¾ × 1¼. £3.10.0. Post and insurance 3/-.
**Silicon Rectifier.** Equiv. BY100 750mA 400V, 10 for 20/-.
**Miniature Pickup** for 7in records made by Cosmocode, crystal cartridge with sapphire stylus only 3/9 or 36/- dozen.
**Telescopic Aerial** for radio or transmitter, chrome plated, 6 section extends from 7¾in to 47in, 7/6 each, £4 per dozen.
**Midget Neons** for mains indicators, etc., 1/3 each or 12/- dozen.
**Midget Relay** twin 250 ohm coils, size approx. 1¼in × 1in × 1in. 4 pairs changeover contacts 7/6 each.
**P.O. Type Relay.** Twin 200 ohm coils, size approx. 3in × 2in × ⅞in. 4 pairs changeover contacts. 8/6 each.
**Printed Circuit Board, Edge Connector,** solder terminations. 32 contacts, standard spacing for veroboard, etc. 6in long but easily cut. 7/6 each, 80/- doz.
**1,000W Fire Spiral,** replacement for most fires. 1/3 each, 12/- doz.

**PPS Eliminator.** Play your pocket radio from the mains! Save £s. Complete component kit comprises 4 rectifiers—mains dropper resistances, smoothing condenser and instructions. Only 6/6 plus 1/- post.

## PHOTO-ELECTRIC KIT

All parts to make light operated switch/burglar alarm/counter, etc. Kit comprises printed circuit, Laminated Boards and chemicals, Latching relay, Infra-red sensitive Photocell and Hood, 2 Transistors, cond., Terminal Block, Plastic case. Essential data, circuits and P.C. chassis plans of 10 photo-electric device including auto. car parking light, modulated light alarm. Simple invisible ray switch—counter—stray light alarm—warbling tone electronic alarm—projector lamp stabiliser, etc., etc. Only 39/6, plus 2/- post and insurance.

## Be first this year SEED AND PLANT RAISING

Soil heating wire and transformer. Suitable for standard size garden frame. 19/6, plus 3/6 post and ins.

## CONTROL DRILL SPEEDS

## DRILL CONTROLLER

Electronically changes speed from approximately 10 revs. to maximum. Full power at all speeds by fingertip control. Kit includes all parts, case, everything and full instructions 19/6, plus 2/6 post and insurance. Or available made up 32/6, plus 2/6 post and insurance.

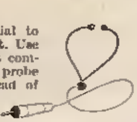
## SUPERTONE G.C.V.

**Saves you work—**
**It's partly built**

Like its predecessors this latest Companion has full fi performance—such as only a good wooden cabinet and biflux speaker can give, and due to its being partly built you will have it going in an evening. Note these features.

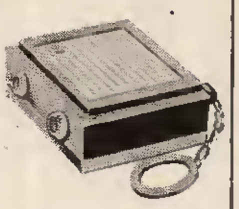
- 7 Transistors, superhet circuit.
- Two-tone Cabinet, size 11 × 8 × 3in.
- All circuit requirements—Push-pull output—A.V.C. and feed back, etc.
- Printed circuit board all wired only connections, e.g., to Volume control W.C. Switch and Tuning Condenser.
- Pre-aligned IF stages complete with full instructions. Price only £4.9.6 plus 6/6 post and insurance.

## RADIO STETHOSCOPE



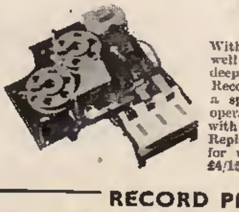
**Easiest way to fault find**—traces signal from aerial to speaker—when signal stops you've found the fault. Use it on Radio, T.V., amplifier, anything—complete kit comprises two special transistors and all parts including probe tube and crystal earpiece 29/6—twin stetoset instead of earpiece 7/6 extra post and ins. 2/9.

## THIS MONTH'S SNIP MICRO-SONIC



7 transistor Key chain Radio in very pretty case, size 2⅜in × 2⅛in × 1¼in—complete with soft leather zipped bag. Specification: Circuit—7 transistor superheterodyne; Frequency range—530 to 1,600kc/s; Sensitivity—5mV/m; Intermediate frequency—465kc/s, or 455kc/s; Power output — 40mW; Antenna—ferrite rod; Loudspeaker—Permanent magnet type. In transit from the East these sets suffered slight corrosion as the batteries were left in them but when this corrosion is cleared away they should work perfectly—offered without guarantee except that they are new, 19/6 plus 2/6 post and insurance, less batteries.

## BATTERY OPERATED TAPE DECK

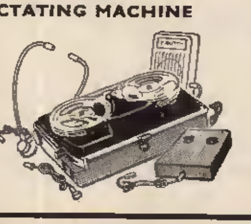


With Capstan control. This unit is extremely well made and measures approx. 6 × 5 × 2in deep. Has three piano key type controls for Record, Playback and Rewind. Motor is a special heavy duty type intended for operation off 4/5 volts. Supplied complete with 2 spools ready to install. Record, Replay head is the sensitive M4 type intended for use with transistor, amplifier. Price £4/15/-. Post and insurance 4/6.

## RECORD PLAYER SNIP

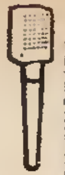
The "Princess" 4 speed automatic record changer and player engineered with the utmost precision for beauty, long life and trouble free service. Will take up to ten records which may be mixed—7in, 10in or 12in. Patent stylus brush cleans stylus after each playing and at shut off, the pick-up locks itself into its recess—a most useful feature with portable equipment—other features include pick-up height adjustment and stylus pressure adjustment. This truly is a fine instrument which you can purchase this month at only £5.19.6, complete with cartridge and ready to play. Post and insurance 7/6 extra.

## CASSETTE LOADED DICTATING MACHINE



Battery operated and with all accessories. Really fantastic offer, a British made £31 outfit for only £6/19/6, brilliantly designed for speed and efficiency—cassette takes normal spools, drops in and out for easy loading—all normal functions—accessories include stethoscopic ear-piece—crystal microphone has on/off switch—telephone pick-up—tape reference pad—DON'T MISS THIS UNREPEATABLE OFFER—SEND TO-DAY. £6/19/6, plus 7/6 post and insurance. Footswitch 18/6 extra. Spare Cassettes at 7/6 each, three for £1.

## SENSITIVE HAND MICROPHONE



Dynamic type. Low impedance, moving ion, fitted in unusually neat plastic head with anti-microphonic coupling to handle. Extra small size but very sensitive. 15/- each.

**B7G Valve Holders** with bottom screen—p.t.f.e. insulation finest for HF and VHF, 1/- each; 10/- doz.
**Fractional H.P. Motor.** 240V 50c/s—open construction ideal for ventilation fan—blower heater, etc.
**Clock Motor.** 230V 50c/s synchronous—self starting, 6/6.
**Pentode Output Transformer**—standard size, 40–1, ex equipment but O.K., 4/3 each; 48/- doz., post paid.
**Neon Mains Tester,** 1/3 each; 12/- doz.
**MAINS TRANSFORMER.** Upright mounting with primary tapped 200, 220, 240V H.T. secondary is 250-0-250V at 100mA and it has two L.T. secondaries of 6·3V 1½A—unused (removed from equipment), 15/- plus 3/6 post and insurance.

## FLUORESCENT CONTROL KITS

Each kit comprises seven items—Choke, 2 tube ends, starter, starter holder and 2 tube clips, with wiring instructions. Suitable for normal fluorescent tubes or the new "Grolux" tubes for fish tanks and indoor plants. Chokes are supersilent, mostly resin filled. Kit A.—15-20W, 19/6, Kit B—30-40W., 17/6. Kit C—80W., 17/6, Kit D—125W., 22/-. Kit E—65W., 19/6. Kit MF1 is for 6in., 9in. and 12in. miniature tubes 19/6. Postage on Kits A and B 4/6 for one or two kits then 4/6 for each two kits ordered. Kits C, D and E 4/6 on first kit then 3/6 for each kit ordered. Kit MF1 3/6 on first kit then 3/6 on each two kits ordered.

## MAINS TRANSISTOR POWER PACK

Designed to operate transistor sets and amplifiers. Adjustable output 6V, 9V, 12V for up to 500mA (class B working). Takes the place of any of the following batteries: PP1, PP3, PP4, PP6, PP7, PP9, and others. Kit comprises: mains transformer rectifier, smoothing and load resistor, condensers and instructions. Real snip at only 16/6, plus 3/6 postage.

## MAINS MOTOR

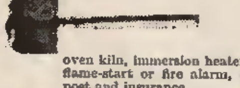
Precision made—as used in record decks and tape recorders—ideal also for extractor fan blower heater, etc. New and perfect. Snip at 9/6. Postage 3/- for first one then 1/- for each one ordered. 12 and over post free.

**RELAY SWITCHES.** These enable micro switches, delicate thermostats or other low current devices to control up to 30A. Ideal to switch thermal storage heaters—motors, etc., made by the famous AEI group these are listed at £25 each—you can buy if you hurry at a very keen price of 39/6 each and we will include diagrams and data. Mounted on panel size approx. 6 × 7 × 2in deep.

## THERMOSTATS

**Type "A"** 15A for controlling room heaters, greenhouse, airing cupboard. Has spindle for pointer knob. Quickly adjustable from 30–80°F. 9/6 plus 1/- post. Suitable box for wall mounting 5/- P. & P. 1/-.

**Type "B"** 15A. This is a 17in long rod type made by the famous Sunvic Co. Spindle adjusts this from 50–550°F. Internal screw alters the setting so this could be adjustable over 30° to 1,000°F. Suitable



for controlling furnace, oven kiln, immersion heater or to make flame-start or fire alarm, 8/6 plus 2/6 post and insurance.

**Type "D".** We call this the Ice-stat as it cuts in and out at around freezing point. 2/3 amps. Has many uses, one of which would be to keep the loft pipes from freezing, if a length of our blanket wire (16 yds. 10/-) is wound round the pipes. 7/6. P. & P. 1/1.

**Type "E".** This is standard refrigerator thermostat. Spindle adjustments cover normal refrigerator temperatures. 7/6 plus 1/- post.

**Type "F".** Glass encased for controlling the temp. of liquid—particularly those in glass tanks, vats or sinks—thermostat is held (half submerged) by rubber sucker or wire clip—ideal for fish tanks—developers and chemical baths of all types. Adjustable over range 50°F to 150°F. Price 18/- plus 2/- post and insurance.

Where postage is not definitely stated as an extra then orders over £3 are post free. Below £3 add 2/9. Semiconductors add 1/- post. Over £1 post free. S.A.E. with enquiries please.

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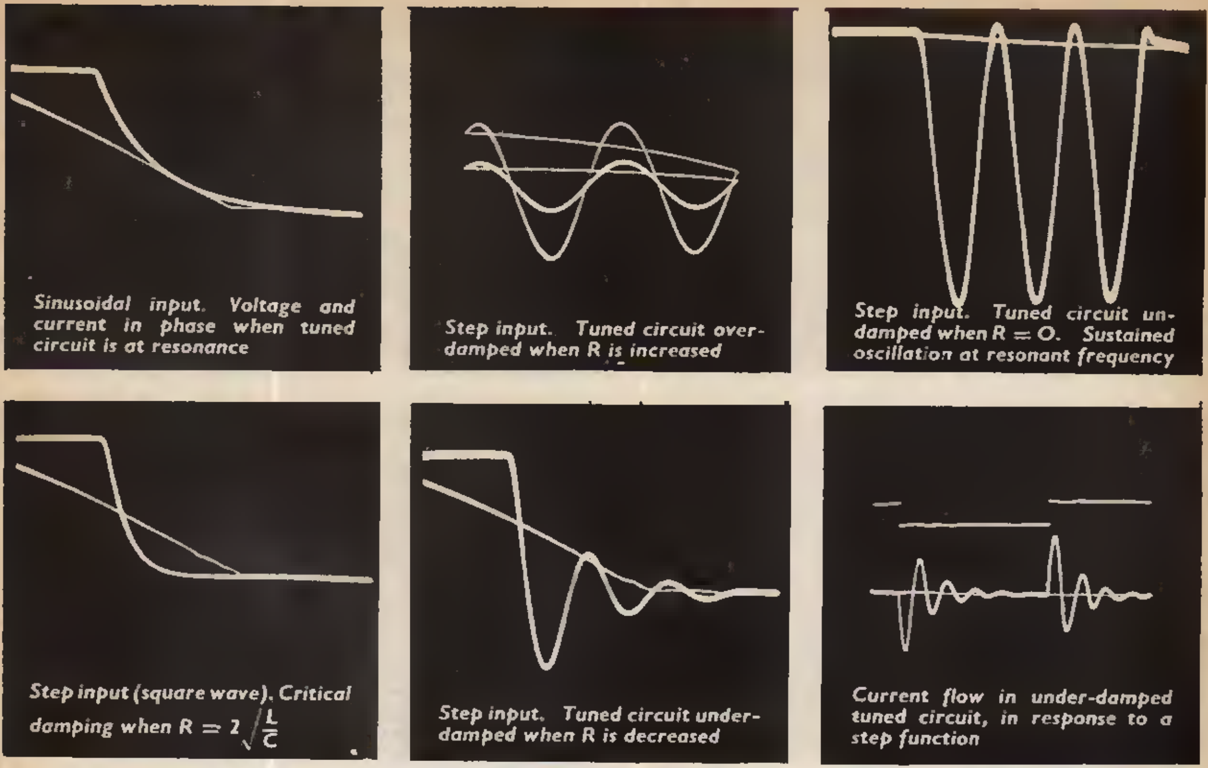
*also at* **266 LONDON ROAD, CROYDON, SURREY** *S.A.E. with enquiries please*



Sinusoidal input. Voltage and current in phase when tuned circuit is at resonance

Step input. Tuned circuit over-damped when R is increased

Step input. Tuned circuit un-damped when R = O. Sustained oscillation at resonant frequency

Step input (square wave). Critical damping when $R = 2\sqrt{\frac{L}{C}}$

Step input. Tuned circuit under-damped when R is decreased

Current flow in under-damped tuned circuit, in response to a step function

*Fig. 5.7. Response of a simulated tuned circuit*

Apply a 2V r.m.s. 50Hz signal to OA1/Input 2, and monitor by means of a reliable 10V a.c. meter of not less than 1 kilohm/volt sensitivity. The input function should preferably come from a low impedance source to avoid serious loading errors when the voltmeter is removed. Next, connect the a.c. voltmeter to the output of OA1 and adjust CP1 so that OA1 input and output voltages are exactly equal. CP1 could alternatively be set by the reference voltage and d.c. voltmeter method mentioned earlier, for a coefficient of 0·1. If the CP2 setting is altered it will be discovered that the simulated circuit goes off resonance, and can be tuned by CP2 between approximately 5Hz and 50Hz.

UNIT "A" will now be ready for analysis of the Fig. 5.6a tuned circuit, and will also cover a useful range of other values for *L*, *C*, and *R* in real time.

When handling sinusoidal or step functions, an amplifier will still have a maximum output voltage swing of $\pm$10V, but this will be the peak voltage value. To check for overloading with an a.c. meter, ensure that amplifier output voltages do not exceed 7·07V r.m.s. for a sine wave function, and 5V mean for an equal mark-space square wave.

## RESCALING PROBLEM EXAMPLE 3.

To rescale the problem for larger or smaller values of *L* and *C*, beyond the coverage of CP2, and by abandoning real time operation, note that a tenfold increase in tuned circuit frequency corresponds to a hundredfold increase in $1/LC$. For most applications, where the series resistance *R* will lie between zero and just beyond critical damping ($R > 2\sqrt{[L/C]}$), the scaling of $R/L$ can stay as it is for all reasonable values of *L* and *C*, but should anyway only be changed by adjustment of the gain factor at OA1/Input 1. Similarly, the $f(t)/L$ gain of 100 at OA1/Input 2 can remain fixed.

It is not necessary to use inconveniently large or small input functions when rescaling for new voltages and currents. 2V r.m.s. could equally well represent an input function of, say, 0·2V r.m.s., and from Ohm's Law the current *I* will automatically become 2mA, instead of the former 20mA, even though it is still represented by 2 computer volts.

If it is desired to extend the computer operating time, by adjustment of integrator and inverting amplifier closed-loop gains, refer to Table 5.2, while remembering that integrator closed-loop gains are calculated on the basis of $1/R_{in}C_f$ where *R* is in ohms and *C* is in farads.

For reasons of reduced accuracy, it is not advisable to use computer operating frequencies above 1kHz or below 0·05Hz in connection with Problem Example 3. It should be mentioned that although frequencies in the region of 0·05Hz are too low for display on an a.c. coupled oscilloscope, the behaviour of a system can be demonstrated in slow motion by the oscillating movement of a d.c. voltmeter pointer (centre-zero).

Some typical oscillograms are given in Fig. 5.7 to show the response of a simulated tuned circuit. If the computer oscilloscope is provided with a good graticule, and has a linear response, amplitude and time measurements which are accurate to within approximately 5 per cent may be obtained straight from the trace.

The behaviour of a real tuned circuit can be evaluated by comparison with a simulated circuit. A tracing is made of the real circuit oscilloscope display, and is then superimposed on the readout given by the simulated circuit. The computer is adjusted so that time scales are related by a known factor, and tracing and readout display are identical, then quantitative measurements are taken from the computer voltages and dial settings.

**Next month: The construction and operation of UNIT "B"**

# DENTOPHONICS

## BY F.R.BERTRAND, B.D.S.

THE term Dentophonics has been applied to the technique of broadcasting speech from the mouth by the use of electronics.

Dentophonics works on the same principle as a throat microphone, where a transducer picks up the sonic energy transmitted through the tissues as a person speaks. This is quite distinct to normal microphone techniques which rely upon air pressure waves.

Dentophonics (DP) is easily demonstrated by the following experiment. Plug a sonic probe into the input socket of an audio amplifier. Press the sonic probe against a subject's tooth as that subject is speaking, and the voice of the subject will be clearly heard through the loudspeaker.

### TISSUE TRANSMISSION

A sonic probe with a broad surface will pick up sound from various parts of the head, including the forehead, temple, cheekbone, and the cheeks themselves. To obtain good speech reproduction from the cheeks, the sonic probe has only to be gently pressed against a cheek. This shows quite clearly that sound is transmitted through both hard and soft tissues of the body, and it would therefore be better to drop the term "bone conduction" and use the term "tissue transmission".

The extent of the tissue transmission of sound is shown by the following experiment.

A sonic probe was held firmly in a subject's extended right hand. This sonic probe was connected to the output of an audio amplifier, and a signal generator was connected to the input socket of the same amplifier. The same subject held another sonic probe in his extended left hand and this second sonic probe was connected to the input of another amplifier, a loudspeaker being connected to the amplifier output. The subject holding the probes was in one room, and the loudspeaker was in another room. When a signal of 1,000Hz was transmitted through the sonic probe in the subject's right hand, this signal was picked up by the sonic probe in the subject's left hand, and was clearly heard by an observer in the room with the loudspeaker.

### BUILT-IN ELECTRONICS

Whilst speech may be picked up by a transducer from various sites of the head, the mouth offers the most interesting possibilities, in that there would appear to be no reason why miniaturised electronic equipment should not be built-in, at this present time. Already in various experiments to obtain information on the occlusion of the teeth, up to six radio transmitters have been "built into" the mouth.

Any miniaturised electronic equipment designed for placing in the mouth could be incorporated into bridges or dentures. The miniaturised equipment could be designed to be removable, and capable of being switched on or off.

A dentophonic appliance will have the advantages over a throat microphone, of being less bulky, and also of giving better and clearer speech reproduction. A DP probe will pick up speech from an artificial tooth provided the artificial tooth is firmly fitted.

The great advantage of dentophonics is the elimination of background noise. Transducers used for DP are designed to pick up the transmission of sound in solids, and should not pick up airborne sound. This means that the speech of a subject in a high level of background noise could be heard quite clearly without any interference by the background noise.

Another advantage of DP is that there will be no need for the so called "microphone technique" that the public speaker or performer has to learn.

One objection to DP is that the noise of the teeth occluding will be picked up; but this objection would only be valid where a subject has nervous clenching habits, as normally the teeth mainly occlude during mastication, the position of rest being with the teeth slightly apart.

### POSSIBLE APPLICATIONS

The applications of DP will be many and varied, but this technique could certainly be used by the following persons: outside television and radio commentators, motor racing drivers, aviators and astronauts, public speakers, theatrical performers, and deep sea divers.

Where background noise is such that a subject's hearing may be damaged, the ears could be protected by muffling, and communication established by using the DP technique.

DP could be used for teaching deaf children to speak. The DP probe would pick up the sound of the deaf child's own voice, and even if the child had no hearing whatsoever, the child would be able to compare the movement his or her voice produced with the movement that the teacher's voice produced.

### THROUGH SOLID MASS

Another interesting experiment can be described.

Two audio amplifiers were used, one had a microphone and a probe connected to it; the other had a DP probe and a loudspeaker connected to it. A subject spoke into the microphone, and as he was speaking the probe was pressed against the wooden casing of the first amplifier, and the second probe was pressed against the other end of the wooden casing of the same amplifier. The subject's voice was clearly heard over the loudspeaker. Thus, audio sound had been transmitted through a solid and picked up at the other end.

Perhaps this technique could be applied as a means of communicating with people who become entrapped in certain tragedies such as occur in mines or at sea.

Finally, it is apparent that dentophonics in conjunction with the audiodental technique opens up a new, relatively untried, but highly promising field of communications.

# 4-STATION INTERCOM


**£7/5/0**

Solve your communication problems with this **4-Station Transistor Intercom** system (1 master and 3 Subs), in de-luxe plastic cabinets for desk or wall mounting. Call/talk/listen from **Master to Subs** and **Subs to Master**. Ideally suitable for Business, Surgery, Schools, Hospital, Office and Home. Operates on one 9V battery. On/off switch. Volume control. Complete with 3 connecting wires each 66ft. and other accessories. P. & P. 7/6.

## WIRELESS INTERCOM

**No batteries—no wires.** Just plug in the mains for instant two-way, loud and clear communication. On/off switch and volume control. Price **12 gns.** P. & P. 7/6 extra.

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**59/6**

Why not boost business efficiency with this incredible De-Luxe **Telephone Amplifier.** Take down long telephone messages or converse without holding the handset. A useful office aid. On/off switch. Volume control. Battery 2/6 extra. P. & P. 2/6. Full price refunded if not satisfied in 7 days.

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7in × 5in board with the following components attached:
- 2 GET872A transistors
- 2 Mullard OA10 diodes
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- 8 Midget Capacitors various values.

Including postage in Great Britain 4/- each

## BARGAIN BOARD NO. 2

5½in × 4in printed board with the following long lead components: 20 diodes, including Mullard OA73 and OA86; 12 5% ¼W resistors. Including postage in G.B. 3/- each

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|---|---|
| AA120 | 2/6 each |
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| AC167 | 5/- each |
| AC165 | 5/- each |
| 2N397 | 2/6 each |
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| Matched 2G378B and 2G339B | 4/- the pair |
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## SPECIAL LINES

Power transistor heat sinks 7in × 2in 1/- each
Double transistor copper cooling clips 9d each
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Double pole rotary ON/OFF mains switch 2/- each
On one bracket 2·500kΩ pre set pots plus 1 D.P. rocker mains switch, 1/9
250kΩ pre set pot linear 1/- each
Midget 5kΩ pot with D.P. switch 2/6 each

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|---|---|
| 9½in × 8in | 2/6 each |
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2 valve Medium and Long Wave tuner with power supply, will give good reception through any amplifier. Price on this item includes Postage and Packing, £4. 0. 0.

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| 1BG5 | 32mF | 450V | 4/6 |
| 1BG6 | 32mF | 350V | 3/- |
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| 1BG14 | 2mF | 500V | 3/6 |
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By R. B. HAYLE

## MODIFICATION FOR PRE-HEATING THE LAMP ELECTRODES

We have been advised by a well known lamp manufacturer that the 6W 9in lamp employed in the Fluorescent Camping Light (March 1968) is designed to be used only in circuits which arrange to pre-heat the lamp electrodes either before, or simultaneously with, the application of a pulse or steady state voltage across the lamp in order to start it.

It is explained that the practice of cold starting, as in our published design, can result in very heavy lamp end blackening, and a very short lamp life.

We are therefore publishing an alternative circuit by R. B. Hayle which incorporates a pre-heat facility.

In the modified circuit Fig. 1 the "low" output switch position is omitted, and a three-pole switch is used in place of the two-pole switch specified in the original circuit. This enables the electrodes to be energised via R4, which should be selected so that, with a 12V supply battery, the preheating current is not less than 160mA.

Under these conditions, switch S1 should be held in position 2 (pre-heat) for at least one second before going over to position 3. Capacitor C2 is permanently connected to C1, R1, R2, and T1. The switch is now used entirely for preheating and running. The amount of rewiring involved is not great, and readers will be able to convert their Camping Lights with little difficulty.

A modified wiring diagram of S1 is shown here in Fig. 2. Similarly modified versions of the main unit wiring are shown in Fig. 3.

The pot-core assembly LA5 can be obtained from retail outlets of Mullard components including Henry's Radio Ltd. whose address is on the back cover.

The author does not advise the circuit to be converted for a 6 volt battery supply. The saturation voltage across the transistor becomes a significant factor and leads to reduced efficiency. A 6V version would have lead to undesirable circuit complications.

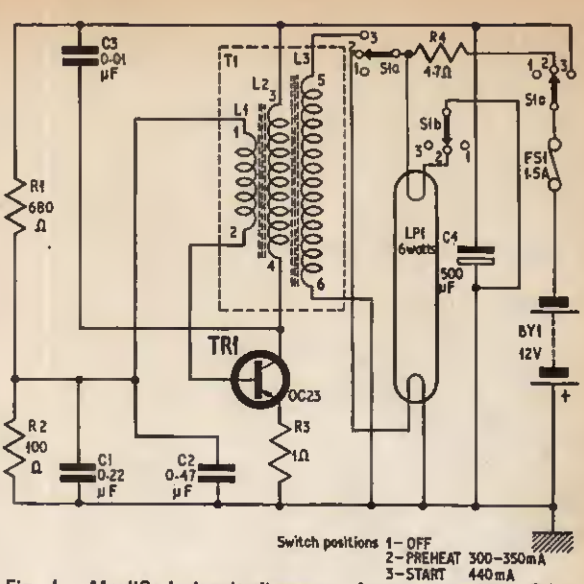



*Fig. 1. Modified circuit diagram. An extra resistor R4 is needed*

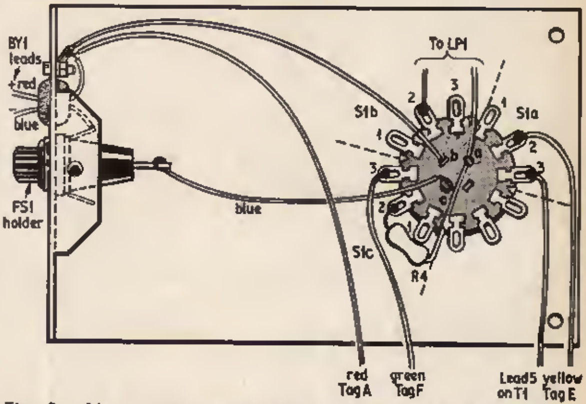



*Fig. 2. New wiring details of S1. Resistor R4 is 4·7Ω 3W wirewound*

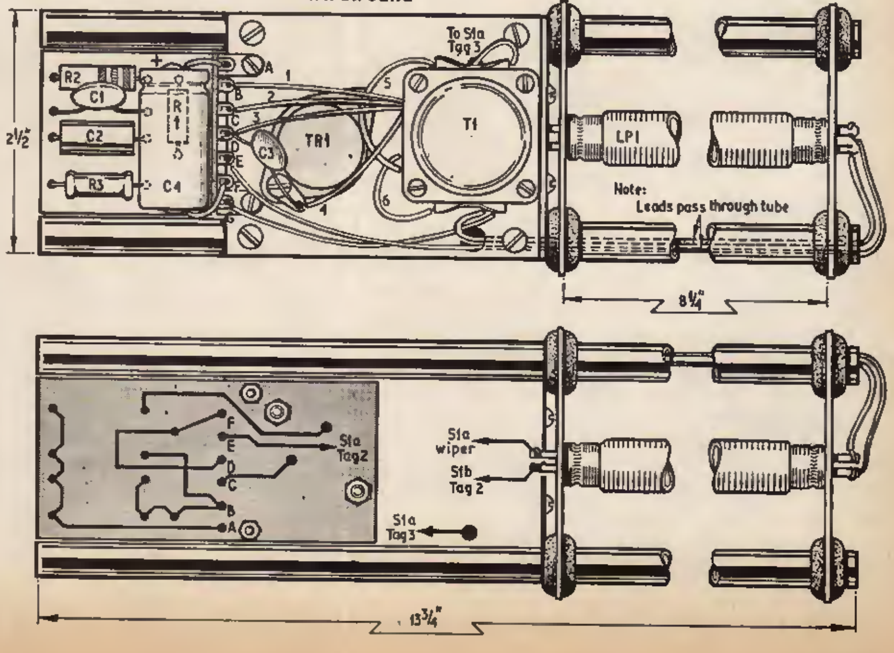



*Fig. 3. Top and underside views of the electronics including the modified wiring details*

# Readout—
## A SELECTION FROM OUR POSTBAG

### Traffic delay

Sir—I am interested in the mechanical delay system employed in car reverberation units that I have seen and heard on recent visits to the U.S.

Radiomobile have done some research but have since dropped the idea as they feel there is insufficient interest over here (or so they say).

One problem appears to be the harder springing of U.K. vehicles than that found on U.S. cars, however, I hear there is even one delay system now that allows the car to be driven off the curb without vibration to the unit.

I am told that the spring (or whatever) assembly should be mounted along the car axis and not across it.

I am not deterred by hard springing and am keen to build one and use it in conjunction with my car radio, and do not see the electronics posing too much of a problem.

I am advised that a 2 watt output from the echo amplifier would be sufficient against the 8 watt output of my radio. Control of echo is normally done from a potentiometer mounted under the dashboard.

A speaker mounted on the back shelf (if possible) alongside the main speaker makes the sound appear to be 100ft behind you. A marvellous sensation for relaxing in heavy traffic.

In conclusion, I should appreciate any information you or any readers could give me as to the best drive, pick-up units (to avoid microphony) and the best suspension to avoid rattle.

M. C. Bell,
Henley-on-Thames.

*Any suggestions?*

### Cranky?

Sir—Whilst this magazine publishes many interesting and useful projects it sometimes contains circuits which are complicated when compared with the function they are intended to perform. I feel that there is a real danger of using electronics simply for the sake of using them. This could easily detract from the useful purpose of the magazine and the good standing of electronic experimenters. Any person using a complicated circuit to perform a simple function must be regarded as a "crank". For *Impact Counter* (March 1968) with a transducer, Schmitt trigger, twenty resistors, eleven capacitors, seven transistors, five diodes, etcetera, why not connect the electro-mechanical counter to a pair of contacts and a battery? The contacts may wear but the saving on the other components would more than pay for them. As for the steam presence alarm, same issue, dare I suggest a whistling kettle?

F. Crimmins,
Folkestone, Kent.

*IMPACT COUNTER. To answer this criticism, it is necessary to explain the particular problem this device was designed to cope with.*

*The original purpose of the impact counter was to count small neon lamps, which weigh $\frac{1}{30}$oz. The contacts must not close more than once per neon, and must always close whether the neon wire leads are upwards or downwards. It is not possible to use anything but a very open funnel as the neons tend to bridge. The closure time must be long enough for the counter to operate properly, therefore the monostable pulse is adjusted so that it allows the neon to bounce inside the pulse length.*

*For industrial use reliability and ease of replacement are important. This circuit divides readily into four parts which can be tested independently.*

*STEAM PRESENCE ALARM. You can certainly suggest a whistling kettle, but it would be no use to a deaf person, or if you are out in the garden. The simple sensor can be used with an electronic relay to operate an audible alarm, or even to switch off the stove if you wish.*

*May we suggest these are two good examples of electronics being used practically?*

### What's in the box?

Sir—I was very interested by C. F. Weir's article in the February issue of P.E. on *Cine and Tape Sync.* His suggestion at the end for an all-electronic version prompted some thinking on my part because I possess a similar cine system to that of Mr Weir, but in 8mm.

It occurred to me that a 16 frame/sec projection has each frame flashed three times on the screen to avoid flicker, this being done by a rotating disc with three sectors in the optical projection system. Thus the screen picture flashes 48 times per second.

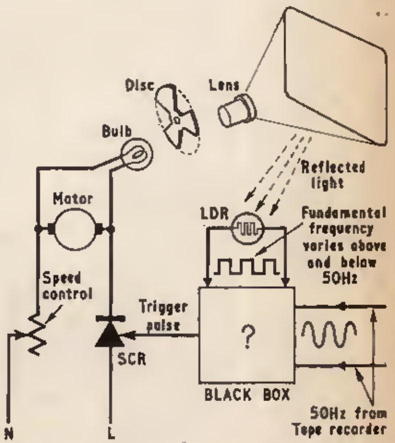
If the projection rate is increased to $16\frac{2}{3}$ frames/sec, then the picture flashes become 50 per sec. This could be synchronised with a 50Hz signal from the second track of a tape recorder, if the flashes are detected by a light sensitive resistor. At this point I am stumped, because the next step is to convert any error in the two frequencies into a signal which will fire an s.c.r. in the power leads to the projector. The problem is set in the following diagram.

Could any readers possibly suggest a circuit for the black box?

The tape recorder need not be a full stereo type, but it should be four track with leads to the head winding which is not actually playing the sound track. This is the case with many Philips/Cossor/Stella machines which are mono with a stereo outlet socket. If the model is transistorised, then the same socket could provide power for the "black box", since a few milliamps at about —20V are available. Two-track machines could have a third head mounted to scan the lower track, which should be prerecorded, when the upper track is recorded with 50Hz from a step-down mains transformer.

It is important to note that the s.c.r. will only control an a.c./d.c. type motor, and the control should never feed a transformer which is used to power a low voltage projector bulb.

D. Watts,
Lincoln.




### Series of talks

Sir—Your Sussex readers may be interested in the following announcement, which will shortly be locally advertised:

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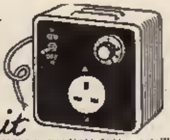

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