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Inside this Issue

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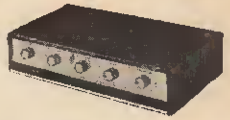

Cabinet £2. 5. 0 extra

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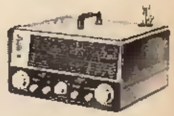

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5"	600'	Except Agfa	21/–	16/10
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7"	1200'	Except Agfa	35/–	28/–

LONG PLAY			LIST PRICE	OUR PRICE
3"	210'	Not Scotch or Kodak	9/–	7/3
3"	300'	Scotch only	9/6	7/6
3½"	300'	Kodak only	12/–	9/6
4"	450'	Except Kodak	14/6	11/8
4½"	600'	BASF, Agfa only	21/–	16/10
*5"	900'		28/–	22/6
*5½"	1200'		35/–	28/–
*7"	1800'		50/–	40/–
8½"	2400'	BASF, Scotch only	72/6	58/–
10"	3280'	Agfa only	85/–	68/–
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C. 60	17/6	14/–
C. 90	25/–	20/–
C. 120	33/6	27/–

DOUBLE PLAY			LIST PRICE	OUR PRICE
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3"	400'	Scotch only	16/6	13/2
3½"	400'	Kodak only	18/9	15/–
4"	600'	Not Kodak	25/–	20/–
4½"	900'	Agfa, BASF only	30/–	24/–
5"	1200'		42/–	33/8
5½"	1650'	Kodak only	57/6	46/–
*5½"	1800'	Not Kodak	55/6	44/6
*7"	2400'		77/6	62/–
10"	4600'	Agfa only	140/–	112/–

TRIPLE PLAY			LIST PRICE	OUR PRICE
3"	450'	Not Scotch	22/–	17/8
3"	600'	Scotch only	24/9	19/6
3½"	600'	Kodak only	30/–	24/–
4"	900'		39/–	31/3
*4½"	1200'	Agfa, BASF only	49/–	39/3
5"	1800'	Not Scotch	66/–	52/10
5½"	2400'	Agfa, BASF, Kodak only	90/–	72/–
7"	3600'	Agfa, BASF, Kodak only	115/–	92/–

QUADRUPLE PLAY			LIST PRICE	OUR PRICE
3"	600'	Kodak only	36/6	29/6
3½"	800'	Kodak only	46/–	37/–
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541–12	1,150' Long Play on 5½" reel	35/–	28/–	82/6	162/–
541–18	1,800' Long Play on 7" reel	50/–	32/6	96/–	189/–
551–12	1,200' Double Play on 5" reel	42/–	35/–	103/6	204/–
551–16	1,650' Double Play on 5½" reel	56/–	45/–	133/6	264/–
551–24	2,400' Double Play on 7" reel	72/6	55/–	163/6	324/–

"600" SERIES PROFESSIONAL AUDIO TAPE (MYLAR BASE)

TYPE	DESCRIPTION	LIST PRICE	ONE	THREE	SIX
641–9	900' Long Play on 5" reel	30/6	23/–	66/6	127/6
641–18	1,800' Long Play on 7" reel	52/6	39/6	116/–	226/–
651–12	1,200' Double Play on 5" reel	46/–	34/6	101/–	197/–
651–24	2,400' Double Play on 7" reel	80/–	60/–	177/–	348/–

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LGS26	1200' D/P 5" reel	42/–	29/6	86/–	166/–
LGS26	1800' D/P 5½" reel	55/–	38/6	112/6	219/–
LGS26	2400' D/P 7" reel	77/6	49/6	145/6	285/–
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600' on 3" reel Gevasonor	27/6	17/6	51/–	99/–
900' on 4" reel Gevasonor	39/–	24/6	72/–	140/–
1,800' on 5" reel Gevasonor	66/–	41/6	122/–	238/–
2,400' on 5½" reel Zonal	90/–	55/6	165/–	324/–

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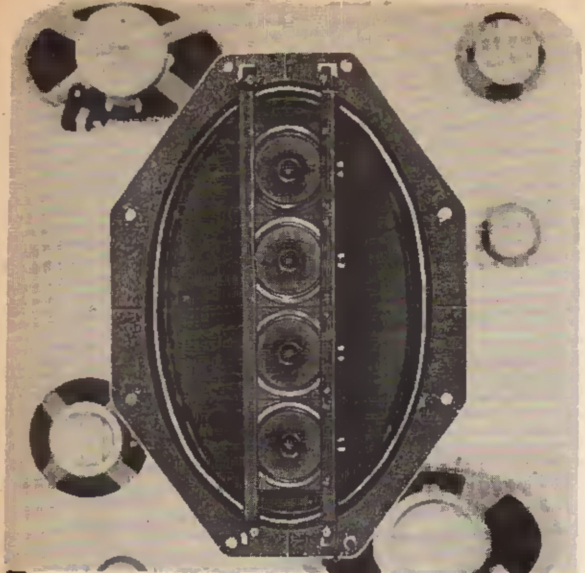

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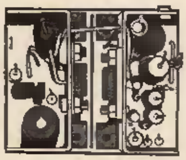
X101 10 WATTS (RMS) SOLID-STATE HI-FI AMP. WITH INTEGRAL PRE-AMP



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.

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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.

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- A.F. module built and tested.
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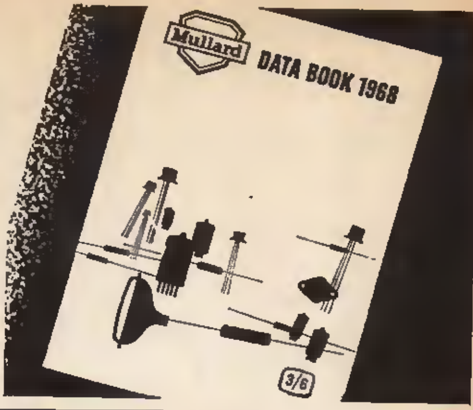

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5in.	D.P.	1,200ft.	15/-
5¾in.	D.P.	1,800ft.	22/6
7in.	D.P.	2,400ft.	25/-
3in.	T.P.	600ft.	12/6
4in.	T.P.	900ft.	15/-
5in.	T.P.	1,800ft.	30/-
5¾in.	T.P.	2,400ft.	40/-
7in.	T.P.	3,600ft.	50/-

P. & P. 2/6 per order.

BARGAIN TELEPHONE SYSTEM

World famous Tele "F" No. 1 Mk. II telephone set giving communication by wire up to 5 miles. Robust, heavy duty complete with wooden storage case and internal batteries ready to use. Will last a lifetime. Mint condition.

Only £6.10.0 pair carr. 15/-

Sold singly at £3.10.0 each, carr. 7/6.

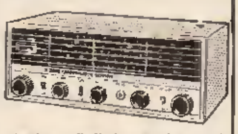
Ideal for all outdoor and indoor uses—sports events, fetes, regattas, van salesmen, etc., etc. 12 volt 16 watt. Amplifier size only 1¾in × 3¾in × 5¾in with inputs for mike, radio and tape recorder. Can be mounted on any car or boat, etc. Complete with dynamic microphone and mounting brackets.

PRICE 12 gns.

REFLEX HORN SPEAKERS

Waterproof, Shockproof, Light-weight. 5in. dia. 3gns. each 12in. dia. 7gns. each.

STAR COMMUNICATIONS RECEIVER SR.40



4 wavebands 540kc/s to 30 Mc/s. Exceptionally sensitive tuning circuit. Extra large easy to read dial with Bandspread tuning. "S" meter for fine tuning. Built-in speaker and telescopic aerial. BFO. Phone output socket. Standby switch, etc. A.C. 200/250V.

Gee's Price P. & P. 10/- **Only 17 gns.**

NEW MODEL U-500 MULTI-TESTER, 20,000 O.P.V. MIRROR SCALED WITH OVERLOAD PROTECTION.

Ranges: D.C. volts: 100 mV., 0·5 v., 5 v., 250 v., 1,000 v. A.C. volts, 2·5 v., 10 v., 50 v., 250 v., 1,000 v. D.C. current: 5 µA., 0·5 mA., 5 mA., 50 mA., 250 mA. Size: 5¼ × 3¼ × 1¾in: Complete with batteries and test prods,

£5.15.0

GARRARD LAB 80

Only £23.10.0 Carr. 10/-

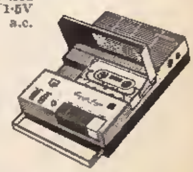
GARRARD A70 on metal plinth. With Sonotone 9TA Stereo cartridge with diamond stylus. Ready wired for connection to amplifier.

BARGAIN PRICE 18 gns. Carr. 10/-.

Both brand new in makers sealed cartons.

NOW AVAILABLE! AUDIO-TECHNICA STEREO MAGNETIC CARTRIDGE AT6, with diamond stylus. ONLY £5.5.0.

TELETON MODEL DENON TRC.105 CASSETTE TAPE RECORDER



All transistorised operating on five 1·5V batteries or 240V a.c. mains—can be used anywhere. Uses universal C-60 Compact tape cassette giving 1 hour's playing time. Push button operation. Tone and volume controls. Recording level and battery strength meter. Built in P.M. speaker. Wonderful value, guaranteed. Size only 8¾in × 6¼in × 2¾in. Supplied complete with tape cassette, microphone with remote control switch, earphone, batteries, recording lead and instruction book.

GEE'S PRICE **Only £21** P. & P. 7/6

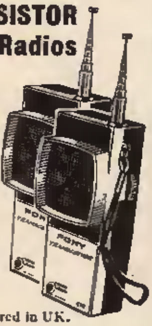
AUTOMATIC AERIAL —ADDS LUXURY TO ANY CAR!

Today's value 15 gns. Tamper proof electrically operated car radio aerial, 4 section telescopic, extends automatically to 48in. and retracts to 1in. at the flick of a switch. Depth below wing 15in. Robustly made, heavy chrome finish 12V d.c. operation. Quickly and easily fitted, supplied with cable, switch and all fixing parts.

PONY 9 TRANSISTOR Super 2-Way Radios

26 gns. VALUE

FOR ONLY **17 gns.** PAIR



Complete 2-way communication for Business, Home, Farms, Boating, etc. Brilliant design, beautifully finished. Built-in speaker, microphone. 10 section telescopic aerial. Battery strength indicator. Size 5¾in. × 1¾in. × 2¾in. Complete with batteries, earphones, wrist straps. GPO licence required in UK.

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Top British mylar/P.V.C.

Standard Play			Double Play		
3"	150ft.	2/3	3"	300ft.	4/-
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5"	600ft.	7/6	5"	1200ft.	15/-
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7"	1200ft.	13/6	7"	2400ft.	27/-
Long Play			**Triple Play**		
3"	225ft.	2/9	4"	900ft.	13/-
4"	450ft.	5/6	5"	1800ft.	25/-
5"	900ft.	10/6	5¾"	2400ft.	34/-
5¾"	1200ft.	13/-	7"	3600ft.	44/-
7"	1800ft.	18/6	**Quadruple Play**		
			3"	600ft.	8/-

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End folding attachments for radio chassis. Tray and Box making for 36in. model, 5/6 per ft. Other models **3/6.** The two smaller models will form flanges. As supplied to Government Departments, Universities, Hospitals.

One year's guarantee. Money refunded if not satisfied. Send for details.

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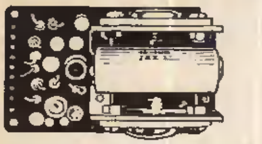

MICROMATIC RADIO. KIT ONLY 49/6 P. & P. 2/6. MICROMATIC RADIO BUILT. ONLY 59/6. P. & P. 2/6. MICRO FM. KIT—£5.19.6 complete. P. & P. 2/6. Z12 Hi-Fi AMPLIFIER £4.9.6. P. & P. 2/6. STEREO 25 Control Unit £9.19.6. P. & P. 2/6. PZ4. Mains Power Supply Unit £4.19.6. P. & P. 2/6.

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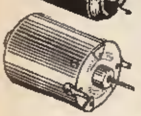
A must for Radio and T.V. Engineers

OM.B. 9 Capacitance ranges. 0·0001, 0·0010, 0·0022, 0·0047, 0·01, 0·022, 0·047, 0·1, 0·22mF. With leads and clips, 29/6. P. & P. 2/-. OM.O. Two Resistance ranges. Low: 15Ω to 10kΩ (1 watt resistors). High: 15kΩ to 10MΩ (½ watt resistors). Selects 24 separate resistances. With leads and clips, 42/6. P. & P. 2/-.

AERIALS TV UHF VHF STEREO

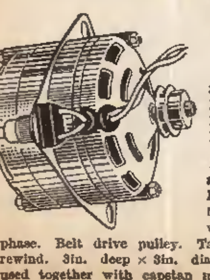
Vantena Table Top V Aerial BBC/ITV, 26/6. **Cresta** Room Aerial Band I/II/III. Cream or Black **26/6**. **Veemaster** Table Top VHF/UHF Tunable Aerial, Chrome or Grey, 76/6. **YAGI** all Channel Table Top Aerial BBC1/2/ITV/VHF, 65/-. **HL523 Loft Aerial HILO V +5** for vertical Band I/III. With mounting arm and bracket, 53/-. **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, 57/6. **E1. Explorer** 18 element BBC2 Aerial as above, 69/-. **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, 87/-. Please add 4/- postage.

MOTOR BARGAINS



Ideal for model makers, record players, tape decks, etc.

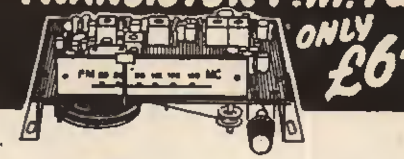
6·3 d.c. Motor. 10,900 r.p.m. at 230MA. 1½in. × 1in. dia. Shaft ½in. long × 3/64. dia., 9/6. P. & P. 2/6.



9V d.c. Gram deck replacement motor. 2in × 1½ in. dia. Shaft ½ in. long × 3/32in 17/6. P. & P. 2/-.

200/250V a.c. Tape Deck Motor. 50c/s. 50 watts, single phase. Belt drive pulley. Take up and rewind. 3in. deep × 3in. dia. Two are used together with capstan motor. Easy mounting, 27/6. P. & P. 5/6.

TRANSISTOR F.M. TUNER ONLY £6-7-6 P&P 4/-



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. ONLY FROM LIND-AIR!

For the Stereo enthusiast. Multiplex adaptor for Stereo Radio reception, **£5.19.6** extra.

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, 33⅓, 16⅔ 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 × 8½in 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).

GARRARD DECKS

TEAK FINISH PLINTHS with perspex cover 6½ gns. (For LAB80 8½gns.).

Agents for Thorens, Dual, Goldring.

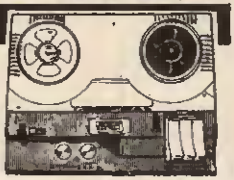
Prices on request.

Model 3000 with Sonotone 9TAHC Stereo Cartridge	£8.19.6
AT60 Mk. I less cartridge	£10.19.6
AT60 Mk. II less cartridge	£12.19.6
SP25 Mk. II less cartridge	£10.19.6
LAB80 Mk. II less cartridge	£24.19.6

P. & P. and Ins. 12/6.

Mono Cartridge 17/6 extra.
Stereo Cartridge 22/6 extra.

MAGNAVOX-COLLARO 363 TAPE DECKS

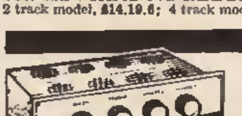


The very latest 3-speed model—1⅞, 3¾, 7½ i.p.s. available with either 2 track or 4 track head. Features include: pause control; digital counter; fast forward and rewind; new 4 pole fully screened induction motor; interlocking keys. Size of top plate 13½ × 11 × 5½in. deep below unit plate. For 200/250 V a.c. New unused and fully guaranteed.
2 track £10.10.0. 4 track £13.9.6.
Carriage and Packing 12/6.

MARTIN TAPE AMPLIFIERS

FOR USE WITH ABOVE TAPE DECKS
2 track model, £14.19.6; 4 track model, £15.19.6. Carriage and Packing 7/6.

LINEAR AMPLIFIERS



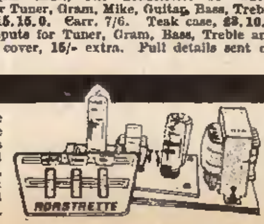
Latest a.c. mains models offering highest quality at modest cost.

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.

PTA15. (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.

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.



MULTIMETERS

TTC1001 (as illus.) 20,000 opv £3.19.6 C1000. 1,000 opv £2.2.0 Caby NH 200 20,000 opv £6.10.0 Caby B40 400 opv £6.10.0 TMK500 30,000 opv £9.19.6 TTC Model 1030 50,000 opv £9.19.6 TTC Model 1031 100,000 opv £12.19.6.
Also stockists of Avo, Nombrex, Eagle etc. Test equipment P.P. 3/6.

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Input 0–200, 220, 240V.
Output 110V

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100W	£2.5.0	2,000W	£18.10.0
150W	£2.15.0	3,000W	£25.10.0
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
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Input 200–250V 50c/s

24V	3A	£2.12.6	24V	8A	£5.5.0
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Mains and Output Transformer lists available on request.

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EZ81	6/6
PCC84	8/6
PCL85	11/6
PCL82	10/6
PCL86	11/6
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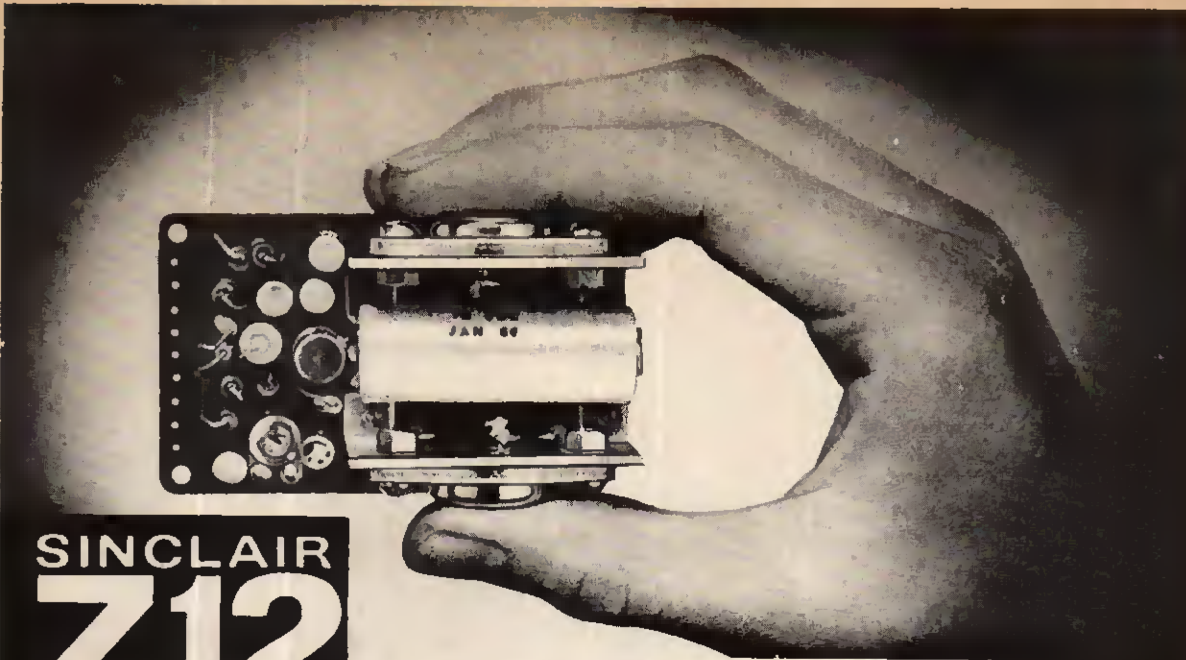

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COMBINED 12 WATT HI-FI AMP AND PRE-AMP

UNCHALLENGED LEADER IN ITS FIELD

No constructor's transistor amplifier has ever achieved such success as the Sinclair Z.12. It favours the user in so many ways—with fantastic power-to-size ratio, with far greater adaptability, with freedom to operate it from batteries or mains power supply unit (the new PZ.4 is ideal for this) with the opportunity to obtain superb stereo reproduction for very little outlay. Countless thousands of Z.12s are in use throughout the world—in hi-fi installations, electronic guitars and organs, P.A. installations, intercom systems, etc. This true 12 watt amplifier is supplied ready built, tested and guaranteed together with the Z.12 manual which details control circuits enabling you to match the Z.12 to your precise requirements. For complete listening satisfaction, use your Z.12 system with Q.14 loudspeakers. It assures superb quality with substantial saving in outlay.

- 3″ × 1¾″ × 1¼″
- **Class B Ultralinear output**
- **15–50,000Hz ± 1dB**
- **Suitable for 3, 5, 8 or 15Ω speakers. Two 3-ohm speakers may be used in parallel.**
- **Input—2mV into 2kΩ**
- **Output—12 watt, R.M.S. continuous sine wave (24W peak)**

"I made this (Z.12) stereo record player for my work as hospital chaplain and it has been a great success."
K.S.B. Basingstoke

"The Z.12 and Q.14 live up to your high standard. I could spend pages praising these products."
I.A.W. Hereford.

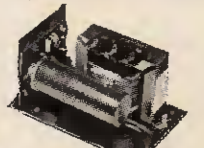
Ready built, tested and guaranteed. **89/6**

SINCLAIR STEREO 25

For use with two Z.12's or any good hi-fi stereo system. Frequency response 25Hz to 30 kHz ± 1dB connected to two Z.12's. Sensitivity Mic. 2mV into 50kΩ : P.U. —3mV into 50kΩ : Radio —20mV into 4.7kΩ. Equalisation correct to within ± 1dB on RIAA curve from 50 to 20,000Hz. With brushed and polished aluminium front panel with solid aluminium knobs to match. Size 6¾in × 2½in × 2¼in plus knobs.

BUILT TESTED AND GUARANTEED **£9.19.6**

SINCLAIR PZ. 4
STABILISED POWER SUPPLY UNIT



A heavy duty a.c. mains power supply unit delivering 18V d.c. at 1·5A. Designed specially for Z.12 assemblies. Ready built and tested. **99/6**

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THE MAGNIFICENT ROAMER 7 MK IV

SEVEN WAVEBAND PORTABLE AND CAR RADIO WITH A SUPER SPECIFICATION

- 7 FULLY TUNABLE WAVE BANDS—MW1, MW2, LW, SW1, SW2, SW3 and Trawler Band.
- Extra Medium waveband provides easier tuning of Radio Luxembourg, etc.
- Built in ferrite rod aerial for Medium and Long Waves.
- 5 Section 22 in. chrome plated telescopic aerial for Short Waves—can be angled and rotated for peak S.W. listening.
- Socket for Car Aerial.
- Powerful push-pull output.
- 7 transistors and two diodes including Philco Micro-Alloy R.F. Transistors.
- Famous make 7×4 in. P.M. speaker.
- Air spaced ganged tuning condenser.
- Separate on/off switch, volume control, wave change switches and tuning control.
- Attractive case with hand and shoulder straps. Size 9×7×4 in. approx.
- First grade components.
- Easy to follow instructions and diagrams make the Roamer 7 a pleasure to build with guaranteed results.

Total building costs £5.19.6 P. & P. 6/6

Parts price list and easy build plans 3/– (FREE with parts).

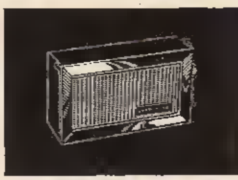
TRANSONA FIVE

MEDIUM WAVE, LONG WAVE AND TRAWLER BAND PORTABLE

Attractive case with red speaker grille. Size 6¾ × 4½ × 1¾in. Fully tunable. 7 stages—5 transistors and 2 diodes—ferrite rod aerial, tuning condenser, volume control, fine tone super dynamic 3in. speaker, all first grade components. Easy build plans and parts price list 1/6 (FREE with parts).

Total building costs 42/6 P. & P. 3/6

POCKET FIVE



MEDIUM WAVE, LONG WAVE AND TRAWLER BAND PORTABLE

Attractive black and gold case. Size 5½ × 1¾ × 3¾in. Fully tunable over both Medium and Long Waves with extended M.W. band for easier tuning of Luxembourg, etc. All first grade components, 7 stages—5 transistors and 2 diodes—supersensitive ferrite rod aerial, fine tone 3in. moving coil speaker, etc. Easy build plans and parts price list. 1/6 (FREE with parts).

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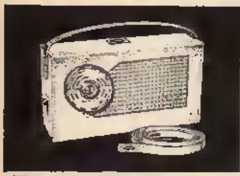
MELODY SIX

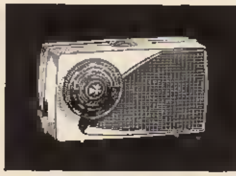


TWO WAVEBAND PORTABLE WITH 3in. SPEAKER

Handsome leather-look case, size 6¾ × 3½ × 1¾in. with gilt trim and hand and shoulder straps. Fully tunable over both Medium and Long Waves. Incorporates pre-tagged circuit board, 8 stages—6 transistors and 2 diodes—ferrite rod aerial, push-pull output, wave change slide switch, tuning condenser, volume control, 3in. moving coil speaker, etc. Easy build plans and parts price list 2/- (FREE with parts).

Total building costs 59/6 P. & P. 3/6

MELODY MAKER 6



THREE WAVEBAND PORTABLE WITH 3in. SPEAKER

Smart pocket size case, 6½ × 3¾ × 1½in. with gilt fittings. Fully tunable over both Medium and Long Waves with extra M.W. band for easier tuning of Luxembourg, etc. 8 stages—6 transistors and 2 diodes—top grade 3in. speaker, 2 R.F. stages for extra boost, high "Q" ferrite rod aerial. Easy build plans and parts price list 2/- (FREE with parts).

Total building costs 69/6 P. & P. 3/6

ROAMER SIX

SIX WAVEBAND PORTABLE WITH 3in. SPEAKER

Attractive case with gilt fittings, size 7½ × 5½ × 1½in. World wide reception. Tunable on Medium and Long Waves, two Short Waves, Trawler Band plus an extra M.W. band for easier tuning of Luxembourg, etc. Sensitive ferrite rod aerial and telescopic aerial for Short Waves. All top grade components, 8 stages—6 transistors and 2 diodes including Philco Micro-Alloy R.F. Transistors, etc. (carrying strap 1/6 extra). Easy build plans and parts price list 2/- (FREE with parts).

Total building costs 79/6 P. & P. 3/6

SUPER SEVEN

THREE WAVEBAND PORTABLE WITH 3in. SPEAKER

Attractive case size 7½ × 5½ × 1½in. with gilt fittings. The ideal radio for home, car or outdoors. Covers Medium and Long Waves and Trawler Band. Special circuit incorporating 2 R.F. stages, push-pull output, ferrite rod aerial, 7 transistors and 2 diodes, 3in. speaker (will drive larger speaker) and all first grade components. Price list 2/- (FREE with parts).

Total building costs 69/6 P. & P. 3/6

RADIO EXCHANGE Ltd

61a HIGH STREET, BEDFORD

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VOL. 4 No. 4
April 1968

PRACTICAL ELECTRONICS

CIRCUIT COMPLICATIONS

WHEN a number of our readers suggested that a certain design was needlessly complicated, we immediately turned up page 139 of the February issue and took another cool, hard look at the article in question. What we found was a circuit incorporating five common or garden transistors. Closer examination revealed this to be made up of two well-known and widely used electronic building blocks: a bistable switch, plus relay driver, and a multivibrator.

Surely no complexity here—once the whole has been analysed and reduced to its essential elements. It set us wondering why such objections should be put forth. Can it be that complexity is sometimes measured in terms of the total number of transistors employed? Maybe there is an unconscious equating of a transistor stage with a *valve* stage.

All the attendant problems which arise with the inclusion of an additional valve stage are still well remembered—even by the long converted. The extra ancillary components, the power supply requirements, to say nothing of the mechanical problems involved in finding chassis accommodation for just one extra valve, could never be lightly dismissed. Nor could the cost.

A radically different situation exists in the case of transistorised circuits. The mechanical and spatial problems to be faced when fitting another transistor are minimal—the operation is barely more difficult than the wiring in of a resistor. The cost is, generally speaking, not prohibitive either.

Clearly one approaches the design and construction of solid state equipment with a different outlook to that appropriate to valve equipment. The distinction between the two techniques is obvious—but yet still needs emphasising on occasions, it seems.

No rash extravagance is being proposed, but there should be fewer inhibitions about using a number of solid state devices where the possibilities for sensibly exploiting rather more elegant circuit arrangements exist. Particularly is this true in switching applications (such as the project referred to above), for here it is possible to use transistors of a kind abundantly available at around 2s. a time.

And now we must mention the booklet presented free to our readers with this issue. This contains a fine distillation of electronic circuit know how, in the form of basic circuits and essential facts about these building blocks. As a pocket *aide-memoire*, this booklet should be invaluable to the experienced amateur, while it will certainly be indispensable to the beginner. We think it will dispel many complications.

F. E. Bennett—*Editor*

THIS MONTH

CONSTRUCTIONAL PROJECTS

SPECIAL SERIES

GENERAL FEATURES

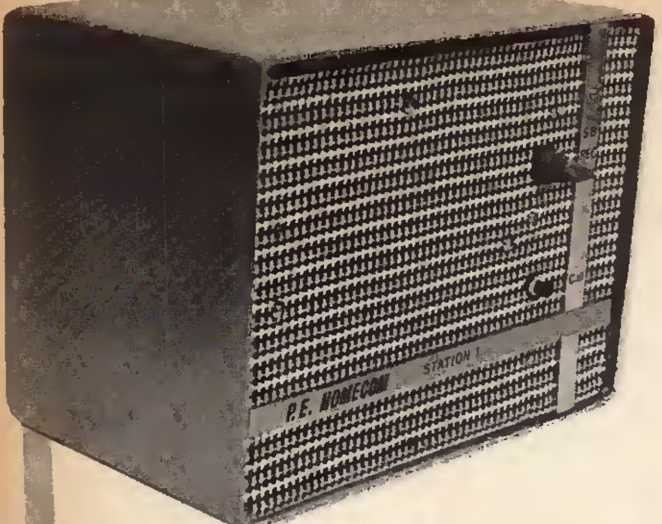
BEGINNERS

NEWS AND COMMENT

Our May issue will be published on Tuesday, April 16

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.

P.E. HOMECOM



A COMMON requirement for most intercom systems is the matching of speech transducers to the input and output impedances of the relevant amplifier stages. In the past this magazine has published designs employing balanced armature earpieces and low impedance loudspeakers as transducers, both methods involving the use of comparatively expensive matching transformers. The first of these methods suffers from volume limitations and restricted availability of suitable components. With the second method, improvement in the unit's performance, both in pick-up sensitivity and output, can be achieved by using speakers of relatively large cone diameter.

It would therefore seem that what is needed is a simple amplifier which will employ any kind of low impedance loudspeaker which can serve in the dual capacity of microphone and loudspeaker with none of the attendant cost of matching transformers in the input and output stages. This method has been adopted in the P.E. Homecom.

DIRECT COUPLING OF LOUDSPEAKERS

The relatively low input and output impedances of the power transistors used in the present circuit (see Fig. 1), a two stage amplifier of common emitter configuration, permits direct coupling to the loudspeakers. Bias current is supplied to both transistors by way of potential divider networks.

Most readers are probably aware of the principle of operation of a loudspeaker where alternating current flowing through the speech coil produces a dynamic reaction with the magnetic field provided by the permanent magnet; the cone, being connected to the coil, reproduces these electrical oscillations as sound waves. If the order of this process is reversed we then have the principle of the moving coil microphone, and it is in this capacity as induced current driver that the loudspeaker functions when spoken into.

FUNCTIONS OF SWITCHES

The circuit diagram shows the master switch S1 in its "standby" (SB) position. It can be seen that the power supply to the unit is disconnected by S1f. Station 1 loudspeaker LS1 is connected to the collector circuit of TR2. A regenerative feedback loop is provided by C2 and limiting resistor R5. The path of this loop is completed by S1c.

When Station 2 call button S3 is depressed this completes the supply line broken at S1f and the amplifier comprising TR1, TR2 now acts as a two stage phase shift oscillator producing a "call" tone at Station 1 loudspeaker.

When in response to this call, Station 1 master switch is moved to the central "Receive" (REC) position, this action disconnects the feedback line at S1c and completes the battery supply circuit via S1f, so overriding the remote call switch S3. Station 2 is now in a position to speak, the loudspeaker LS2 acting as a microphone, being connected between point "A" and TR1 base by S1d and S1e.

At the third position of the master switch—"Speak" (SPK)—the station functions are reversed by the switching of S1a, b and S1d, e. Loudspeaker LS1 is connected between points "A" and the base of TR1 by S1a and S1b; loudspeaker LS2 is connected to the collector circuit of TR2 by S1d and S1e, thus Station 1 can now speak to Station 2.

Switches S1c and S1f remain unchanged when moving from position two (REC) to three (SPK), and so the battery supply remains connected and the feedback line disconnected.

If Station 1 wishes to initiate a call, normal practice would be to go straight through to the "speak" position from "standby" and put through the oscillatory call tone by pressing S2. Then with S1 released, Station 1 is immediately on "receive" since the lever of S1 is biased to this (mid) position.

CALL TONE

If, in the final assembly, the pitch of the call tone is considered too low, this can be raised by decreasing the value of C2. A similar tailoring by "cut and try" can be exercised on R5 for increasing the call signal volume. For the loudest call R5 can be removed, but this results in the transistors being driven hard with consequent peak clipping, raucous tone and increased current consumption.

CONSTRUCTION

The first detail in order of assembly should be the circuit component board, see Fig. 2. It should be noticed from the underside view of the transistors (shown with the circuit diagram) that the base and emitter

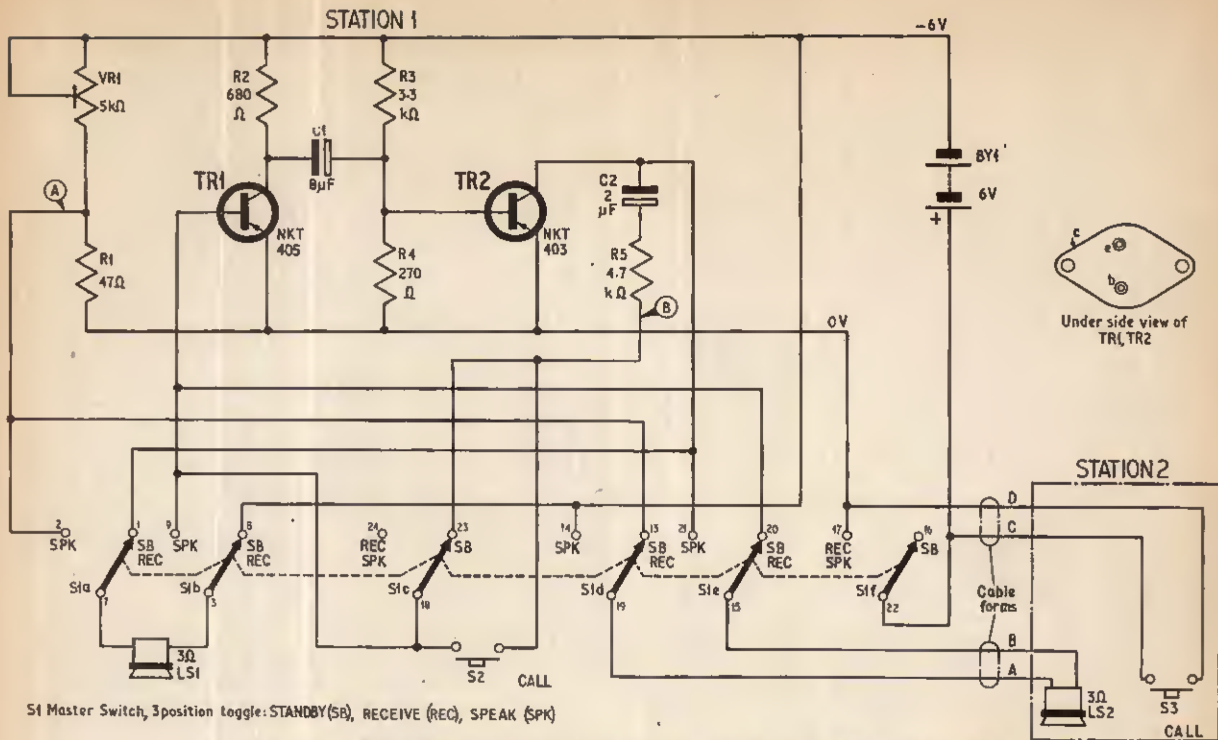


Fig. 1. Circuit diagram of the Homecom two station communication system

poles are slightly offset from centre and care should be taken in identifying these pins prior to soldering. The transistors should be mounted clear of the board as the case and collector are common and any shorting to adjacent wires might produce expensive damage. The collector connection is made by a soldering tag fitted to one fixing hole of each transistor; this is not bolted through the board. The transistors are supported by the two pins.

At this stage no flying connections are made and the completed board assembly should be placed to one side.

FRONT PANEL

The front panel is prepared from a piece of hardboard, dimensions and drilling details are given in Fig. 3. Loudspeaker and switch cut-outs are made and holes drilled for screw fixing. If loudspeaker fabric is used for covering, these holes can be easily cleared from one side of the panel.

The loudspeaker and the two switches can now be mounted, making sure that the miniature lever keyswitch S1 is positioned so that the key is up on lock or "Standby" (SB). The rear view of the switch terminals will appear as is Fig. 4. With the 12-way connecting strip screwed in position the wiring of S1 can be commenced.

Soldering to the tightly spaced tags on the master switch demands the use of an iron with a slender bit, and all connections should be made in a progressive sequence either horizontally or vertically. Random connections will probably result in insulation charring and consequent short circuits when adjacent leads are fitted.

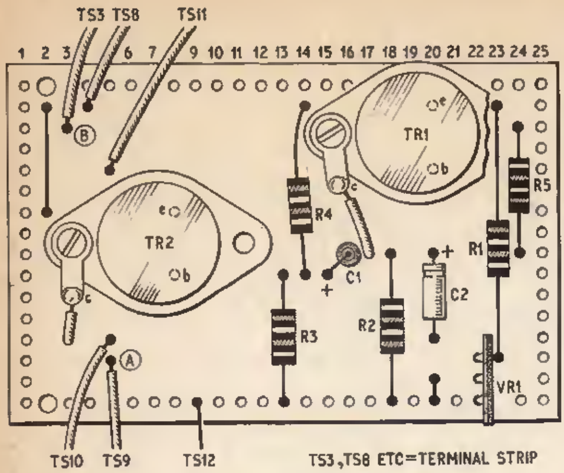
Inspection of the switch wiring (Fig. 4) will show a number of tags which are electrically common. Wire links could have been used on the switch, but it makes wiring more untidy. It is easier to make single connections at the switch tags with lengths of 1/·024 solid sleeved wire and mechanical joins at the terminal strip.

MOUNTING THE COMPONENT BOARD

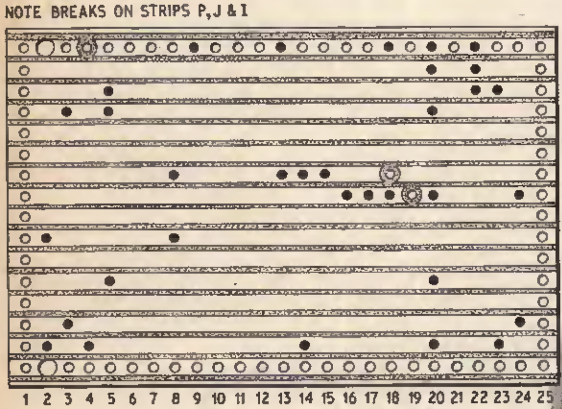
The component board is mounted on a piece of angle aluminium using nylon nuts and bolts or bushes in the fixing, and the whole is attached to the front panel, see Fig. 4. The complete assembly is now integral to this panel which facilitates any later servicing, as the unit can be readily withdrawn from its press-fit attachment to the recessed main housing. See Fig. 5.

With the front panel conveniently held in a vice, flying leads to the circuit component board can be

By G.M. Harvey

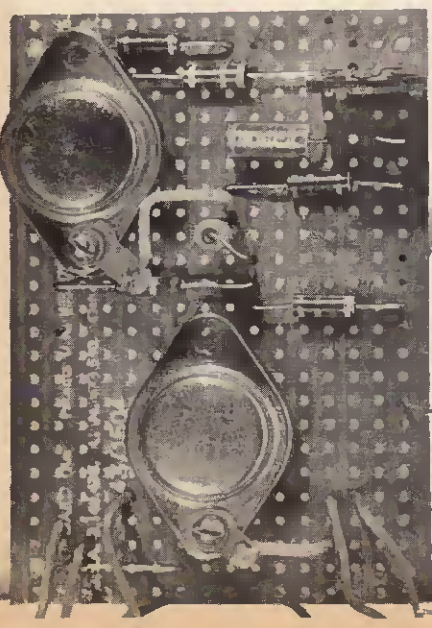


(a) Arrangement of components



(b) Underside view of board

Fig. 2. Circuit component board. Note the three breaks which have to be made in the copper strips



COMPONENTS . . .

Resistors
R1 47Ω
R2 680Ω
R3 3·3kΩ
R4 270Ω
R5 4·7kΩ
All 10%, ½W carbon

Capacitors
C1 8μF elect. 15V
C2 2μF elect. 15V

Potentiometer
VR1 5kΩ linear skeleton preset

Transistors
TR1 NKT405 } (Newmarket)
TR2 NKT403 }

Switches
S1 Miniature lever key switch 4CL/4CN (Keyswitch) (Home Radio)
S2, 3 Miniature push-to-make s.p.s.t. (Home Radio) (2 off).

Loudspeakers
LS1, 2 3Ω, permanent magnet, 5in dia. (see text)
BY1 6V battery—2 × 3V twin cell batteries (800 type Ever Ready)

Miscellaneous
Terminal strip, 12 way
Terminal strip, 4 way
Veroboard 3¾in × 2½in
Solder tags.
Hardboard for front panel (2 off)
Material for cases. Aluminium strip
Tygan or speaker grille
Length of cable as required; 4-core, or 2 × 2-core mains flex

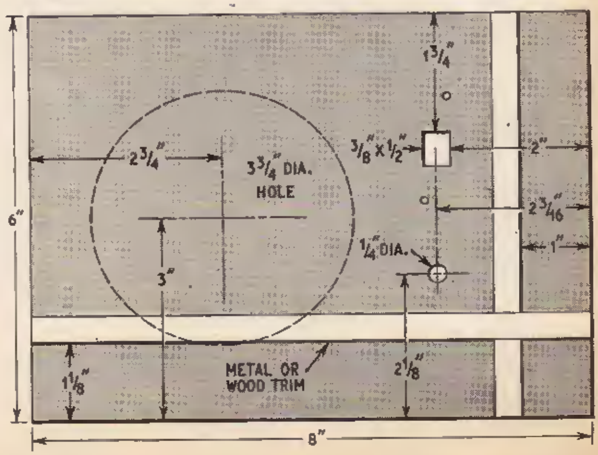


Fig. 3. Front panel cutting and drilling details. Suitable material is ⅛in hardboard

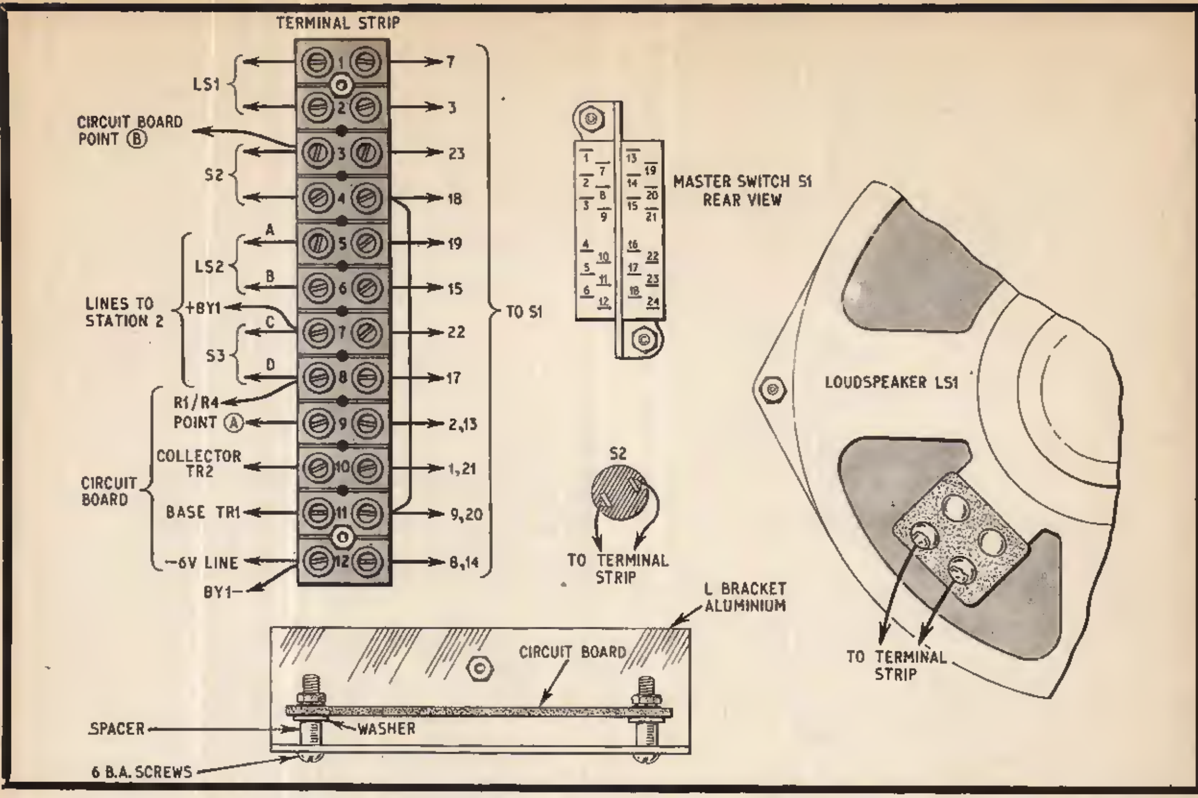
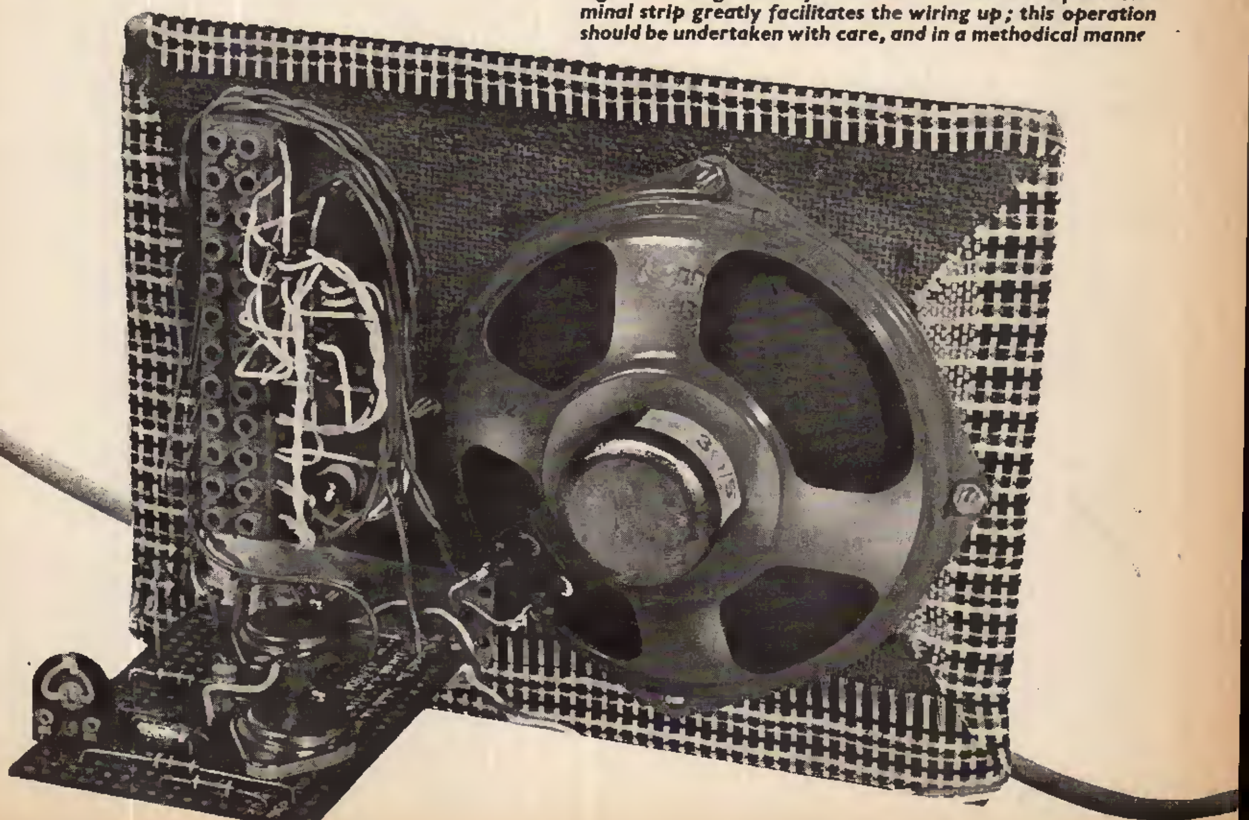
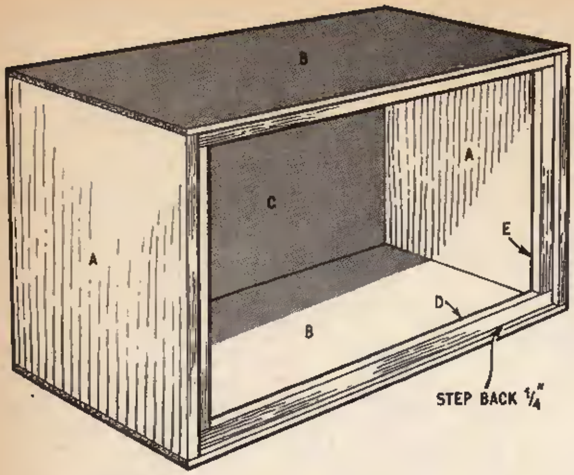


Fig. 4. Wiring details for Station 1. The use of the terminal strip greatly facilitates the wiring up; this operation should be undertaken with care, and in a methodical manne





A = 5" x 6" x 3/8" WOOD (2 OFF)
B = 8 3/4" x 5" x 1/8" HARDBOARD (2 OFF)
C = 8 3/4" x 6 1/4" x 1/8" HARDBOARD
D = 3/8" x 1/4" x 8" WOOD FILLET (2 OFF)
E = 3/8" x 1/4" x 5 1/4" WOOD FILLET (2 OFF)

Fig. 5. Construction details for the Homecom housing. Note that the case for Station 2 can be of less depth than stated above if desired. Four screws secure the front panel

connected. At this point it is as well to make sure that the retaining screws of the terminal block are making clean connections to the wire and not the sleeving.

THE CASE

A suitable housing for both units is a wooden or metal case of internal dimensions 8in × 6in × 5in. This provides ample room for the two twin cell 3V batteries (connected in series) immediately behind the loudspeaker in Station 1.

Aluminium strip can be used for front panel embellishment, and provides a good base for Letraset marking of switch functions. This embellishment also allows a distinction to be introduced between the frontal appearance of Station 1 and Station 2.

As Station 2 contains only the press switch S2 and a loudspeaker LS2 the disposition and mounting of these components should duplicate Station 1, that is, if the loudspeakers used are of equal diameter. The depth of the case could however be reduced to about 2½in if desired. Wiring details are given in Fig. 6.

A small hole should be drilled in the back panel of each case for feeding out the interstation cables.

LOUDSPEAKERS

Almost any low (3–15 ohm) impedance loudspeaker of various cone diameter may be usefully employed. Of course, it follows that input and output sensitivities will be a function of the loudspeaker diameter. It should be noted that loudspeakers of differing impedances were not tried, but in view of the swamping value of VR1 such unbalances should not upset the preliminary sensitising of the circuit.

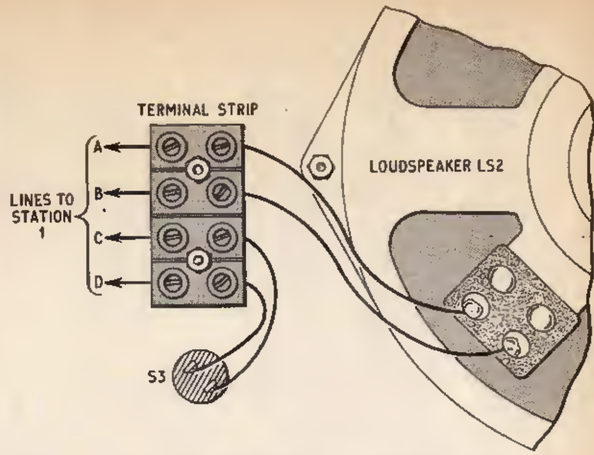


Fig. 6. Wiring details for Station 2

INTERSTATION CONNECTIONS

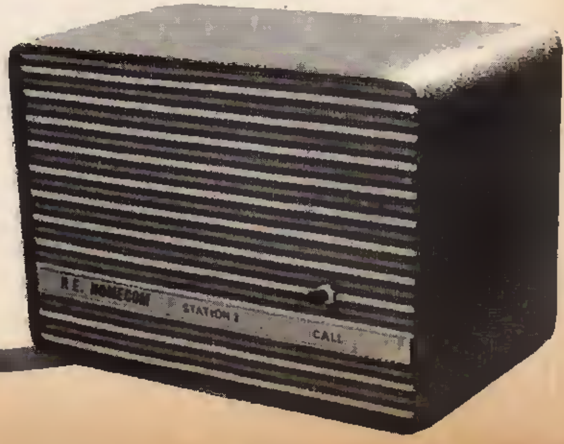
Two twin lengths of 2A flex can be used for interstation connections. In the prototype 3 ohm 5in loudspeakers were employed, with a four-way standard screened cable between stations. As the input impedance is low such screening was found to be completely unnecessary. Satisfactory operation was achieved with a 60ft length of cable between stations.

It should be borne in mind that 3 ohm transducers in the output stage will contribute to a greater collector dissipation, however this is well contained in the unsinked assembly of TR2. Higher impedance loudspeakers whilst providing better power transfer have the advantage of overcoming the power lost in the interconnecting line resistance.

SENSITIVITY ADJUSTMENT

In the preliminary setting up of the Homecom, the required cable length should be maintained *in situ*. With power connected VR1 potentiometer should be reduced from its maximum value until the "microphone" loudspeaker becomes alive—which will be prefaced by a rushing noise in the output loudspeaker. In this adjustment both stations should be reasonably separated to prevent acoustic feedback.

The optimum loudspeaker sensitivities will depend on the speech coil impedances employed and interstation line length, but this adjustment of VR1 should be carefully carried out both for best possible transmission and reception. ★



REACTALYSER

By B.H. BAILY

THERE are several ways of putting human reaction to the test, whether it be of a light-hearted nature or of more serious intent. Some reactions are very quick, such as the kick of a leg after a gentle tap at the knee.

Probably one of the most useful forms is in the time it takes for the hands to react from an impulse stimulated by a visual movement. If a dog was to dart in front of your car while driving, how quickly can you take evasive action? Readers no doubt will find several examples which require alertness of mind coupled with well controlled reaction of the body.

How can we put reaction to the test without actually setting a scene that might be difficult or even impracticable?

The "Reactalyser" described in this article will fit the bill and will be found to be simple to build and operate. If required it can form the basis of an amusing game of skill at a party (particularly after a round of drinks).

The instrument uses a simple panel mounting moving coil meter, mounted in a plastics box with two push-button controls.

To operate it, the subject is required to press both buttons together, release one, then wait till this button pops up after a random time of a few seconds, before releasing the second. The time elapsing between the pop-up of the first button and the operator's release of the second is then shown by the meter pointer.

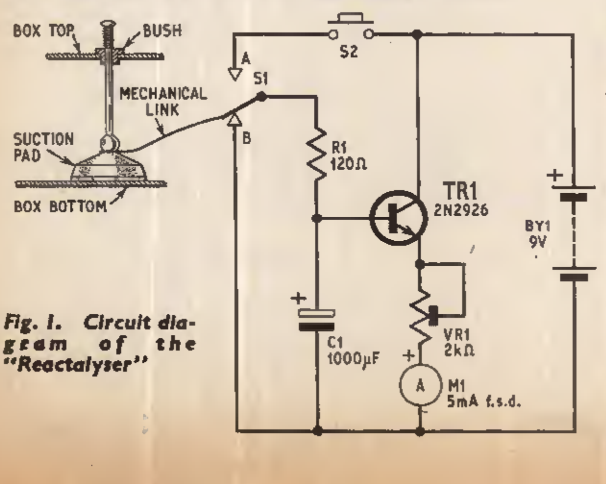


Fig. 1. Circuit diagram of the "Reactalyser"

LOADED EMITTER FOLLOWER

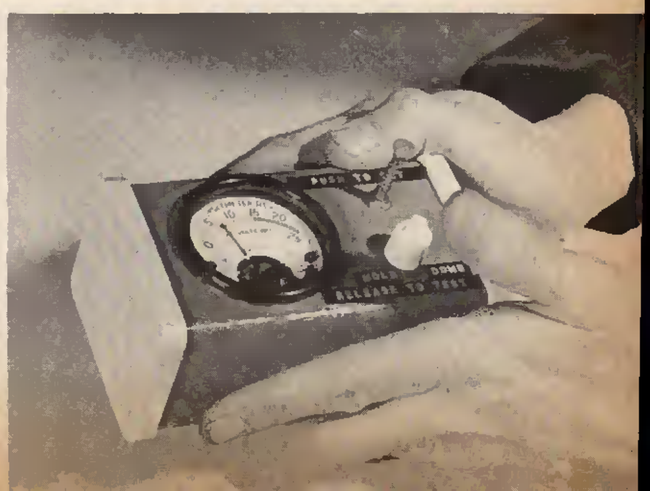
The circuit is a single emitter follower stage in which the emitter load is a 0–5mA meter in series with a preset variable resistance VR1 (see Fig. 1).

In the non-operating condition S1 is held against its upper contact A by the spring fitted to the push-button rod. Switch S2 is a conventional push-button switch normally open circuit. When the subject operates the device, he holds down S1 and S2. TR1 base is now grounded via R1.

Pressure is now released from the rod attached to S1 but S2 is held depressed until the gradual air leak releases the suction pad. The rod kicks up and changes the state of S1 so that TR1 is now connected to the battery positive line via R1 and S2.

Immediately this happens, C1 begins to charge at the time constant determined by the values of C1 and R1. As C1 charges exponentially, the base voltage also rises exponentially and the emitter follows it faithfully. The meter indicates the climbing potential as TR1 is now conducting. The emitter voltage continues to rise until the subject removes his finger from S2. Once he does this, the charging path to C1 is broken, and the final charge attained on C1 is represented by the indication on the meter scale.

The capacitor will tend to discharge through TR1 base-emitter circuit, since S1 has, by this time, reverted to position A. Since this discharge path is of relatively



high resistance, and the value of C1 is high, there is sufficient time to read the meter before any significant drop in current is indicated.

The meter scale can be calibrated in time and VR1 is set to facilitate this (see notes on calibration).

COMPONENT VALUES

The values shown for components are critical, and have been chosen as a result of experiments. All are based on the use of a 0–5mA meter movement. If a 0–1mA meter were used, VR1 would have to be about 10 kilohms maximum, again using the same supply of 9 volts.

The choice of the 2N2926 for TR1 was chiefly one of convenience, but most silicon types (*npn*) would suit this circuit.

The omission of an on/off switch may justifiably be questioned, but in fact the design of the circuit makes this component unnecessary since the current drain through TR1 is almost zero when C1 is discharged, provided S1 is momentarily depressed and no further charge can build up until the next time S2 is operated. Therefore, the instrument should be left in this condition after use. Alternatively, the battery can be removed if the period of non-use is likely to be long.

Capacitor C1 can be 1,000μF or (as in prototype) four capacitors 250μF each connected in parallel. The knitting needle was a handy means of making a plunger for S1. Readers could make their own style from ⅛in steel rod.

CONSTRUCTION

Any convenient box may be used, the principal feature being only that it will house the meter comfortably with a little room to spare for the circuit and battery (see photograph). The circuit was built on a single 5-way tag strip (Fig. 2), this being held in position by a spot of glue.

RANDOM TIMER MECHANISM

The random timer press-button rod is made from a No. 10 knitting needle fitted with a compression spring under its head. In the prototype, the rod passes through a 3·5mm jack socket from which the contacts have been removed, but this could be replaced by a less expensive guide brush through which the needle may readily slide up and down.

The bottom end of the needle is fitted into a rubber suction pad to which it is secured by rubber adhesive (Fig. 3). When the needle knob is firmly depressed, the suction pad is forced on to the bottom of the case where it adheres. To prevent permanent adhesion, a little talcum powder is dusted on the suction pad rim, and on the box bottom. This ensures a slow air leak which eventually leads to the suction pad succumbing to the action of the spring.

The time taken for this to happen depends on more than one factor, and may vary from 3 to anything like 12 seconds; this prevents the subject under test anticipating his cue.

A miniature microswitch could be used for S1, provided that it had a single pole changeover contact set. In the prototype a switch was constructed by soldering a short length of close-wound light tension spring to the end tag of a short tag strip. The other end tag is bent up to contact the spring when the latter lies along the strip.

The spring formed the moving arm and the second changeover contact was fashioned by bending a short

COMPONENTS . . .

Resistor
R1 120Ω 10% ¼W

Potentiometer
VR1 2kΩ linear preset skeleton

Capacitor
C1 1,000μF 12V

Transistor
TR1 2N2926

Meter
M1 0–5mA f.s.d. moving coil

Battery
BY1 9V type PP3

Switches
S1 Single pole changeover (see text)
S2 Single pole push on, release off, push button

Miscellaneous
6-way tag strips (2 off)
Spring for S1 (see Fig. 3)
Knitting needle No. 10 with head
Rubber suction pad
Plastics box 2⅝in × 2⅛in × 4in long with end caps (D.E.W. Ltd., 254 Ringwood Road, Ferndown, Dorset)

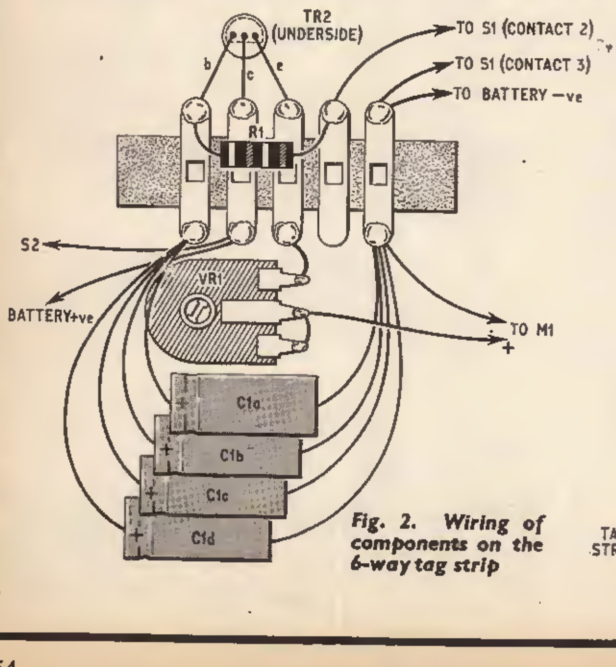


Fig. 2. Wiring of components on the 6-way tag strip

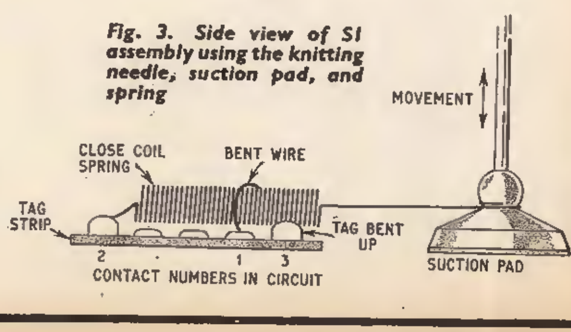
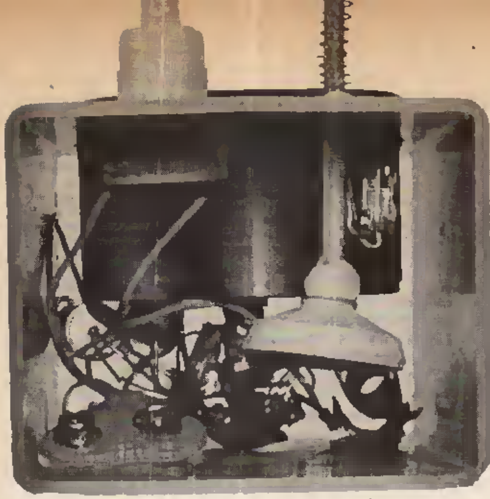


Fig. 3. Side view of S1 assembly using the knitting needle, suction pad, and spring



piece of stout wire to form an inverted "L" over the spring, which makes contact when it is raised off the lower tag. The wire contact was anchored by soldering it to an intermediate tag. The last $1\frac{1}{2}$ turns of the spring are bent out from the coil and looped around the waist of the suction pad.

CALIBRATION

Calibration is simple. Start with VR1 set for maximum resistance in circuit and the random time rod S1 in the "up" position. Hold S2 depressed and watch the meter read part-scale deflection: it will settle very quickly.

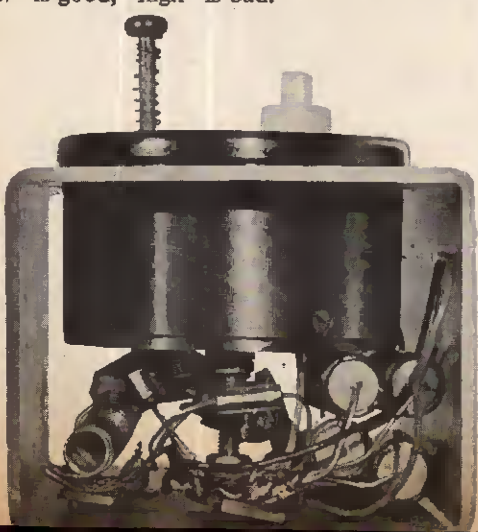
Keep S2 pressed and turn VR1 very slowly until M1 just reads full scale. Do not exceed this position or the meter may be damaged. The instrument is then ready for use.

The meter scale could easily be re-calibrated if desired, to suit the constructor's taste. The author coloured the higher end of the meter scale in red (having once found he could always score better than half-scale, of course).

OPERATION

To test your own reaction, simply press S1 and S2 firmly down, release S1 and, while still holding S2 down, wait for S1 to pop up. Remember that every millisecond that elapses after this will count against the competitor, and that the reaction time of the circuit is quicker than his.

Quick release of S2 when S1 pops up is important to achieving a competitive reading on the meter. Your "score" is shown inversely on the meter scale; i.e. "low" is good, "high" is bad. ★



TECHNICIAN ENGINEERS

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In this article E. A. Bromfield outlines the purpose and activities of the Institution of Electrical and Electronics Technician Engineers, of which he is the Secretary

In the electrical and electronic engineering industries of today there are, broadly speaking, two distinct types of well qualified engineer: the Chartered Engineer and the Technician Engineer.

Technician engineers (who link the scientist and technologist on the one hand with the technician and craftsman on the other) are expert in the application of specific engineering techniques in all sectors of these industries; whether in manufacture, operation, maintenance, development, and research; they are also engaged in those other industries that use electricity as a means of power, control, and communication. Technician engineers provide the detailed information from which engineering decisions are made, and influence the selection of materials and apparatus.

During the past decade there had been an acute awareness of the need for an organisation, of the learned society kind, to provide a recognised status and technical qualification for these senior engineers, for many of whom the route to chartered status has gradually been closing.

THE IEETE

The Institution of Electrical and Electronics Technician Engineers (IEETE) was set up in 1965 with the full encouragement of industry and with the firm support of the Institution of Electrical Engineers, to fill this great need. Since technician engineers are needed in the ratio of four to one of chartered engineers it is estimated that potential membership for IEETE is about 80,000. Already the IEETE membership strength is over 9,500.

ACTIVITIES AND PLANS

The main educative aims of the IEETE are the dissemination of knowledge in the fields of electrical and electronic engineering techniques, and the encouragement of attainment by the members themselves of the highest possible standards of technical competence. To accomplish these objectives, the IEETE is promoting conferences, discussion meetings and lectures, and arranging visits to places of technical interest. Programmes of lectures are running in London and throughout the nine regions in which Centres have been set up so far.

The Institution's Journal "The Electrical and Electronics Technician Engineer" bears technical material of general interest, and carries news of Institution activities.

IEETE plans for immediate and future developments include the formation of specialised divisions; lectures and discussion meetings covering specialised interests, technical information and library services, and other facilities.

MEMBERSHIP

There are four categories of membership: Graduates (three guineas); Corporate Members—Member (six guineas) and Associate Member (five guineas); Associates (five guineas); and Students (one guinea). Income Tax relief is allowable on all subscription rates.

Corporate Members are entitled to use the description "Incorporated Technician Engineer (Electrical and Electronics)", and the initials M.I.T.E. or A.M.I.T.E. These designatory initials are already as unmistakable a means of identification as are those denoting membership of the institutions for chartered electrical and electronics engineers.

The standard of technical education required of a candidate for election as a Corporate Member is the Higher National Certificate in Electrical and/or Electronic Engineering, or the City and Guilds of London Institute's Telecommunication Technicians' Certificate together with at least two certificates in Supplementary Studies (Regulations 49/300), or the City and Guilds of London Institute's Electrical Technicians' Certificate, together with two Endorsement Certificates in Group "A" subjects (Regulations 57).

Those persons over 30 not able to satisfy the requirements for Corporate Membership but who have had no less than five years' experience as an electrical or electronics technician engineer may be admitted as Associates. An Associate who wishes to transfer to the class of Associate Member may present and discuss an engineering report before a panel of Assessors appointed by the Council.

WHAT IS OFFERED TO THE STUDENT?

Students now have a "stepping stone" to status; for those on courses towards a National Certificate or City and Guilds Certificate can enjoy all the IEETE learned society activities and facilities and pursue their studies with a recognised electrical and electronic engineering qualification in mind.

There is now a first class incentive: no longer is their study a "dead end".

GROWING RECOGNITION

The prospectuses of a growing number of educational establishments include the IEETE qualifications in their lists of nationally-recognised distinctions; and more and more employers are beginning to specify the qualifications in their advertisements for senior technical staff appointments.

Further information about the IEETE and its activities, and membership proposal forms, may be obtained from the Secretary, The Institution of Electrical and Electronics Technician Engineers Limited, 2 Savoy Hill, London, W.C.2. (Telephone 01-836 3357.)

AN "EXTRA SHOT"

Surveyor VII, the last of the unmanned spacecraft which the U.S.A. will send to the moon, was dispatched on a Sunday in January. As the previous *Surveyors* had covered the full extent of the environmental investigation, this one was an extra, so to speak. This being the case a certain amount of risk could be taken with it so far as landing was concerned. Accordingly it was decided to choose a landing place that was known to be very rough.

The three legged vehicle carries a larger pay load than any of its predecessors. It has a rotating television camera, a small power shovel, a chemical sampler, four magnets, and ten mirrors, including one for stereoscopic picture work. The total weight is of the order of 1,480kg.

The spacecraft was directed at the part of the moon never before explored by the 27 previous vehicles, these include all the photographic, hard and soft landed units. This particular area of the moon is the crater with the craggy layer of debris which was created when a huge meteorite ploughed into the lunar surface probably millions of years ago. The debris may be from as much as 30km below the surface of the moon and what is left is the crater Tycho and a very extensive rocky terrain.

The vehicle landed about 30km north of the crater, narrowly missing a huge boulder which could have ruined the landing. Since Tycho is one of the youngest of the craters on the moon there is a good chance that there will be less contamination of the debris by other impacts or other material from outer space. Examination and analysis of the material of the lunar crust and that lying below the crust should offer new clues to the origin of the moon.

SOIL ANALYSER

More than 3,000 pictures were relayed to earth during the first two days of operation. Pictures were also obtained of the releasing of the soil analyser which had become hung up on its nylon cord. It was thought that this was the result of dust thrown up on landing. An attempt was made to release it by bumping it with the arm of the digger but this did not proove successful. After experimenting with a mock up at the Jet Propulsion Laboratory at Pasedena, engineers found that the most likely method would be pressure rather than bumping. The command was so arranged and the analyser fell to the ground and immediately began operation.

This type of analyser makes use of the Alpha radiation emitted by caesium to arrive at an analysis. A trench was dug eighteen inches deep into which the analyser could be lowered to check the subsoil. Hardness tests have also been made. Altogether this must rank as one of the most successful landings.

For those who would like to examine the crater Tycho, will find it just west of the moon's south pole.

MOON SHIP TEST RUN

The unmanned *Apollo* moonship was put through severe tests to assess its readiness for the manned flight to the moon late next year. The eight hour period of testing was rather longer than was originally thought to be required before launch was a qualified success.

SPACEWATCH

By Frank W. Hyde

There were certain difficulties which were overcome by man control over-riding computer control. The computer stopped the firing of the first engine prematurely because of figures it received not matching exactly. Engineers on the ground however interpreted the figures as indication of correct conditions of the thrust build-up. The ground controllers took over the flight and turned what might well have been failure into success. Astronauts aboard a moonship would have done this and it is concluded that this is a safe situation. The computer by itself would say not safe and be unable to try again, the astronaut however could try again.

The mission proved that the craft is spaceworthy: the attitude control system can maintain stability during the firing of the ascent and descent engines, the guidance system is satisfactory, the 10,500 pound thrust descent engine can brake the fall to the moon and bring the ship down gently, and the 3,500 pound thrust ascent engine can back the ship off the moon to rejoin the mother ship in the lunar orbit for return to earth.

AERIAL PHOTOGRAPHY

Progress in aerial photography has made some rapid strides with the operation of the *Advanced Technology Satellite 3.* This geo-stationary spacecraft set in orbit at 22,300 miles is in the position suggested a number of years ago by Arthur C. Clarke who pointed out that three such satellites would be able to cover the whole world in a communication network.

The *ATS–3* is situated at 0°N and 47°W, that is above the mouth of the Amazon in South America and on the equator. Because of its distance from the earth it remains stationary with respect to the earth, hence its name of geo-stationary spacecraft. The previous satellite of this type is over the Pacific and working well at its job of watching the weather.

COLOUR PICTURE OF HEMISPHERE

The prime purpose of these vehicles is meteorological. In the case of *ATS–3* an important forward step has been taken which extends the horizons of earth studies. For the first time a colour picture of a whole hemisphere has become available. It is the highest colour picture of the earth that has ever been taken.

When the first astronauts return from the moon they will see the disc of the earth grow bigger and change colour as they approach. When they start their journey back the earth will appear silvery with shadowy markings on it. As they come closer to home the disc will become colourful and three dimensional.

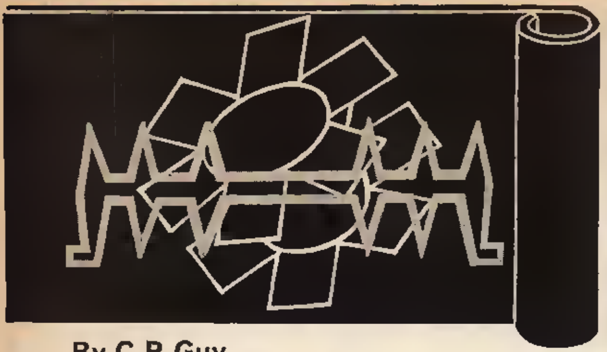
MINERAL DETECTION

This is of particular interest, for not only are the pictures obtained during the Gemini flights confirmed but even more detail is recorded. Some of the colour pictures taken at the lower levels with hand-held cameras showed remarkable detail which did not appear in black and white pictures. Weather has been plotted quite well with black and white for some years but now not only is there more detail in this respect, it is furthermore found possible to detect mineral deposits.

Naturally enthusiasm has suggested that the movement of fish could be detected due to the change in colour of the water. The mixing of warm streams and cold as well as fresh water mixing with saltwater has already been shown by Gemini astronauts.

The possibility of seeing the whole weather as it changes over a hemisphere adds enormously to the benefits of early warning of large scale weather changes. Used in conjunction with the faster orbiting units the picture of world wide weather is complete.

Wide-angle picture from Surveyor VII shows cluster of rocks near the craft's landing site in the rough lunar highlands some 30km north of the crater Tycho. The horizon, northeast of the vehicle, is formed by a ridge characteristic of the undulating topography on the flank of the crater, which is located near the moon's south pole



HEATSINKS FOR SEMICONDUCTORS

By C.P. Guy

IT IS not so long ago since transistors were regarded primarily as low power devices—transistor amplifiers for audio necessitated expensive devices if their output power was to be much more than one watt. The general availability of high power devices now means that the amateur can entertain building high power amplifiers at moderate cost.

The main drawback of power transistors, however, is that it is able to generate more heat than its own mass can dissipate. This can have damaging consequences, more so for germanium devices than silicon. It is often essential to fit heat sinks and radiators, these being available commercially in a wide range of shapes and sizes, but it is a simple matter to make one's own heat sinks. Design or selection of a suitable heat sink is quite simple and a few minutes' calculation may save a couple of expensive output transistors from destruction.

WHENCE DOES THE HEAT COME?

The amount of heat generated by a transistor depends largely on four factors: mode of operation; signal amplitude; bias level; waveform of applied signal.

When referring to a transistor data sheet, figures are quoted for the maximum collector voltage and current and maximum power dissipation. If the transistor is used as a square wave generator or class B square wave amplifier, very little power is dissipated by the transistor compared with an amplifier operating in class A with the same signal output power. The reason for this is that in class B, when driven by a square wave input signal, the collector voltage will be high with low collector current (i.e. transistor "cut off") or low collector voltage with high current (i.e. transistor is "saturated"). The net result is a very low average power dissipation.

If the transistor is driven too fast by the square wave input, then the time taken for the transistor to switch from cut-off to saturation will become an appreciable fraction of the pulse time and the average power will rise. Similarly, if the transistor is loaded too heavily, the output square wave will develop rounded corners, due to the internal resistance. Consequently, internal heating occurs.

Two interesting points arise from this: firstly, this partially explains the reason why the designer of digital equipment (in which transistors are used as on/off switches) is so interested in the cut-off frequency of the device he uses, since a lower frequency device may generate considerable internal heat when driven by too fast a train of pulses. He is, of course, also interested in

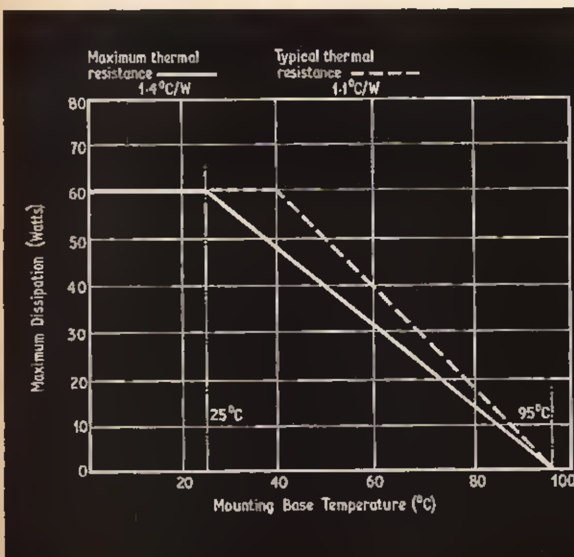


Fig. 1a. Transistor Derating Curve for germanium

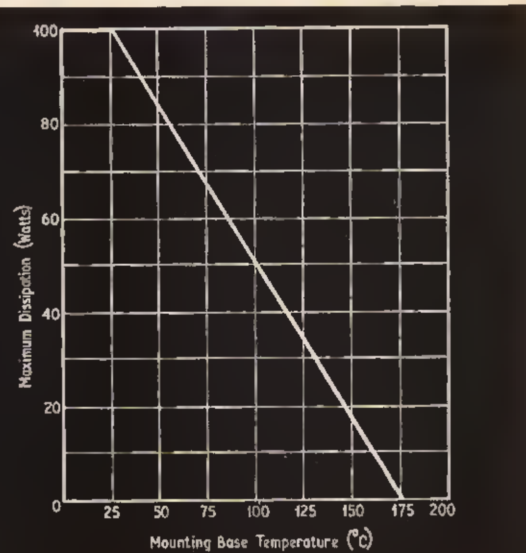


Fig. 1b. Transistor Derating Curve for silicon

whether or not the device will "follow" the input waveform reliably.

Since a large number of transistors are required in most digital equipment, coupled with the fact that equipment becomes physically smaller and smaller, careful thermal analysis is necessary and forced airflow is often employed.

The other interesting point to be deduced from the power transfer efficiency of class B amplifiers is the apparently large output power of pulse-width modulated amplifiers. In these, the output transistors are used as on/off switches and, consequently, dissipate very little power. Therefore, low power devices can be used for high output powers.

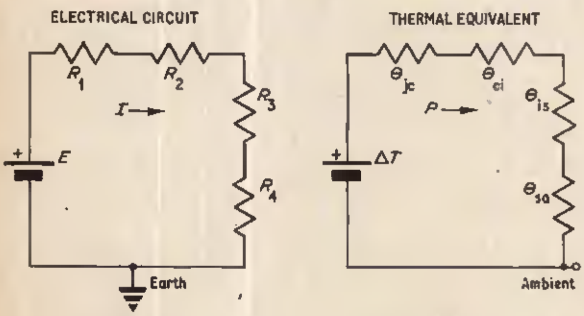
Much audio equipment is operated in either class AB or class A mode. Class AB operation eliminates crossover distortion inherent in pure class B amplifiers by the application of a slight forward bias which produces a relatively small collector current (known as the quiescent current). Whenever current flows through a resistor (the junction in this case), heat is generated, so that even the quiescent current will cause the junction temperature to rise to a steady state temperature level.

When the transistor is driven by a sine wave input signal or the complex waveforms encountered in audio working, the average time that current is on is increased; power dissipation in each transistor is increased until it reaches approximately 20 per cent of the maximum stage output. This figure will vary according to the type of input waveform (i.e. programme material).

Class A operation results in a much higher amount of heat dissipation. The quiescent current is set at approximately the mid-point of the I_C/I_B transfer characteristic. There is a relatively large "no-signal" current (about half of the peak collector current) and, hence, the power dissipated at the junction is considerable.

GERMANIUM OR SILICON

Germanium transistors are cheaper than silicon and possess more restrictive characteristics. In general, the maximum junction temperature is in the order of 85 to 100 degrees C, whereas silicon yields figures in the order of 175 to 200 degrees C. Germanium transistors also have the added disadvantage that the leakage current is generally some orders of magnitude higher than in silicon types.



$E = IR_{tot}$

$R_{tot} = R_1 + R_2 + R_3 + R_4$

$\Delta T = P\theta_{tot}$

$\Delta T = T_j - T_{amb.}$

$\theta_{tot} = \theta_{jc} + \theta_{ci} + \theta_{is} + \theta_{sa}$

Fig. 2. Electrical analogue to thermal circuit

It is possible, in certain circuit configurations, for a transistor to destroy itself by a process known as "thermal runaway". This is caused by the fact that leakage current increases with temperature.

It is possible, under certain circumstances, for the increase in leakage current to cause a further rise in junction temperature which, in turn, causes more leakage current; both current and temperature interact and increase until the maximum junction temperature is exceeded. Quite soon after this occurrence, it becomes necessary to replace the transistor and re-design the circuit to prevent a recurrence.

Maximum ratings on a data sheet are generally quoted at a certain temperature, usually 25 degrees C. It is common practice to derate the power dissipation linearly from the maximum power quoted at 25 degrees C to zero dissipation at the maximum operational temperature. Typical graphs from a manufacturer's data sheets are shown in Figs. 1a and 1b.

Alternatively, it may be specified that the power dissipation should be reduced so much for each degree rise in temperature. This figure is the thermal conductance of the device which is the inverse of the thermal resistance.

ELECTRICAL ANALOGUE TO THE OPERATION OF A HEAT SINK

It is perhaps helpful to create an analogy between heat power and electrical power: it should be remembered that the heat sink attempts to lower the temperature of the device junction to the ambient temperature (i.e. the temperature surrounding the complete assembly). The junction temperature is usually referred to as T_j and that of ambient temperature as T_{amb}.

Consideration of the electrical circuit in Fig. 2 reveals that, in order to produce a flow of electrical charge (coulombs) from one point to another, a difference in electrostatic pressure (voltage) must exist. The rate of flow of charge may be given in coulombs per second, or amperes. Whatever impedes this flow is called electrical resistance (R) and is measured in ohms (Ω).

Similarly, in order to produce a flow of heat energy (joules) from one point to another, a difference in heat "pressure" (temperature) must exist. The rate of flow may be measured in joules per second, or watts. Whatever impedes this flow is known as thermal resistance (θ) and is measured in thermal ohms (degrees centigrade per watt). Table 1 shows the analogy between electrical and thermal terms.

Table 1: COMPARISON OF ELECTRICAL AND THERMAL TERMS

Electrical Term			Thermal Term
EMF	V	volts	Temperature Differential ΔT (degrees centigrade)
Charge	Q	coulombs	Energy J joules
Current	I	amperes	Power P watts
Resistance	R	ohms	Thermal Resistance θ (degrees centigrade per watt)
Conductance	G	mhos	Thermal Conductance (watts per degree centigrade)

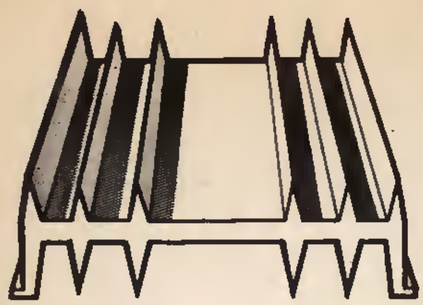


Fig. 3. Typical finned commercial heat sink made of extruded aluminium

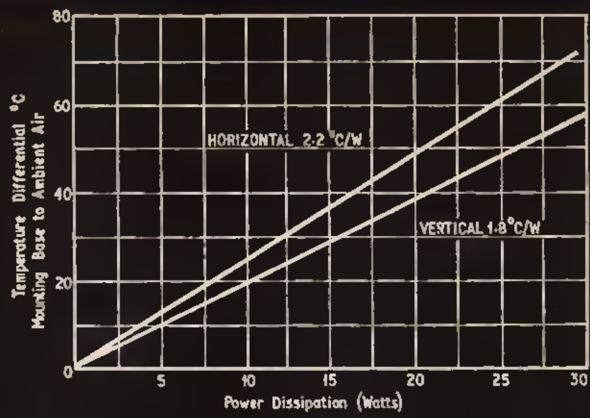


Fig. 4. Thermal characteristics of a finned heat sink

The thermal conductivity path from the transistor junction to the ambient air contains thermal resistances between the junction and the case (θ_{jc}), between the case and heat sink (θ_{cs}), also through an insulator in some cases (θ_{ci}), and finally from the heat sink to the ambient air (θ_{sa}). Due to these resistances, there will always be a temperature differential (ΔT) between junction and ambient and this is the quantity that must be controlled and kept to a minimum.

It is possible to treat these thermal resistances in the same way as electrical resistances and obtain the equation:

$$\theta_t = \theta_{jc} + \theta_{cs} + \theta_{sa} \qquad \ldots (1)$$

or, if an insulating washer is used between the case of the device and the heat sink:

$$\theta_t = \theta_{jc} + \theta_{ci} + \theta_{is} + \theta_{sa} \qquad \ldots (2)$$

where

θ_{tot} = total thermal resistance
θ_{jc} = thermal resistance, junction to case
θ_{cs} = thermal resistance, case to sink
θ_{ci} = thermal resistance, case to insulator
θ_{is} = thermal resistance, insulator to sink
θ_{sa} = thermal resistance, sink to ambient

As a general rule, $\theta_{cs} = \theta_{ci}$. For transistors without a heat sink, θ_{cs} and θ_{sa} combine and become a single quantity, θ_{ca}, the thermal resistance from the case to ambient.

JUNCTION POWER DISSIPATION

The temperature differential depends on the amount of power that the junction is dissipating. The average power dissipation may be approximated as

$$P_d = I_C \times V_{CE} \qquad \ldots (3)$$

where

P_d = average power dissipation in watts
I_C = collector current
V_{CE} = collector-to-emitter voltage

In a single ended class A output stage, the maximum output, P_{tot} may be deduced from the following equation:

$$P_{tot} = \frac{(V_{CE})^2}{2R_L} \qquad \ldots (4)$$

where R_L is the load resistance.

It has already been stated that the class A quiescent current results in a dissipation of approximately half the maximum power output. Under quiescent conditions, the dissipation is maximum since a signal will swing the operating point, and the product of current and voltage on either side of this line will result in less power dissipation. An equation giving an approximation of the maximum power dissipation can be derived from Equation 1.

$$P_d = 0{\cdot}5 \times P_{tot} \qquad \ldots (5)$$

In class AB, the maximum output power is

$$P_{tot} = \frac{2(V_{CC})^2}{2R_{CC}} \qquad \ldots (6)$$

where

V_{CC} = collector-to-collector voltage
R_{CC} = collector-to-collector load

Power dissipation for transistors operated in class B or AB varies according to signal, and it is necessary to resort to integral calculus for accurate results. However, if a sine wave input is assumed, a reasonable approximation is given by

$$P_d = 0{\cdot}4 \times P_{av} \qquad \ldots (7)$$

This is for two transistors in push-pull; therefore, each transistor dissipates half this power, i.e.:

$$P_d = 0{\cdot}2 \times P_{av} \qquad \ldots (8)$$

Notice that both these last two equations only refer to the average output power and not the maximum output power.

It is also necessary to know the new junction temperature (T_j) once the power dissipation (P_d) and total thermal resistance (θ_{tot}) have been calculated. This will be greater than the ambient temperature (T_{amb}) and is given by

$$T_j = P_d(\theta_{tot}) + T_{amb} \qquad \ldots (9)$$

These are the basic equations necessary for the design or selection of a heat sink, and also for the selection of a suitable transistor type. They will be referred to in a typical design procedure described later in this article.

HEAT SINKS

The simplest form of heat sink is a sheet of metal, usually mounted vertically, with the device mounted in the centre. As the amount of power dissipation in the increased in order to expose more surface area to the device is increased, so the size of the heat sink must be surrounding air.

The heat sink material is an important consideration —copper is somewhat better than aluminium but costs more. In fact, the difference in cost outweighs that in performance and aluminium is probably found more frequently in most applications. With any given heat sink, three factors affect its performance as a heat dissipator. These are effective surface area, position, and surface finish.

Commercially available heat sinks generally have fins so that a greater effective surface area is contained in a smaller volume. With finned heat sinks, the effective surface area may be less than the actual surface area but, as a rule, this is not important since the manufacturers invariably quote figures or a graph giving the thermal resistance of the sink to ambient.

A typical graph showing the dissipating characteristics of a commercially available unit (such as that shown in Fig. 3) is shown in Fig. 4. Sometimes figures are given showing the dissipation capability for certain temperature differentials. These reveal that the thermal resistance becomes slightly higher as the temperature differential increases. For instance, the thermal resistance of a finned heatsink was found to be 8 per cent worse for a temperature differential of 60 degrees C, as opposed to the figure for $\Delta T = 20$ degrees C.

For home made heat sinks, the heat transfer curve shown in Fig. 5 may be used. This relates the thermal resistance (θ_{sa}) against the area of one side of an aluminium sheet, $\frac{1}{8}$in thick, mounted vertically. It can be seen that when the area reaches about 140 square inches the thermal resistance reaches a minimum, and increasing the area beyond this limit does not appreciably change the thermal characteristics.

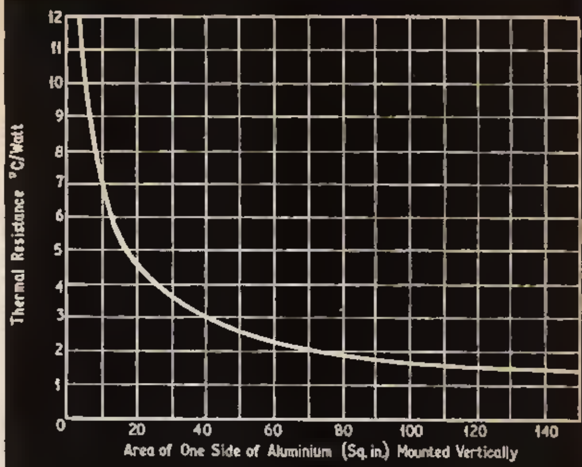


Fig. 5. Heat transfer curve for $\frac{1}{8}$in sheet aluminium

The position (i.e. vertical or horizontal) has a marked effect on the characteristics of the heat sink. It is usual to mount the sink vertically and the heat radiated from both sides is carried away by convection currents. When the heat sink is mounted horizontally, heat is dissipated normally from the upper surface but the air underneath is trapped by the sink itself. The graph of Fig. 4 illustrates the difference between horizontal and vertical mounting.

The heat sink is generally mounted externally to the equipment or, when mounted internally, in a ventilated position so that convection currents can carry the hot air upwards. If no ventilation is provided, the heat dissipated from the sink will raise the ambient temperature within the equipment, perhaps to a dangerous level.

The surface finish of the heat sink is not as important as one might suppose. Commercial heat sinks are usually supplied either in bright aluminium or an anodised finish. The best finish is matt black, but on a commercial heat sink a matt black finish may give only an 8 per cent improvement over the plain anodised finish.

It should be noted that the semiconductor device should be bolted as firmly as possible to the heat sink. Ideally, the pressure between the device and the heat sink should be specified (i.e. as fixing screw torque) but this is rarely done. The use of silicon grease between the device and sink will greatly improve the thermal resistance. In some cases, when the case of the transistor is at a different potential to the heat sink, it is necessary to use a mica insulating washer; this increases the thermal resistance between the case and sink (see Table 2) but is necessary in order to insulate electrically the heat sink from the transistor case.

Table 2: TYPICAL APPROXIMATE THERMAL RESISTANCES

Device or Heat Sink	Approximate Thermal Resistance
Vertical Copper Sheet: 140 square inches $\frac{1}{8}$in thick	1·0°C/W
Vertical Aluminium Sheet: 140 square inches $\frac{1}{8}$in thick	1·4°C/W
Typical Finned Heat Sink (Figure 3)	
Mounted vertically	1·8°C/W
Mounted horizontally	2·2°C/W
Typical Power Transistor (TO3 Case or similar)	
Mounting base	0·9°C/W
Cap	6·5°C/W
Typical Low Power Transistor (TO5 Case)	0·2°C/mW
Typical Low Power Transistor (SO-2 Case)	0·3°C/mW
Typical Small Signal Transistor (TO18 Case)	0·3°C/mW
Mica Insulating Washer	
Dry	0·8°C/W to 0·5°C/W
With Silicon grease on both sides	0·4°C/W to 0·25°C/W

TRANSISTOR ENCAPSULATIONS

Most power transistors have the collector bonded directly to a mounting base of substantial thickness.

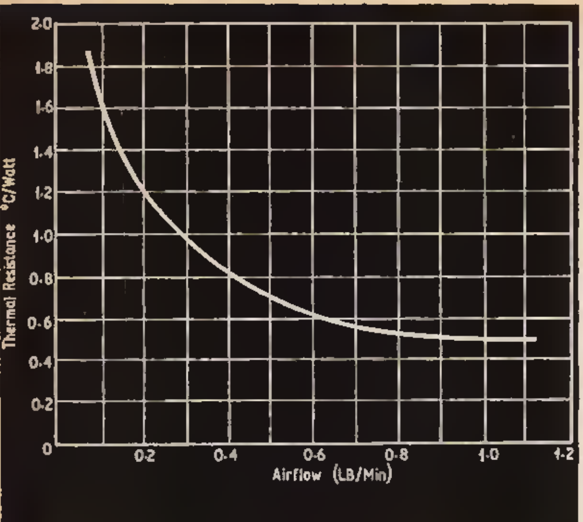


Fig. 6. Heat sink performance with forced airflow

The semiconductor wafer itself is protected by a sheet metal cover bonded to the mounting base. Sometimes the internal space may be filled with a dehydrating agent: in the smaller devices a plastics paste or silicon rubber is used to make the device more robust and improve the thermal conductance between the wafer of the semiconductor material and the case. For this reason, the figures quoted in Table 2 may vary between device types.

If the figures in this table are examined, it can be seen that there is a considerable difference in thermal resistance when the transistor is mounted by its cap to the heat sink, and when it is mounted by its base. This is because the cap is made from thin sheet metal which offers a greater resistance to heat conduction, whereas the base is much more substantial and consequently a better conductor of heat.

Similarly, the smaller transistors have high thermal resistance since they are fabricated from thin sheet metal. It is apparent that there is little point in mounting the smaller transistors on a heat sink since it will do little more than add a safety margin to the device. It will not greatly increase the power dissipation capability from that quoted in free air.

FORCED AIRFLOW

Many commercially available instruments use forced airflow to aid the cooling of devices. This has the effect of helping the action of convection currents and means that a smaller heat sink can be used which can be of importance in miniaturised equipment.

The graph in Fig. 6 shows the improvement which can be obtained by an airflow of 1lb/min with a heat sink that has a still air thermal resistance of 1·7 degrees C per watt ; this figure is reduced by about 60 per cent to 0·6 degrees C per watt. As with the area of the heat sink, a limit is reached above which a higher airflow pressure does not have an appreciably greater effect on the thermal characteristics. This limit is about 1lb of air per minute, and above this figure increased airflow mainly increases the noise level.

Fans are more expensive than sheets of aluminium and are generally only used when there are many (hundreds or even thousands) of components, where it would be both uneconomical and impractical to provide heat sinks for each heat generating component.

DESIGN METHOD

Power Dissipation and Maximum Ratings

For amplifiers, decide on the output power and class of amplification (A, B, or AB) to be employed.

Select the transistor that would seem to be suitable. Use Equations 4 or 6 to check that the maximum collector voltage will not have to be exceeded (remember that the peak voltage in class A will be twice the average voltage).

Find the maximum power that the transistor will have to dissipate using Equations 5 or 8. Check that the maximum collector current rating is not exceeded by using Equation 3. (Again, remember that the peak current in class A will be twice the average current.)

Total Thermal Resistance—θ_{tot}

Using Equation 1, calculate the total thermal resistance. For the moment, use a convenient value for θ_{sa}—this may have to be changed later. θ_{jc} and θ_{cs} should be obtained from the manufacturer's data sheet; they are generally quoted as a combined value since they cannot be modified without redesigning the device. Do not forget to include θ_{ci} if an insulating washer is to be used (a value for this can be obtained from Fig. 3 if necessary) when Equation 2 is used.

Junction Temperature—T_j

Use Equation 9 to find the new junction temperature. The ambient temperature should be the highest that the equipment is likely to be subjected to: 50 degrees C is a realistic figure for domestic equipment.

Derating

Refer to the manufacturer's data sheet and use the figure calculated for the junction temperature to find how much the transistor should be derated at this temperature. If the transistor's maximum power rating, once it has been derated, is exceeded by power which will be dissipated (P_d), then the following courses of action can be taken.

1. Increase the size of the heat sink (i.e. decrease θ_{sa}).
2. If this is not practical, then forced airflow might be suitable for reducing θ_{sa}.
3. Supply voltage (and consequently maximum output power) can be reduced.
4. Select a device with a higher dissipation capability.

If the derated maximum transistor power rating is higher than the power dissipated, then the converse of the above procedure could be considered, i.e. reduce the size of the heat sink.

A suitable heat sink may now be constructed from the graph of Fig. 5 if required: otherwise a commercial heat sink with a thermal resistance equal to, or less than the calculated value may be selected.

CONCLUSION

Precise thermal analysis of a circuit would require a computer to solve all the possible factors involved. This article has attempted to describe a simple approach to the subject and, of necessity, a number of approximations have had to be made. Emphasis has been placed on classes A and AB amplifier circuits since it is here that the constructor will most need to use a heat sink. Calculations for other circuits (i.e. d.c. regulators) may be derived from the equations given. ★

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7 transistor Key chain Radio in very pretty case, size 2⅜in × 2⅛in × 1⅛in — 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.
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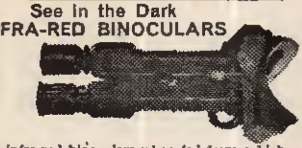
See in the Dark INFRA-RED BINOCULARS



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1 Meg Miniature. Pot-meter Morganite standard ¼in spindle 1/- each; 9/- per dozen.
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Precision Wheatstone Bridge. Opportunity to build cheaply. 100K wire wound pot. 15W rating, only 5/-.
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Transistor Ferrite Slab Aerial with medium and long wave coils, 7/6 each.
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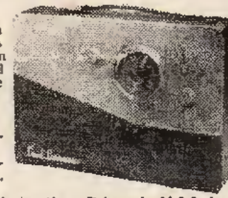
The famous Dutch made food mixer, 3 speed interchangeable beaters 220-240 Volt. Normally 7 gns. Our price 59/6 plus 6/6 postage.

SUPERTONE G.C.

Saves you work—
It's partly built



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- Two-tone Cabinet, size 11 × 8 × 3in.
- All circuit requirements—Push-pull output—A.V.C. and feed back, etc.
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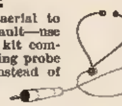

Easiest way to fault find—traces signal from aerial to speaker—when signal stops you've found the fault—use it on Radio, T.V. amplifier, anything—complete kit comprises two special transistors and all parts including probe tube and crystal earpiece 29/6—twin stetoset instead of earpiece 7/6 extra post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

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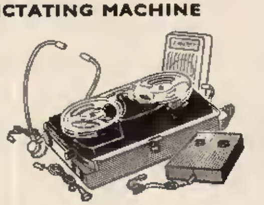

Battery operated and with all accessories. Really fantastic offer, a British made £31 outfit for only £6/19/6, brilliantly designed for speed and efficiency—cassette takes normal spools drops in and out for easy loading—all normal functions—accessories include stethoscopic ear-piece—crystal microphone 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.

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4 speed, gram. motor with lightweight pick up, motor electronically balanced and free from wow and flutter. Speed change by push button—16, 33, 45, 78 r.p.m. Price 39/6. 2 valve amplifier, 32/6. Eliptical Speaker, 9/6. Cartridge extra mono 10/6, plus 4/6 post and insurance. DON'T MISS THIS TERRIFIC BARGAIN.

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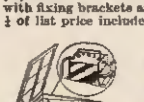

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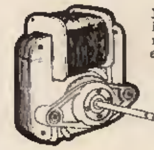

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ALL PRICES GREATLY REDUCED

Type No.	Price	Type No.	Price	Type No.	Price
2N1727	15/-	OA5	5/-	OC72	3/-
2N1728	10/-	OA10	6/-	OC75	3/-
2N1742	25/-	OA47	3/-	OC76	3/-
2N1747	25/-	OA70	2/-	OC77	7/-
2N1748	10/-	OA79	2/6	OC78	3/-
AC107	9/-	OA81	2/6	OC78D	3/-
AC127	4/-	OA85	2/6	OC81	3/-
ACY17	8/6	OA90	2/6	OC81D	3/-
ACY18	5/6	OA91	2/6	OC82	3/-
ACY 9	6/6	OA200	3/3	OC82D	3/-
ACY20	5/6	OA202	4/3	OC83	4/-
ACY21	6/-	OC20	12/6	OC84	4/6
ACY22	4/6	OC22	10/-	OC139	8/6
AF114	4/-	OC23	8/-	OC140	12/6
AF115	4/-	OC24	15/-	OC170	5/-
AF116	4/-	OC25	8/-	OC171	4/-
AF117	4/-	OC26	7/6	OC200	9/-
AF118	4/-	OC28	8/-	OC201	12/6
AF139	12/6	OC29	17/6	OC202	13/6
AF186	17/6	OC35	10/-	OC203	12/6
AFZ12	15/-	OC36	15/-	OCP71	15/-
ASZ21	15/-	OC38	12/6	ORP12	8/6
BC107	14/6	OC42	6/6	ORP60	10/-
BY100	4/6	OC44	3/-	SB078	6/6
BYZ13	7/6	OC45	3/-	SB305	8/6
MAT100	6/6	OC46	3/-	SB251	10/-
MAT101	7/6	OC70	3/-	ST140	3/-
MAT120	6/6	OC71	3/-	ST141	4/6
MAT121	6/6				

P.O. Type Relay. Twin 200 ohm coils, size approx. 3in × 2in × ¾in. 4 pairs changeover contacts, 8/6 each.
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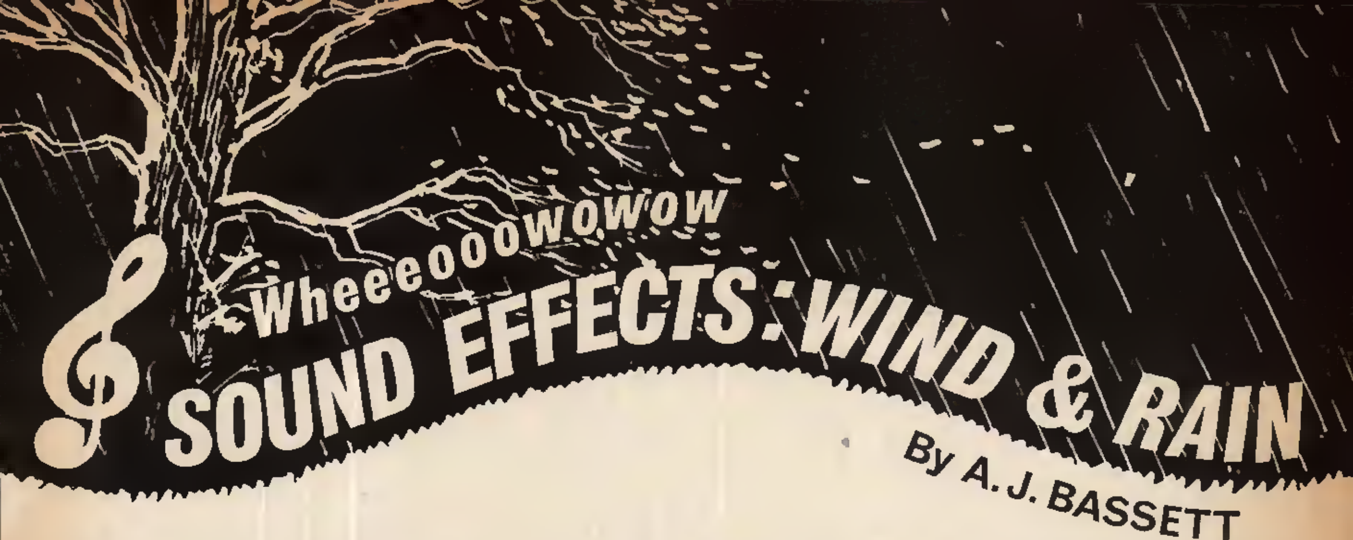


Wheeeooowowow SOUND EFFECTS: WIND & RAIN

By A. J. BASSETT

THE output from a white noise generator may be modified greatly by the action of audio filter circuits. The circuit described here gives the effects of howling, moaning wind and driving rain. No doubt, readers will make other effects as suggested by the section on operation.

Figs. 1 and 2 show suitable basic filter circuits using a transformer. An extension of this idea is shown in Fig. 3, where different pitches of sound are selected by operation of the switches to introduce different values of capacitor. This is basically a switched variable tuned circuit to accept or reject a pre-determined range of white noise frequencies.

When the higher values of capacitor are in circuit, the sound takes on a low moaning characteristic, whereas the lower values give higher pitched louder effects. If S4, S5, and S6 are left open and S1, S2, and S3 are used to control the output, more of the higher frequencies are fed to the output, resulting in a sound like that of very heavy rainfall.

ELECTRONICALLY CONTROLLED L/C FILTER

A simple voltage-controlled R–C filter was featured in the *Rhythmic Sound Effects Unit* (last month). A similar technique of electronic control can easily be applied to the circuit of Fig. 3, with the advantages of a more gradual transition from one effect to another. This gives added realism, and the possibilities of automatic and remote control over the filter circuit.

Fig. 4 shows this modified circuit, in which the switches (S1–S6 in Fig. 3) are replaced by transistors.

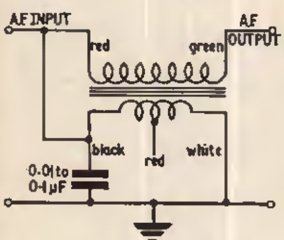


Fig. 1. Simple basic idea of the filter using only the transformer and one capacitor from 0·01μF to 0·1μF

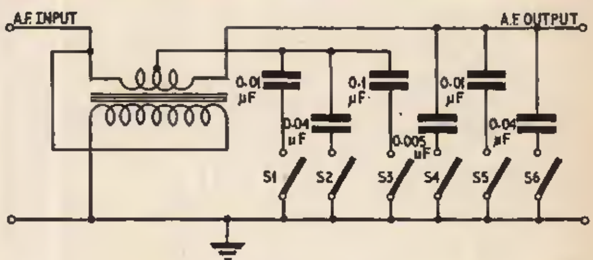


Fig. 3. Extending the two simple versions for giving different pitch sounds

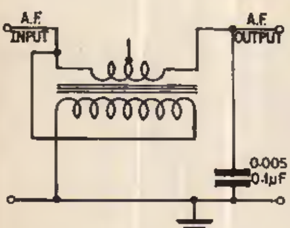
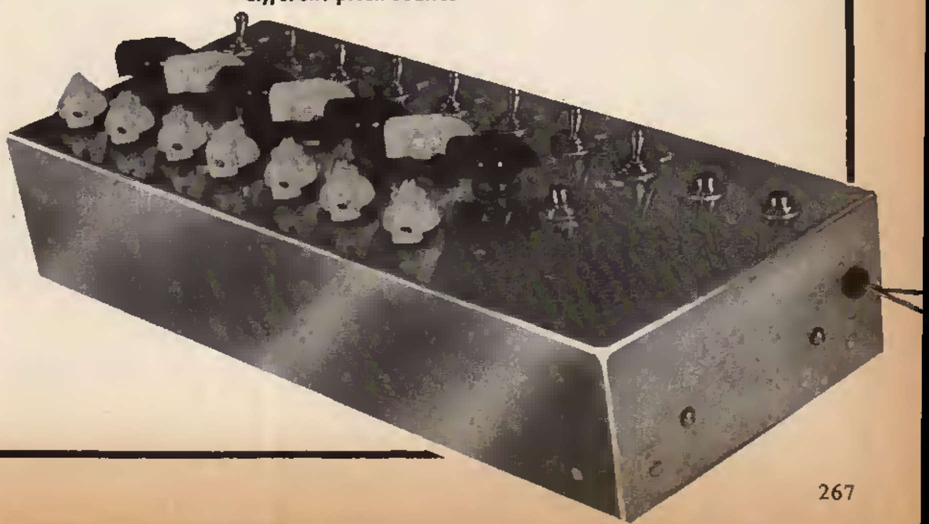


Fig. 2. Alternative circuit to that in Fig. 1. The capacitor value can be between 0·005μF and 0·1μF according to the effect required



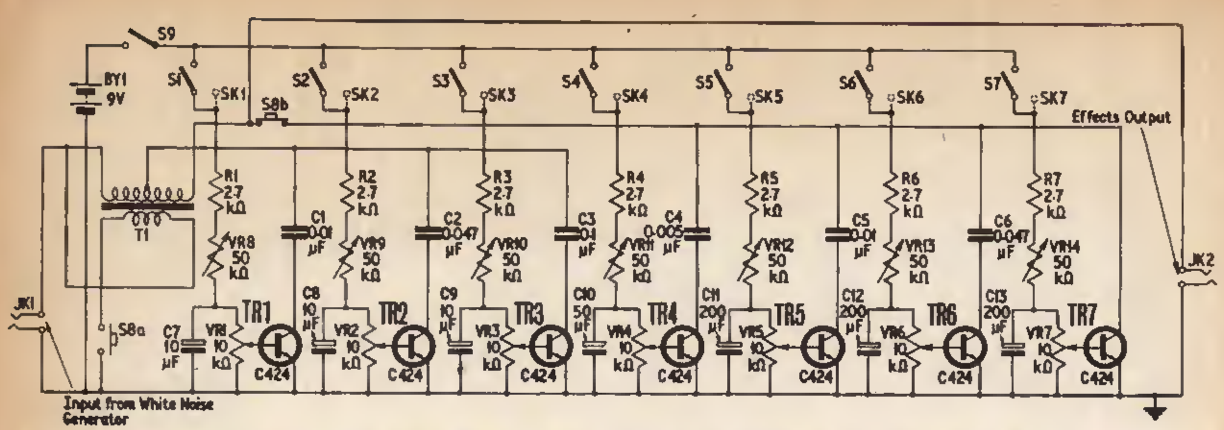


Fig. 4. Final circuit of the electronically controlled filter. The bias points here are terminated in sockets but by the addition of a switch in each bias path the unit can be triggered from a 9V battery. No other battery is necessary

Base bias is supplied to each transistor through its own bias control network; thus electronic control over the filter is achieved by supplying the bias input points from suitable d.c. positive sources. A 9 volt battery may be used, connected by way of switches to each bias input point, although higher and lower voltages, within the limits of the transistor characteristics, can be used quite successfully.

The use of transistors without any obvious source of d.c. collector supply may seem to be a little unusual. With this type of circuit the emitter and the collector are considered as a short circuit to a.c. when the transistor is switched on.

When the trans.stor is biased on at its base, it will pass current between the other two electrodes, emitter and collector. It is conventional to use the transistor as a one-way switch passing d.c. current in one direction only between collector and emitter; in this respect the bi-directional capabilities of the device are largely ignored and often forgotten. When a.c. is applied under certain working conditions the current through collector and emitter alternates its direction in sympathy with the positive and negative half-cycles on the a.c. signal.

ONE STAGE

Consider any one of the transistors in Fig. 4; the working collector supply for the transistor is obtained from the audio signal itself on the positive part of the cycle, by way of a capacitor in the collector circuit Due to the low saturation voltage of the transistor used, the transistor will act almost as a short-circuit when biased fully on, as the collector-to-emitter path will be seen by the external circuit as a very low resistance.

During the negative going part of the cycle the collector will receive a negative potential by way of the capacitor. Once again, as the base current supplied is assumed to be sufficient to bias the transistor fully "on", the emitter-to-collector path is seen by the external circuit as a very low value resistance.

During the full cycle one side of the capacitor in the collector is effectively grounded to a.c. via the transistor, as long as the transistor is biased "on". The capacitor will then appear across the output in conjunction with part of T1. However, when the transistor ceases to receive base bias current, it will then no longer conduct, and the capacitor in the collector circuit will no longer be able to pass audio current. Thus when the transistor ceases to conduct it temporarily cuts off the action of the associated capacitor; conversely, when the transistor conducts, it enables the capacitor to work as a reactive component, its reactance varying according to the frequency applied.

CONSTRUCTION NOTES

The circuit of Fig. 4 has six of these stages; the capacitor in each may be switched in or out by the associated transistor, according to the amount of base-bias received. If the transistor is partly conducting the capacitor will be brought into use with an effective series resistance formed by the collector-emitter path of the transistor.

For automatic or semi-automatic operation, the bias supplies may be derived from triggered bistable

COMPONENTS . . .

Resistors
R1–7 1kΩ 10%, ¼W carbon (7 off)

Potentiometers
VR1–7 10kΩ linear carbon (7 off)
VR8–14 50kΩ log carbon (7 off)

Capacitors
C1 0·01μF
C2 0·047μF
C3 0·1μF
C4 0·005μF
C5 0·01μF
C6 0·047μF
C7–13 10μF upwards depending on attack and decay required (see text). All electrolytic (7 off)

Transistors
TR1–7 C424 (S.G.S. Fairchild) *or* ME4103 (7 off)

Transformer
T1 Standard 3:1 intervalve transformer (Radiospares)

Switches
S1–7 Single pole, on-off, toggle (7 off). Can be replaced by wander plug sockets (see text)
S8 Single-pole changeover, push for changeover (Bulgin type SM357) or double-pole changeover (Bulgin type SRM270)
S9 Single pole, on-off, toggle

Miscellaneous
White noise generator (as in January issue)
Aluminium chassis 12in × 5in × 2½in
Bias supply—9V battery
Audio jack sockets (2 off)

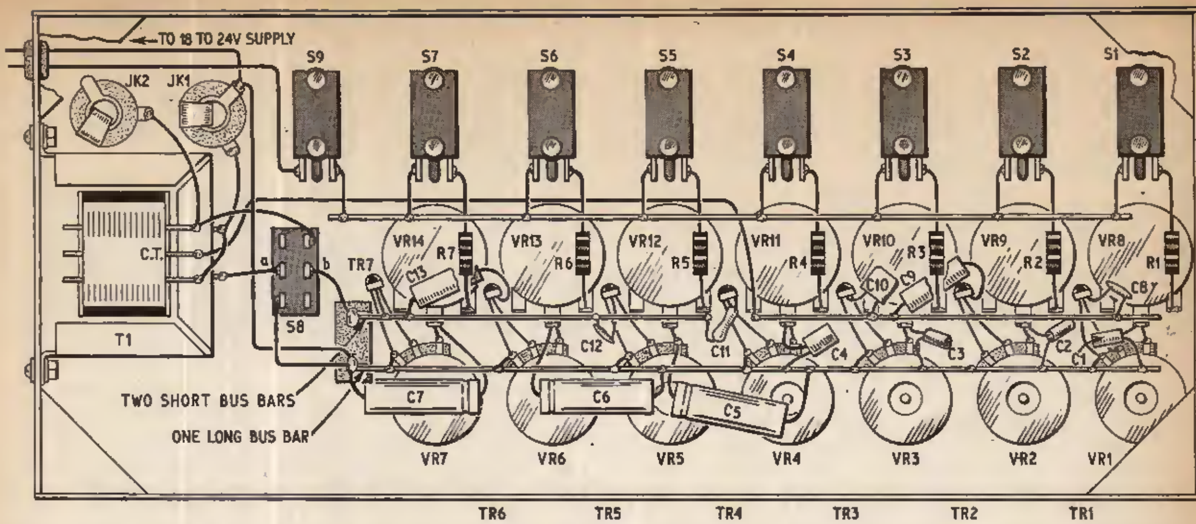


Fig. 5. Layout and wiring of the complete unit. The switches S1–7 can be replaced by sockets for external switching. Transistor TR7 is labelled by the component; other transistors are labelled immediately below the drawing for clarity. The chassis size is 12in × 5in × 2½in and drilled according to the schedule below. Switch S8 shown here is type SRM270. Alternatively, type SM357 with four tags can be used

circuits, ring-counters, or a number of multivibrators similar to that described in the *Rhythmic Sound Effects Unit*.

CONSTRUCTION NOTES

The circuit of Fig. 4 may be built in an 18 s.w.g. aluminium chassis 12in × 5in × 2½in (Fig. 5). The bias points may be connected to a suitable bias source (which may be an internally mounted 9V battery) by way of the switches S1–S7 mounted on the chassis. Alternatively, standard sockets may be used for connection of the bias points to an external switching circuit, and may be mounted at the points otherwise occupied by the switches.

Component positions are not critical but it is obviously easier to minimise wiring as much as possible. Additional stages can be added if required using identical configurations to those shown but with different values of capacitor in the collector leads.

Fig. 5 is reproduced here half scale.

Holes for switches S1–S8—$\frac{7}{16}$in dia.

Holes for potentiometer VR1–VR14—⅜in dia.

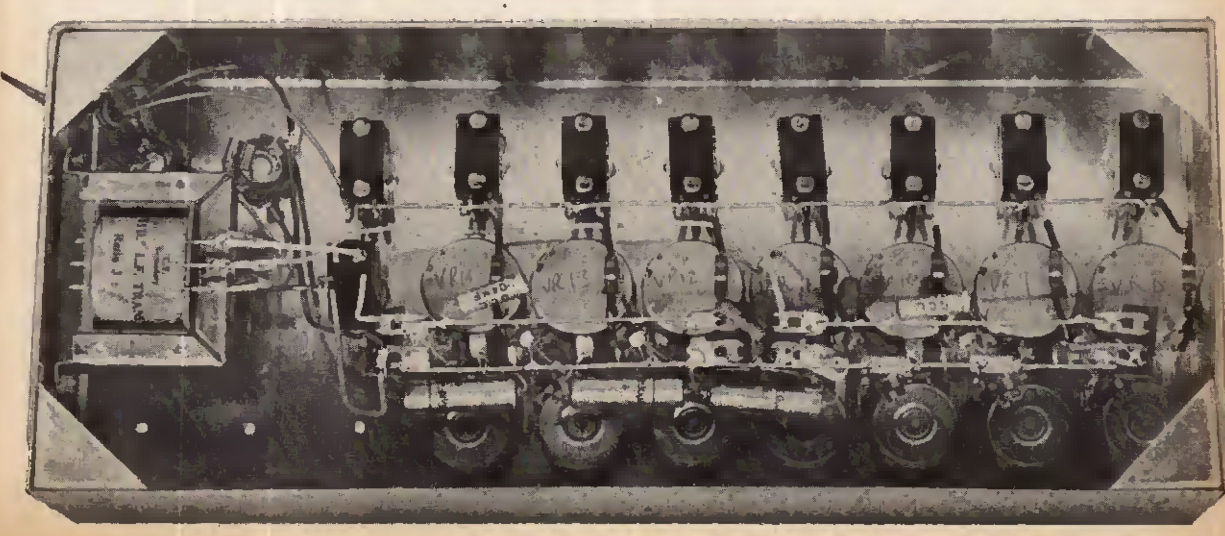
Holes for jacks JK1 and JK2—⅜in dia.

Fixings for transformer—nuts and bolts to suit the component used.

The grommet is mounted in a ¼in hole.

The photograph below shows the tag strips used to suspend the bus bars.

continued on page 288



Transistor Amplifier DESIGN

3 FOUR CIRCUITS USING 2N2926

By A. Foord

Now that high gain *npn* silicon transistors are readily available at low cost, they can be used in place of germanium types, even at audio frequencies. The 2N2926 is a typical example of a planar silicon transistor intended for general purpose applications, and can be obtained in five categories of current gain, each with a spread of two to one. Its ratings are given in Table 3.1.

This article outlines four simple audio circuits which are sometimes used in association with those described earlier in this series.

EMITTER FOLLOWER

Fig. 3.1 shows a common emitter amplifier, followed by an emitter follower. The emitter follower stage is generally used for two reasons: to prevent the output loading the collector of the amplifier stage and to enable loads as low as 1 kilohm to be fed. The maximum output of this circuit is 1V r.m.s. into 1 kilohm.

The three possible positions for connecting the emitter decoupling capacitor enables different degrees of local negative feedback to be applied to the first stage, to reduce the gain if required.

In position A the emitter is completely decoupled (no feedback) and the amplifier has an input impedance of 6 kilohms for a typical gain of 300 times, depending on current gain of the particular transistor used. Without the 220pF capacitor (C3) in circuit the upper 3dB down point is 90kHz; with the 220pF capacitor the bandwidth is reduced to 27kHz. The lower 3dB down point is at 25Hz.

In position B the emitter is only partially decoupled and negative feedback through R4 reduces the gain to 75 times at an input impedance of 10 kilohms.

In position C the gain is 10 times, feedback being nearly 100 per cent through both R4 and R5. The input

Table 3.1. CHARACTERISTICS OF 2N2926 TRANSISTOR

Maximum collector-emitter voltage	18V
Maximum reverse base-emitter voltage	5V
Maximum mean collector current	100mA
Power dissipation in free air at 25°C ambient temperature	200mW
Gain bandwidth product (typical)	120MHz

Colour Code	A.C. current gain at 10V 2mA 1kHz	D.C. current gain at 4·5V 2mA (typical)
Brown	35 to 70	36
Red	55 to 110	62
Orange	90 to 180	115
Yellow	150 to 300	155
Green	235 to 470	215

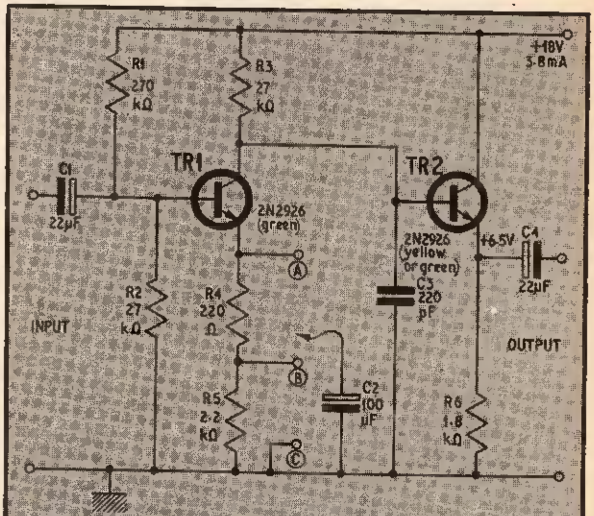


Fig. 3.1: Simple amplifier using a common emitter and emitter follower stage. Capacitor C2 has three alternative connections for setting the degree of a.c. feedback. Position C is equivalent to having no capacitor at all, maximum feedback. Position B gives a small amount of feedback. Position A gives minimum feedback

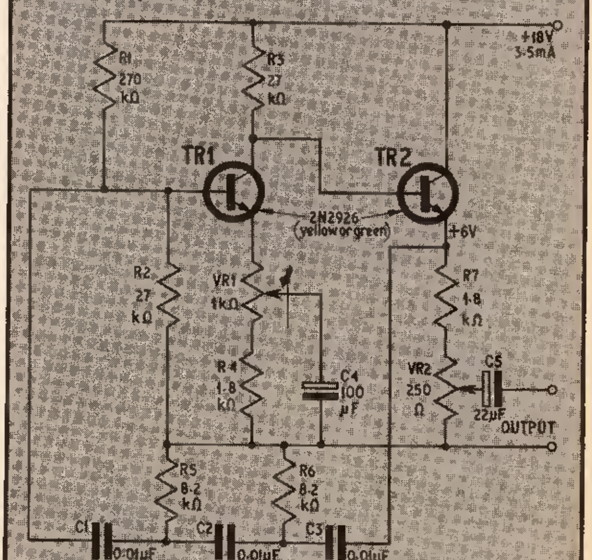


Fig. 3.2: Phase shift oscillator at 400Hz when 360 degrees phase shift is achieved between network and amplifier

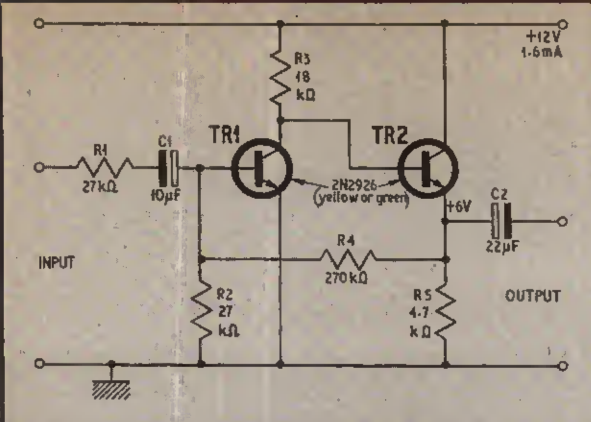


Fig. 3.3. Times ten fixed gain amplifier

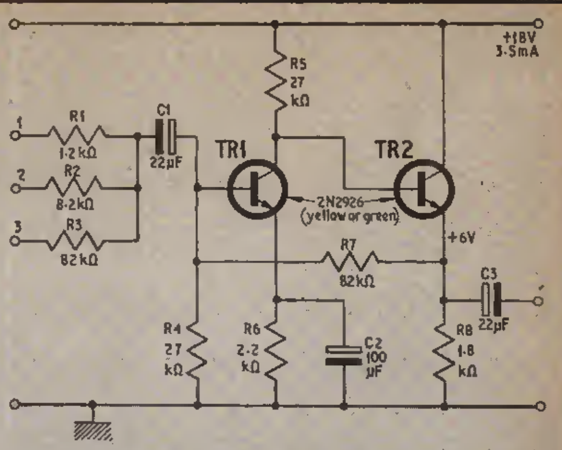


Fig. 3.4. Amplifier providing three fixed gains through the input resistors

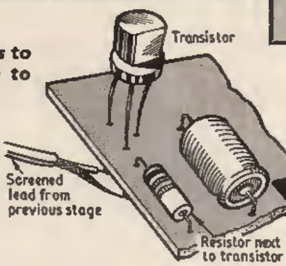


Fig. 3.6b. The correct method is to position the input resistor close to the transistor

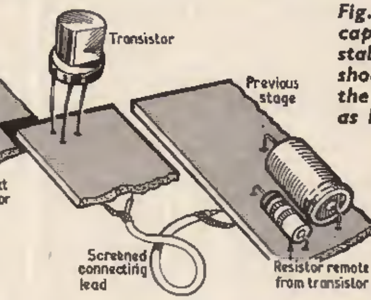


Fig. 3.6a. To avoid stray capacitance affecting a.c. stability the input resistor should not be remote from the base of the transistor as here

impedance is also 10 kilohms. The output impedance is less than 50 ohms in each case.

The frequency response of this circuit is +0 −3dB, 25Hz to 27kHz with C3 connected. If C3 is disconnected, the frequency response is modified to +0 −3dB, 25Hz to 90kHz.

Since this type of circuit has a high input impedance and a low output impedance, several can be cascaded without interaction.

PHASE SHIFT OSCILLATOR

A very similar amplifier circuit can be modified to provide a phase shift oscillator (Fig. 3.2). There is a 180 degree shift in the amplifier and another 180 degree phase shift in the ladder network (C1, C2, C3, R5, R6) so that the complete circuit oscillates at about 400Hz. VR1 should be increased from minimum gain until the circuit just oscillates.

Output is from 0 to 1V peak-to-peak set by VR2. The output is tapped from the emitter chain (R7, VR2) of the second transistor to avoid loading the amplifier and because 1V output is usually enough for most audio testing purposes.

TIMES TEN AMPLIFIER

The common emitter, emitter follower arrangement in Fig. 3.1 has series local feedback applied to the first stage to reduce its gain if required. Negative feedback can also be applied in a different manner (see Fig. 3.3). Here feedback is applied from the emitter of the second transistor to the base of the first. For this arrangement, performance details are:

Gain 10 times.
Maximum output 1V r.m.s. into 2·2kΩ load.
Output impedance less than 50Ω.
Input impedance 27kΩ.
Frequency response +0 −3dB, 20Hz to 80kHz.

FIXED GAINS AMPLIFIER

A more elaborate arrangement, capable of giving various fixed gains and a higher output current is shown in Fig. 3.4. Characteristics here are:

Maximum output 1V r.m.s. into 1kΩ load.
Output impedance less than 50Ω.
Frequency response +0 −3dB, 20Hz to 100kHz.
Input 1—gain 60 times, input impedance 1·2kΩ.
Input 2—gain 10 times, input impedance 8·2kΩ.
Input 3—gain 1 times, input impedance 82kΩ.

In each case the *source* impedance must be less than the value of the input series resistor if the full gain of the circuit is to be realised, so this circuit must be fed from an emitter follower. It can be made to have a gain variable from 1·6 times to 60 times by replacing the input resistor by a series variable resistance of 50 kilohms and a fixed resistor of 1 kilohm.

Construction of all these circuits can follow normal audio practice; printed circuit boards are ideal. For the circuits in Figs. 3.3, 3.4, and 3.5 it is particularly important to keep the leads on the base of the first transistor short. When connecting one of these amplifiers up the resistor should be at the end near the first stage, any stray capacitance up to 20pF or so from TR1 base to earth could cause unwanted oscillations. When using screened input leads, follow the preferred method of connection (Fig. 3.6) with the input series resistor close to the TR1 base to minimise stray capacitance effects between screen and core.

Part 4 next month is the beginning of a deeper investigation into the properties and effects of negative feedback in audio amplifiers. Some examples of practical circuits are included to illustrate this.

SEMICONDUCTOR BASICS

5—LIGHT SENSITIVE DEVICES

By G. J. KING

HAVING shown that current carriers multiply due to thermal activity, this month's article shows how a similar action takes place under the influence of light. Increasing light intensity releases more "free holes" or free electrons into the crystal. This makes the semiconductor less resistive allowing it to pass a greater electric current.

This could upset the normal operation of a transistor; most ordinary transistors are designed to exclude light. Those in a glass construction, for instance, are coated with an opaque paint.

If some of the paint is removed from the case, and the emitter-base junction is subjected to an increase in incidental light, the collector current will be shown (on a milliammeter) to increase quite substantially. However, some transistors are lightproofed internally, making it impossible to carry out this experiment.

A special type of transistor has been developed which is deliberately sensitive to light and will act as an amplifier at the same time. Known as a junction phototransistor, it is subjected to light rays which pass through the case and fall on the base-emitter junction. In circuit, this effectively changes the base current which is then amplified by normal transistor action.

Another light sensitive device, called the photodiode, works on a similar principle, but has no amplifying action. Another device, the light dependent resistor or cadmium sulphide cell, also presents a lower resistance when subjected to increased light rays but does not amplify.

PHOTODIODE

When a *pn* junction is formed there is an interchange of mobile carriers across the junction which builds up a potential barrier or depletion layer.

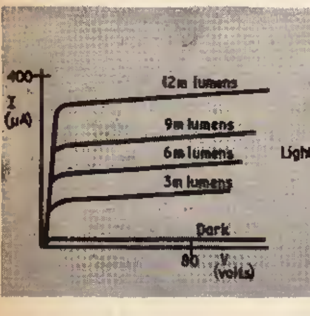


Fig. 5.1. Characteristics of a typical photodiode

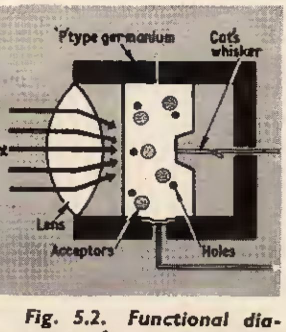


Fig. 5.2. Functional diagram of a point contact photodiode

When reverse voltage is applied across the diode, the barrier potential is increased, but some carriers under this condition generate sufficient energy to interchange across the junction. This is called leakage current or, in a photodiode, it is referred to as dark current.

When light falls on the photodiode junction, hole-electron pairs are developed on both sides. The potential at the barrier or depletion layer effectively "sweeps" the hole carriers one way and the electron carriers the other, thereby causing a flow of current through the diode, which is called light current. This is equal to the dark current (leakage) plus the photoelectric current.

The photodiode, therefore, is the semiconductor equivalent of the photoelectric cell. It consists basically of a piece of germanium or silicon with two regions, *p*- and *n*-type. The whole is encapsulated in an insulated container, designed to allow the passage of light rays on to the *pn* junction.

In action the diode is biased for reverse conduction. Fig. 5.1 shows typical characteristics of such a diode.

As we have point-contact diodes, so there are also point-contact photodiodes. Such a device in elementary form is shown in Fig. 5.2. It comprises a slice of *p*- or *n*-type germanium with a single point contact "cat's whisker", and its characteristics are similar to those of a junction type.

LIGHT DEPENDENT RESISTOR

The full title of the light dependent resistor (l.d.r.) is cadmium sulphide photoconductive cell.

Cadmium sulphide is a crystal which, when shut off from light rays, has an intrinsically high resistance (low conductivity) because the majority of its electrons are tightly bonded to its lattice atoms and very few are available for conduction. The few that are at hand, however, give the material its high dark resistance.

When radiations within the light spectrum fall upon the crystal the energy of radiation is absorbed by the lattice and a number of electrons are released to become current carriers, depending on the light intensity.

Conductivity increases and it becomes quite a good conductor when the light is bright. Hence the term light resistance refers to its minimum resistance under the influence of light.

Enhancement of action results when the basic crystal is doped with an "activating" agent, such as copper, silver or gallium. The doped crystal is powdered, then pressed into small tablets, which are sintered on to the surface of low resistance metal to form electrodes.

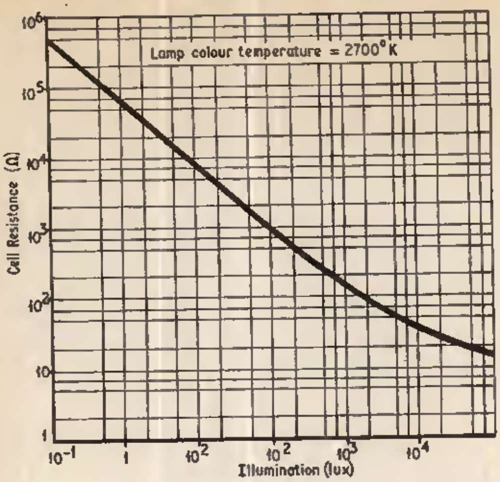


Fig. 5.3. Graph showing the typical resistance of a cadmium sulphide cell for different incidental light intensities

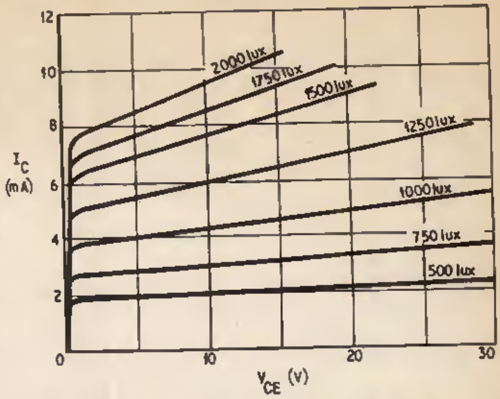


Fig. 5.4. Collector characteristic of a phototransistor over a range of light intensities

To this end the electrodes are arranged into the form of an interleaving comb-like pattern, as shown in the heading picture. Glass or plastic encapsulation is adopted with transparency for the passage of light.

The curve in Fig. 5.3 shows how a typical cadmium sulphide cell resistance falls with increase in illumination. This curve excludes the rise and fall time aspects which are of little concern to the beginner.

PHOTOTRANSISTOR

The phototransistor is equivalent to the combination of a photodiode and a transistor, with the diode being represented by the base emitter junction. The transistor action offers substantially improved sensitivity over the photodiode.

Fig. 5.4 gives the characteristics of a typical phototransistor. Notice how greatly the collector current (I_C) increases with increase in illumination (lux), and how the sensitivity is influenced over a range of collector/emitter voltage (V_{CE}), with most influence taking place at the higher lux values.

Phototransistors are encapsulated to the pattern of ordinary transistors, but an integral glass lens takes the place of the plastic or metal top.

L.D.R. APPLICATIONS

The light dependent resistor can be arranged to operate a relay in response to changes in light intensity, as shown in Fig. 5.5. In Fig. 5.5a the relay is energised only when light falls on the cell, for then its resistance is low and the relay current high.

In Fig. 5.5b the cell effectively shunts the relay when illuminated; the relay is energised only when the illumination is removed.

Light dependent resistors of sufficient power rating are available for direct relay operation, but greater sensitivity is achieved by the addition of transistors, one of which can act as a switch and replace the relay if necessary, as shown in Fig. 5.6. This is the circuit of a car parking light control.

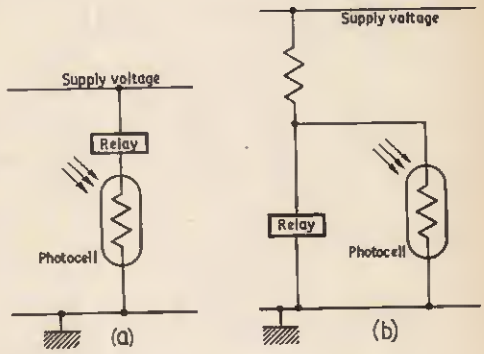


Fig. 5.5. Two simple examples of operating a relay from a cadmium sulphide cell

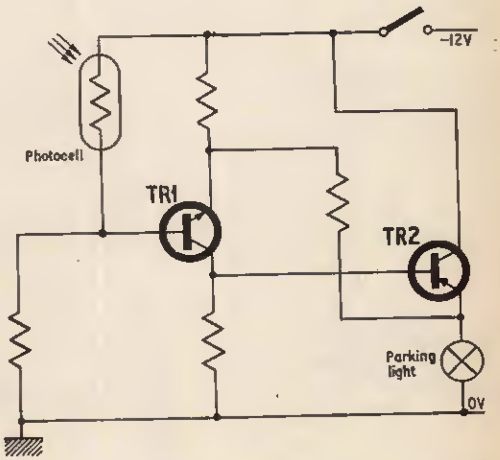


Fig. 5.6. The photocell can also be used to control the working point of a transistor, which in turn operates a switching transistor and lamp

When the cell is fully illuminated TR1 base current falls, but as the illumination falls, base current rises in TR1 due to the cell resistance rising. This makes TR1 collector, and hence TR2 base, more negative. TR2 then passes emitter collector current and the bulb comes on.

An interesting Mullard development incorporating a lamp and light cell, called a "Luxistor", is worth mentioning. This works on a similar principle and can take the place of a volume control in an audio amplifier. By adjusting the brightness of the bulb, a noise-free change in volume level can be obtained. The device is also used for the remote control of television camera equipment.

PHOTOTRANSISTOR APPLICATIONS

The phototransistor can be used to operate a relay or switching transistor; the set-up for direct relay operation is shown in Fig. 5.7. However, the base can be connected to a preset potentiometer (as shown in Fig. 5.8) to provide an adjustment of the light-to-dark current ratio. This makes the device more sensitive to changes at very low intensity light levels. The preset potentiometer is adjusted to the collector current cut-off point with the phototransistor "blacked out". Any slight increase in light would then produce collector current and activate auxiliary circuits.

Typical applications include burglar alarm systems, edge detectors, card reading machines, level indicators, batch counters, infra-red detectors and so forth. It can also be used as a linear light meter, and a suitable circuit for this is shown in Fig. 5.9.

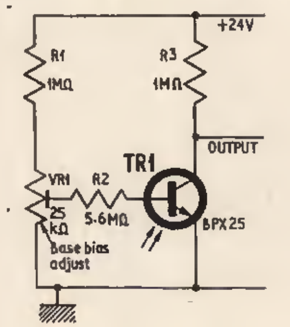


Fig. 5.7 (above). With the base wire left dis-connected the phototransistor can be made to operate a relay direct in the collector lead

Fig. 5.8 (above right). Base bias control is applied by R1 and VR1

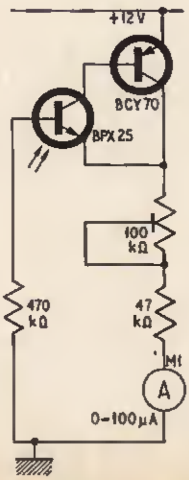
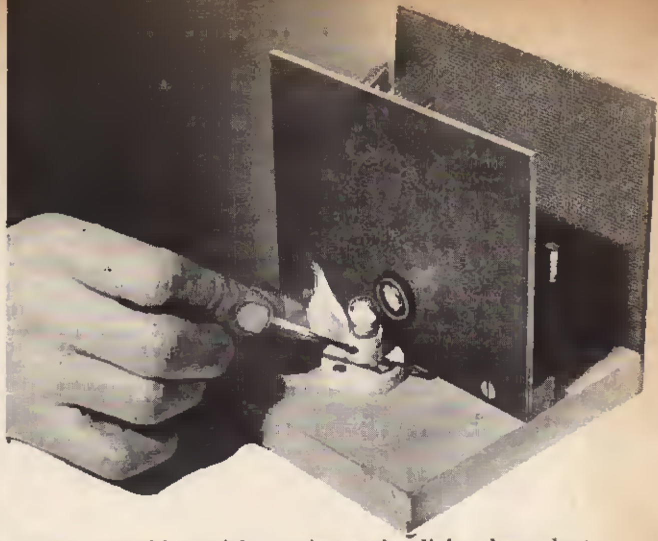


Fig. 5.9 (right). Simple linear light meter using a phototransistor



THIS month's article explores the light dependent resistor (l.d.r.) and its use in controlling a light-operated transistor switching circuit.

CIRCUIT DESCRIPTION

The circuit (shown in Fig. 1) uses a light dependent resistor (l.d.r.) X1 to control base current. The l.d.r. has a "dark" resistance of about one megohm; when light is applied to the cell this resistance will drop to 80 to 300 ohms.

From Ohm's Law it can be seen that when the photocell resistance drops, the base current, which is shared by TR1 and TR2, switches these transistors into saturation.

These transistors are in parallel so that the load current through the bulb is shared by the transistors. The maximum collector current for each transistor is 200mA. Since the bulb is rated at 0·3A or 300mA it is necessary to divide this bulb current to ensure that these transistors do not overheat. This sharing will be slightly unbalanced dependent on the individual gains of the transistors.

LIGHT FEEDBACK

The condition of saturation is also known as "bottoming" which means that the transistors are fully switched and almost all the supply volts appears across the bulb.

The action of latching or holding of the bulb on is created by the light being fed back from the bulb filament to the l.d.r. This regenerative condition maintains the switched action and can only be

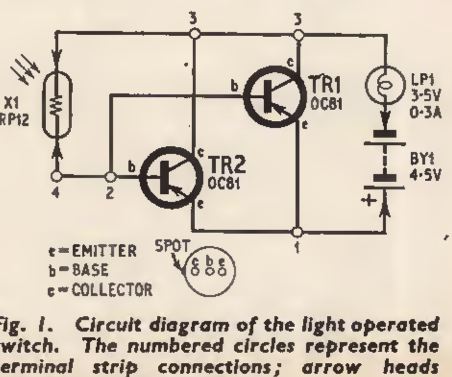


Fig. 1. Circuit diagram of the light operated switch. The numbered circles represent the terminal strip connections; arrow heads represent crocodile clips

Light Operated Switch

Mystify your friends with this "electronic candle" Light it with a match and extinguish it with the fingers!

terminated by "snuffing" or blocking the light to the l.d.r. The l.d.r. will then return to its "dark" resistance and the circuit will be switched off.

CONSTRUCTION

The construction is quite simple and follows the same general procedure as described in previous articles in this series.

Careful reading of the text and close study of the illustrations should be undertaken at each stage of construction, and all connections should be carefully rechecked before connecting the battery. 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.

Commence the construction by first marking and cutting the baseboard and two hardboard panels to size. A $\frac{3}{4}$in diameter hole should be drilled 1in up from the bottom edge and $2\frac{1}{2}$in from one side of the 5in × $4\frac{1}{2}$in hardboard panel. This hole is to receive a rubber grommet which houses the l.d.r.

Once the baseboard and panels have been cut the next step is to wire the four-way terminal strip before mounting on the baseboard.

WIRING

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.

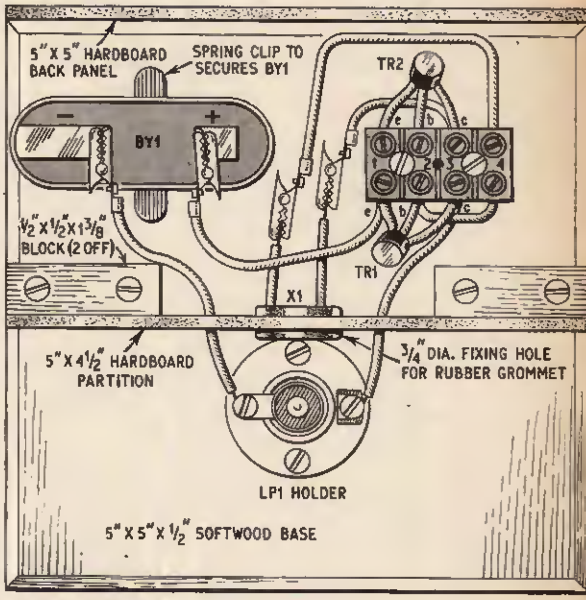


Fig. 2. Constructional and wiring details. Note the transistor connections—refer to key diagram given in Fig. 1

COMPONENTS . . .

Transistors
TR1 OC81 TR2 OC81

Photocell
X1 ORP12

Miscellaneous
BY1 4·5 volt flat pack battery
LP1 3·5 volt bulb
One m.e.s. bulb holder
One four-way plastics terminal strip
One spring clip for holding battery
Wooden baseboard 5in × 5in × ½in
Hardboard panels 5in × 5in and 5in × 4½in
Two wooden blocks ½in × ½in × 1⅜in
Four miniature crocodile clips
Woodscrews for mounting panels, terminal strip and spring clip (No. 4, 8 off) (No. 6, 6 off)
Plastic covered, single core copper wire

Total cost £1 approx.

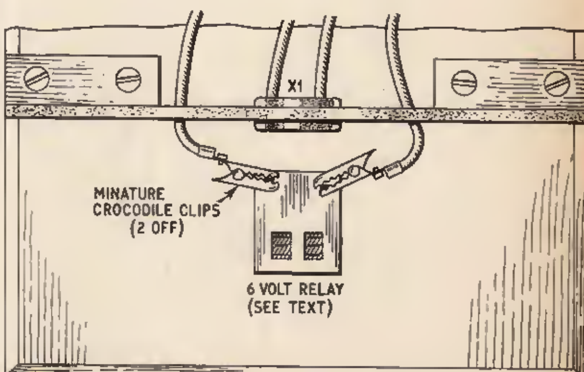
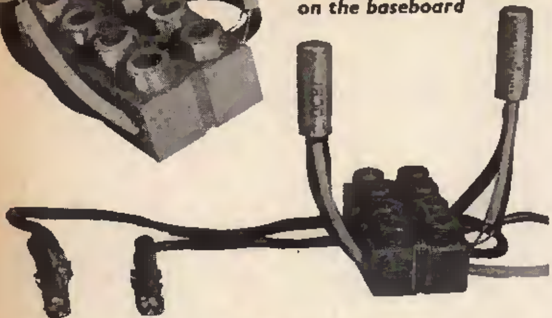
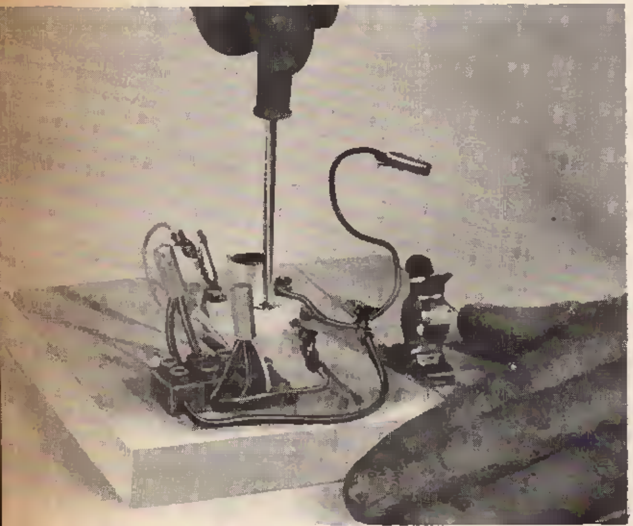


Fig. 3. Wiring details for adding a relay in place of the bulb LP1 to control an external circuit

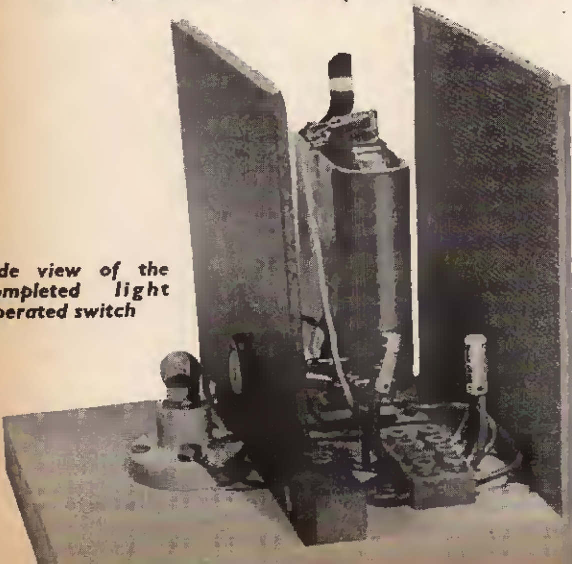
(Left). The transistors and link wire are positioned in the terminal strip



(Below). All components and interconnecting leads are wired to the terminal strip prior to mounting on the baseboard



Mounting the m.e.s. bulb holder on the baseboard



Side view of the completed light operated switch

When the two transistors and link wire, between terminal 2 and 4, have been positioned it only remains to insert the four interconnecting leads. When these leads have been positioned the terminal screws should be tightened and each wire should be given a slight pull to ensure it has been held fast.

Check the terminal strip wiring against the wiring diagram, then screw on to the baseboard with two ¾in No. 4 countersunk wood screws in the position shown in Fig. 2. The battery clip is screwed in position with a ½in No. 6 countersunk wood screw, and the bulb holder mounted on the baseboard with two ¾in No. 4 countersunk wood screws.

One of the leads from terminal 3 is now taken to one of the connecting screws on the bulb holder.

Another lead, with a miniature crocodile clip fixed to one end, should be taken from the other bulb holder connecting screw and clipped on the negative terminal on the battery.

The partition should now be fixed to the baseboard by two ½in × ½in × 1⅜in wooden blocks. The blocks are screwed to the partition by two ½in No. 6 countersunk wood screws and fixed to the baseboard by four ¾in No. 4 countersunk wood screws. Note that two nicks are made in the bottom edge so that the leads from the bulb holder can pass under the partition.

FINISHING

Insert the light cell carefully in the rubber grommet and mount in the ¾in diameter partition hole.

The other lead from terminal 3 should now be fixed to one of the l.d.r. leads by a miniature crocodile clip. The lead from terminal 4 should be clipped to the remaining l.d.r. lead by a miniature crocodile clip. The battery positive lead from terminal 1 is clipped to the positive terminal on the battery by a miniature crocodile clip. This completes the wiring and it only remains to insert the bulb in the holder and the circuit will be ready to function.

Finally, screw the back panel to the back edge of the baseboard by three ½in No. 6 countersunk wood screws. Top and side panels can be stuck in position on the two panels with an impact adhesive to enclose the components completely. The other side piece should be screwed to the side of the baseboard to allow access to the battery for replacement.

To trigger the circuit into action shine a light into the sensitive face of the l.d.r. The small bulb will light instantly but will not go out until the light path to the l.d.r. is blocked. When not in use the bulb should be removed to prevent unnecessary drain from the battery.

ANOTHER APPLICATION

The device just described demonstrates very effectively the action of the light dependent resistor—in a novel and amusing way. This same circuit can also be applied to a more useful purpose by substituting a 6 volt relay for the lamp LP1. The relay contacts may then be used to control some external circuit. See Fig. 3. It is necessary to use an additional 4·5V battery in series with BY1 to provide an adequate supply for the relay coil. A suitable relay is the Keyswitch Relay type MH2; 6V 185 ohm coil, with two sets of changeover contacts.

Next month: Another simple "d.i.y." device

ELECTRONIC THERMOMETER *(March 1968)*

Page 198—The first two paragraphs at the top of the left hand column should be inserted *after* the first paragraph under the side heading "CALIBRATION".

MARKET PLACE

Items mentioned in this feature are usually available from electronic equipment and component retailers advertising in this magazine. However, where a full address is given, enquiries and orders should then be made direct to the firm concerned.

COMPONENTS

The new TS/1 toggle switch, manufactured by **Rendar Instruments Ltd.**, Victoria Road, Burgess Hill, Sussex, is designed as a single-pole changeover switch combining high performance with small physical size and reliability.

It has been tested for an operational life of over 30,000 cycles at 24 volts 3 amps, has an initial contact resistance of 5 milliohms, and is also suitable for use at 250 volts a.c. mains voltage with a maximum current of 1.5A.

The neat appearance and compact dimensions of the switch make it suitable for control panels on audio equipment, car dashboards and other electrical equipment. The ⅜in diameter body requires only 1in depth behind the panel. The dolly is available in a variety of colours.

Vero Electronics Ltd., of Chandlers Ford, Hampshire, have added a new printed circuit board handle, No. Ch/C/10036, to their existing range of circuit board accessories.

This handle is manufactured in black Polycarbonate and is attached to the board by rivets or screws and nuts.

A new series of panel mounted sealed push-button microswitches have been introduced by the **Plessey Components Group's** Microswitch Unit at Titchfield, Hampshire.

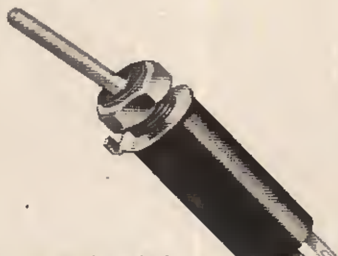
Known as the type 76.2510 Series, a one- or two-pole double-break or changeover switch is fitted as a detachable assembly. Compression of the actuator tabs enables the basic switch assembly to be removed, thereby facilitating easy installation and wiring.

A new photo-cell lamp assembly which is already being used in America by the guitar and audio amplifier manufacturers, is being marketed in this country by **Hird-Brown Ltd.**, Flash Street, Bolton, Lancashire.

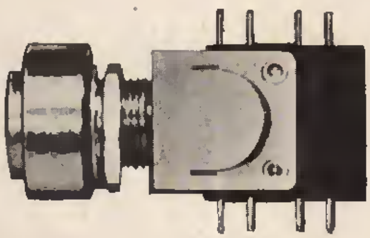
Typical applications of the device include audio switching, light-operated volume controls, tremolo for musical instrument amplifiers, high voltage decoupling and latching circuits, etc.

There are two versions of the photo-cell lamp assembly, a high resistance one and a low resistance one. Both versions can be supplied in single or double cell units and are designed for printed circuit or tag-board assembly.

Circuit board handle from Vero Electronics



TS/1 toggle switch manufactured by Rendar Instruments



Plessey push-button microswitch

Photo-cell lamp assembly marketed by Hird-Brown

LITERATURE

A 20-page guide, described as a Products Portfolio from **Newmarket Transistors Ltd.**, gives in tabular form details of Newmarket's semiconductor devices. The information contained in the portfolio covers the complete standard range of industrial germanium and silicon devices, packaged circuits and film-attachment devices.

A colour coding system enables particular ranges and individual components to be quickly and accurately located, for checking or specification purposes. Coloured headed pages identify the five major product ranges and the Company's special services which includes characteristic selection of devices, matched sets, multiple transistors and CV devices.

Bound in linen textured board with a substantial plastic spine, the Newmarket Transistors Products Portfolio may be obtained direct from the Sales Manager, Newmarket Transistors Ltd., Exning Road, Newmarket, Suffolk.

Taylor Electrical Instruments (Thorn Group) of Slough, has published the second edition of its Valve Data Manual for the Taylor Valve Tester Model 45D.

Data for approximately 400 valves have been added in this new addition; existing data has been amended where necessary to give the latest information available.

The Valve Data Manual provides data for many thousands of valves, including cathode ray tubes, which can be tested on the Model 45D. It forms a rapid and convenient guide to valve testing and overcomes the necessity for consulting individual manufacturer's data sheets.

Copies are available from Taylor Electrical Instruments, Montrose Avenue, Slough, Buckinghamshire, price £2 5s per copy.

Vitality Bulbs Ltd. are now issuing a catalogue (list No. 66) containing details of their sub-miniature, miniature, indicator and vehicle bulbs. Copies can be obtained free from Vitality Bulbs Ltd., Beeton's Way, Bury St. Edmunds, Suffolk.

A catalogue which is available free from the **M-O Valve Co. Ltd.**, from Green Works, London, W.6. may interest the more professional readers. Entitled "Microwave Tubes and Devices" it is a 20-page short form catalogue covering a wide range of electronic tubes and cathode ray devices for industrial and military use.

This illustrated catalogue presents a summary of the characteristics of microwave tubes and other devices. Products covered include S-band, C-band and X-band travelling wave tubes; S-band and X-band magnetrons, duplexing devices and solid state sources.

Checking a circuit board with a multimeter

THEY take their pursuits very seriously at "Camp Technology" but time is also found for light-hearted activities. Such is the keynote to the success of the Summer Camp held each year in the Blue Mountains of New South Wales, Australia.

The "Camp" is attended by 45 high school boys about 70 miles from Sydney and is run by the Inter School Christian Fellowship, a branch of the Scripture Union.

The boys are keen to learn the theoretical and practical aspects of electronics and photography; this is evident from the photographs shown here.

INSTRUCTION

All the staff on the electronics side are active professional engineers or teachers of electronics. All are young enough—in heart at any rate—to enjoy experimenting, and helping the youths to the joys of making something "go".

At the outset, all the boys are given thorough instruction in soldering, and then introduced to the understanding of symbols and the components represented by these symbols. A session on measurements, with an eye to the protection of the multimeters available, concludes the introductory part of the programme.

"HAM" STATION

On the electronics side some boys choose communications and, under the guidance of a licensed "ham", operate the s.s.b. two-way communication system, call sign VK2BCT.

Contacts are made with stations all over the world on this gear, set up specially for the camp with a telescopic 50ft antenna tower. As the location is 3,400 feet above sea level, operating conditions are pretty good. Operating frequencies are 3·5, 7, 14, and 144MHz.

PROFESSIONAL EQUIPMENT

Quite apart from the radio station, a great mass of electronic equipment is made available; some owned by instructors, and much loaned by business houses and organisations.

CAMP

Careful hands with a soldering iron on a piece of Veroboard

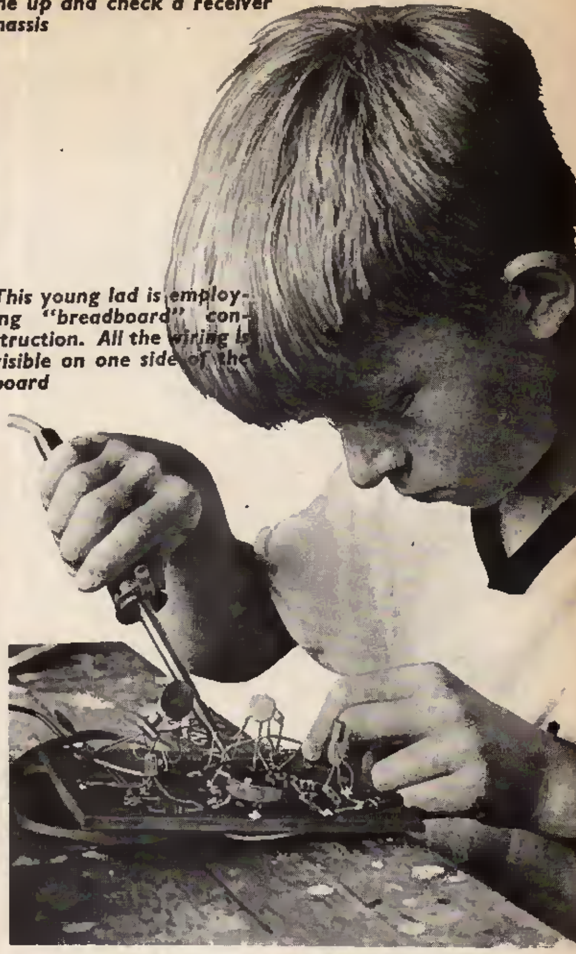
PROJECTS

Projects, for which all parts are provided, include thyristor motor speed controllers; logic circuits used to demonstrate binary notation; tone generators for a basic electronic organ; radio control receiver; tape recorder bias oscillators and amplifiers; an audio-induction remotely controlled model train; a recording studio with turntables, mixer, and recorders; simple receivers; oscillators; and even an electronic siren—used daily to wake the young students.

Beginner constructors work on simple "breadboards", made by drilling holes in a piece of hardboard and inserting a paper fastener in each. When the tops of the fasteners are tinned, components are easily soldered to them.

Others work on matrix board; some use Veroboard, planning their own layout and working out where to cut the copper strips.

High grade test gear is used by the advanced students to line up and check a receiver chassis



This young lad is employing "breadboard" construction. All the wiring is visible on one side of the board

THEORY

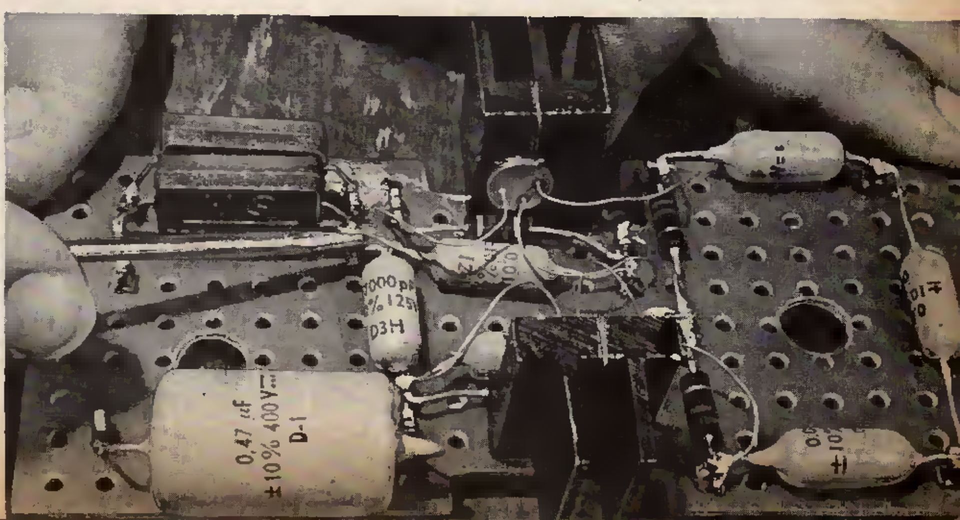
The programme is not usually limited to practical work only; talks are given on theory, with a range as wide as resistor colour code, transistor amplifiers, and tape recorder equalisation.

While in camp, some of the boys prepare and sit for examinations at elementary and junior level, set by the Wireless Institute of Australia in connection with its Youth Radio Scheme.

Yes! it's a good scheme to give the youngsters some useful and beneficial pastime during the holidays, with the added incentive to be constructive and achieve something worthwhile.

TECHNOLOGY

By A. J. Lowe



Matrix board is used by experienced boys. Each board can be attached to an adjacent one by using the shaped blocks on each side. This can also be used, as was primarily intended, as heat sink blocks for transistors

Due to the increased use of semiconductor devices for all purposes the author decided to produce a power unit, with a specification in the £20 to £30 Class, for as little cost as possible.

It was decided that a unit giving 1V to 12V at 1A with good regulation, and up to 3A unregulated would suit most purposes. Such a unit should be useful to Laboratories, Schools, Colleges, Experimenters, Radio Amateurs, Radio Servicing Workshops, etc.

CIRCUIT DESCRIPTION

The circuit diagram appears in Fig. 1. A mains transformer T1 having a 15–0–15 volt secondary winding feeds a conventional bi-phase rectifier circuit. Both of the silicon diodes D1, D2, are protected by a fuse, FS1 and FS2 respectively.

Some 23 or 24 volts (unit off load) are produced across the reservoir capacitor C1 and when S2 is in the "Unregulated" position, the appropriate terminals, TL2, TL4, are connected to C1 via the meter shunt R5 (in the negative lead to TL2).

The Volts/Amps switch S3 is shown in the "Volts" position and the meter M1 with multiplier R8 is connected across the supply lines and thus registers the output voltage.

In the "Regulated" position of S2, a three-stage d.c. amplifier is brought into circuit and provides up to 12V 1A at the terminals TL1, TL3. The final stage of the amplifier TR3 is an OC29 in series with a 5 ohm power resistor R4 capable of dissipating some 50 watts when necessary. The output voltage is adjusted to the required value by means of VR1 connected with R2 across the Zener diode D3. This diode should be suitable for 6V operation or thereabouts.

The potentiometer VR1 sets the emitter voltage of the *npn* transistor TR1, while the base has a voltage decided by the potential divider across the output terminals, VR2, R6, R7. The portion of the output which appears across R6 plus VR2 will decide the extent to which all the three stages of amplification will conduct. TR3 draws current via the power resistor R4 and adjusts the output voltage to that set by the voltage control VR1. The control VR2 can be used to calibrate the output to 12V when the unit is built, but further use of this control is mentioned below. When the output voltage is adjusted to less than 12V, a current in excess of 1A is available. Example: At 8V approximately 1·5A, and at 5V approximately 2·0A.

The collector circuits of TR2 and TR3 are returned to the negative side of C1 to eliminate collector current flow from the shunt R5. The negative busbar of the printed circuit (shown heavy in Fig. 1) draws a small amount of current through the shunt R5, but this is only about 0·1A and causes little difficulty in the use of the meter in the amps position.

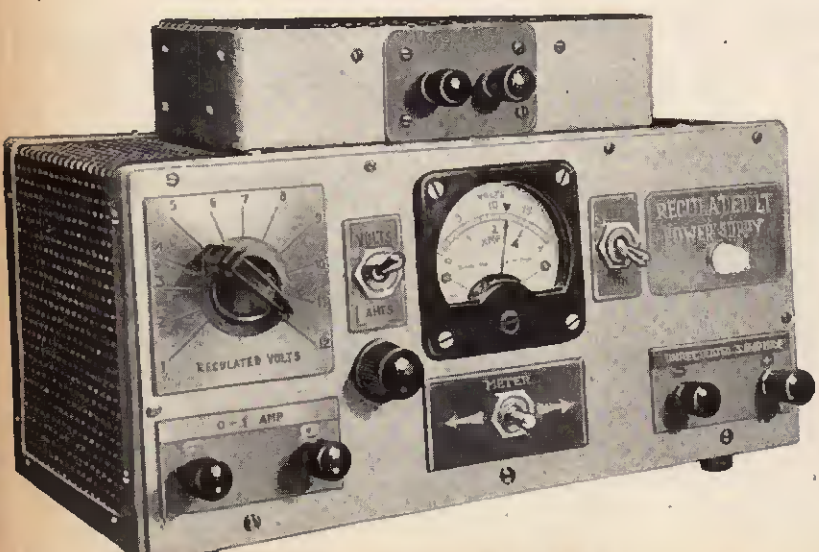
By decreasing the value set by VR2 the output voltage can be increased to 20V if necessary; however, the available current is only 0·18A at this voltage but the higher voltages could be a real asset at times. Fig. 2a shows typical voltages and currents available at more than the nominal 12V. The output voltage dial will of course divide the new voltage into 12 parts. Example: If the output dial of VR1 is set to an indicated "12" and VR2 is used to give a monitored voltage of 18V, then VR1 dial can be interpreted as one division equalling 1·5V.

UNREGULATED OUTPUT

Returning to the unregulated position, Fig. 2b shows the terminal voltage fall against varying load current. A hint can be taken from this curve; it is good practice to monitor the voltage first and *do not* switch to "Amps" if the voltage is shown to be *below 14V*. In the latter event the current will be somewhat more than 4A and the meter switch S3 should therefore be kept in the "Volts" position.

DISSIPATION IN THE OC29

The OC29 power transistor (TR3) should be mounted *directly* (no micas) onto some three inches of 5in wide heatsink and no trouble should be experienced unless there are high ambient working conditions. Fig. 3 shows the dissipation of the OC29 for varying output voltage. It can be seen that regular use of this circuit for outputs of 9V or more and at low current loading would suggest the use of a dummy load on these occasions to make the combined load current about 1A.



Regulated POWER SUPPLY

By A.D.BRAMALL Grad. I.E.R.E., A.M.Inst.E., G3TJT.

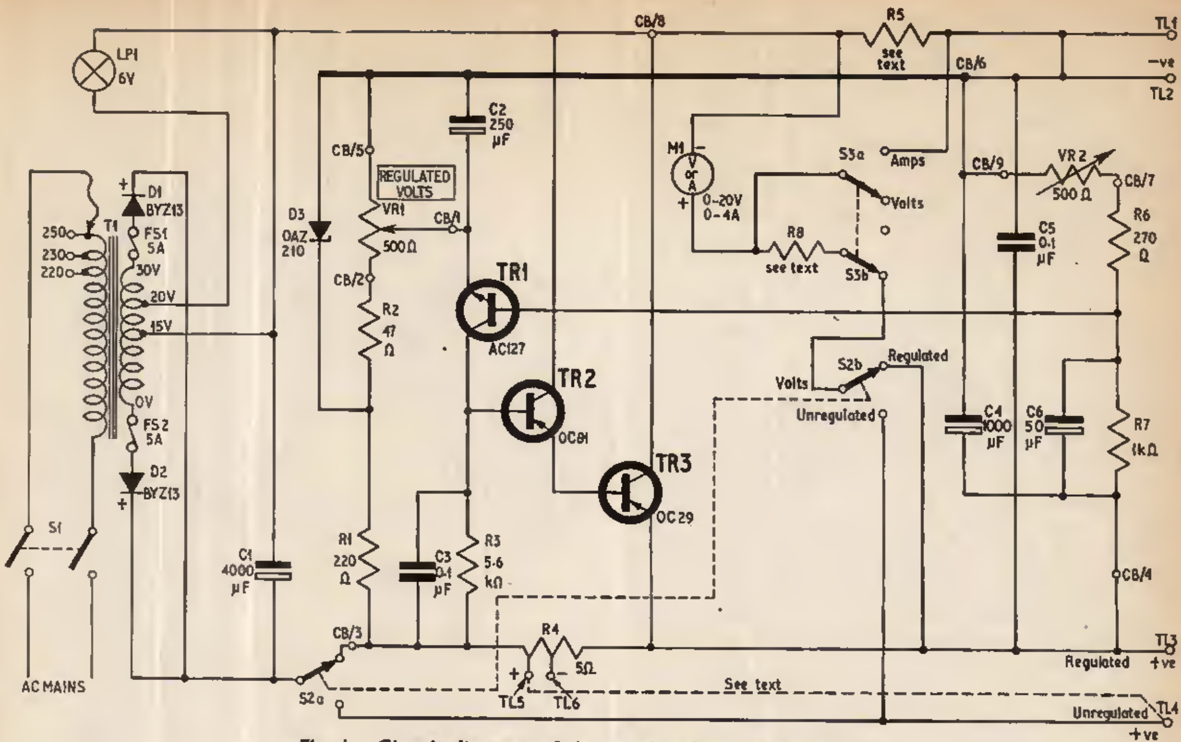


Fig. 1. Circuit diagram of the regulated power supply unit

INCREASED OUTPUT CURRENT

The dissipation in R4 increases as the output voltage is reduced by VR1. When the output voltage is down at 1V or minimum (about 0·74V) the current in R4 will be almost 3A and the power dissipation approximately 45 watts. The dissipation is a little more than 50 watts when the smaller part of R4 is short circuited.

Increased current at all voltages can be obtained by reducing the value of the power resistor R4. To this end a tapping point is fixed in order to reduce the 5 ohm resistor to 3·4 ohms when required. Terminals TL5, TL6 are used to fix a shorting link on the smaller part of R4. CAUTION. This facility should only be included and/or used with care and understanding. Fitting the shorting link without the drawing off of reasonable load current may rapidly burn out the power transistor TR3.

SIMULTANEOUS OUTPUTS

Switch S2a arranges that only the "Regulated" or the "Unregulated" output is available at any one time. It may be desirable to have both outputs in use at the same time and this can be arranged in a simple manner. By linking externally on the unit, connect the positive terminal (TL5) of R4 to the *unregulated* positive output terminal TL4. *On no account must the unregulated positive and regulated positive terminals become connected otherwise the OC29 will be fused instantaneously.*

SHORT CIRCUITS OF THE LOAD

Short circuits in the "Unregulated" position will blow the 5A fuses. The diodes used are a heavy current type and surge limiting resistors have not been fitted. Early tests were made to check on the short circuit current and the particular type of transformer (secondary rated at 2A) was run at 19A on short circuit to varify that diode trouble will never occur.

Short circuits in the "Regulated" position produce a short-circuit current of only 3A via R4 and no damage can result to the unit. More expensive units available on the market sometimes have circuit protection, but costs are high and 3A was not seen as a damaging current in the circumstances.

(a)

Volts	14	16	18	19	20
Amps	0·85	0·6	0·4	0·3	0·18

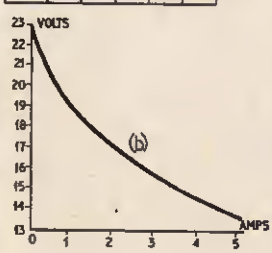


Fig. 2(a). Typical maximum load currents available at various voltages between 14–20V. (b) This curve indicates how the terminal voltage falls as the load current increases

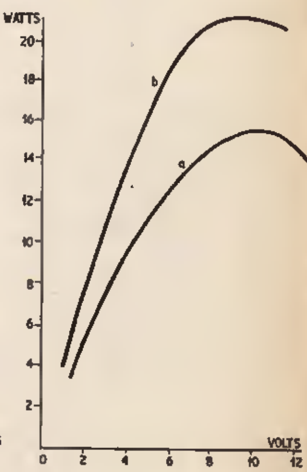


Fig. 3. Collector power dissipation at "off load" for different terminal voltages (TR3, OC29)

REGULATION OF REGULATED OUTPUT AND RIPPLE

The regulation of the output depends upon the gain of the transistors in the amplifier but the constructor should aim for a volts drop of only 25mV for a full load current of 1A (0·025 ohm output). The ripple on the output should be down to about 3mV peak-to-peak.

GENERAL LAYOUT AND CHASSIS ASSEMBLY

The general arrangement of the components can be seen in the plan view photograph, and the various diagrams explain the detail.

Fig. 4 shows constructional details for the chassis assembly, assuming the builder obtains certain components as recommended. The baseboard is ½in plywood to facilitate the general construction.

A metal cover of perforated material completes the enclosure of the unit, see Fig. 5.

WIRING DETAILS

Wiring details are given in Fig. 7. The output terminals are all isolated from the case which is connected back to the mains earth terminal (three-core cable). The heatsink for TR3 is mounted in a large slot in the rear panel and is secured in position by means of 4B.A. nylon bolts. This is shown in Fig. 4.

PRINTED CIRCUIT

The three-stage d.c. amplifier is built on a printed circuit board, see Fig. 6b for full size pattern.

The layout of components on the printed circuit board is shown in Fig. 6a. External connections are made at points 1 to 9.

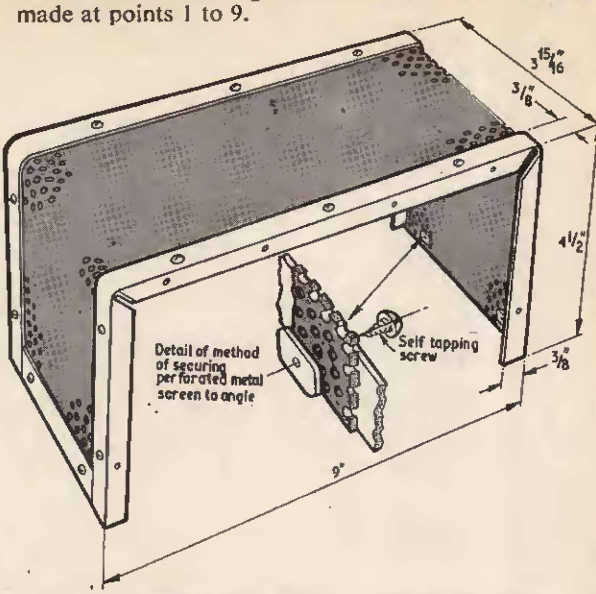


Fig. 5. Metal case to enclose main chassis assembly

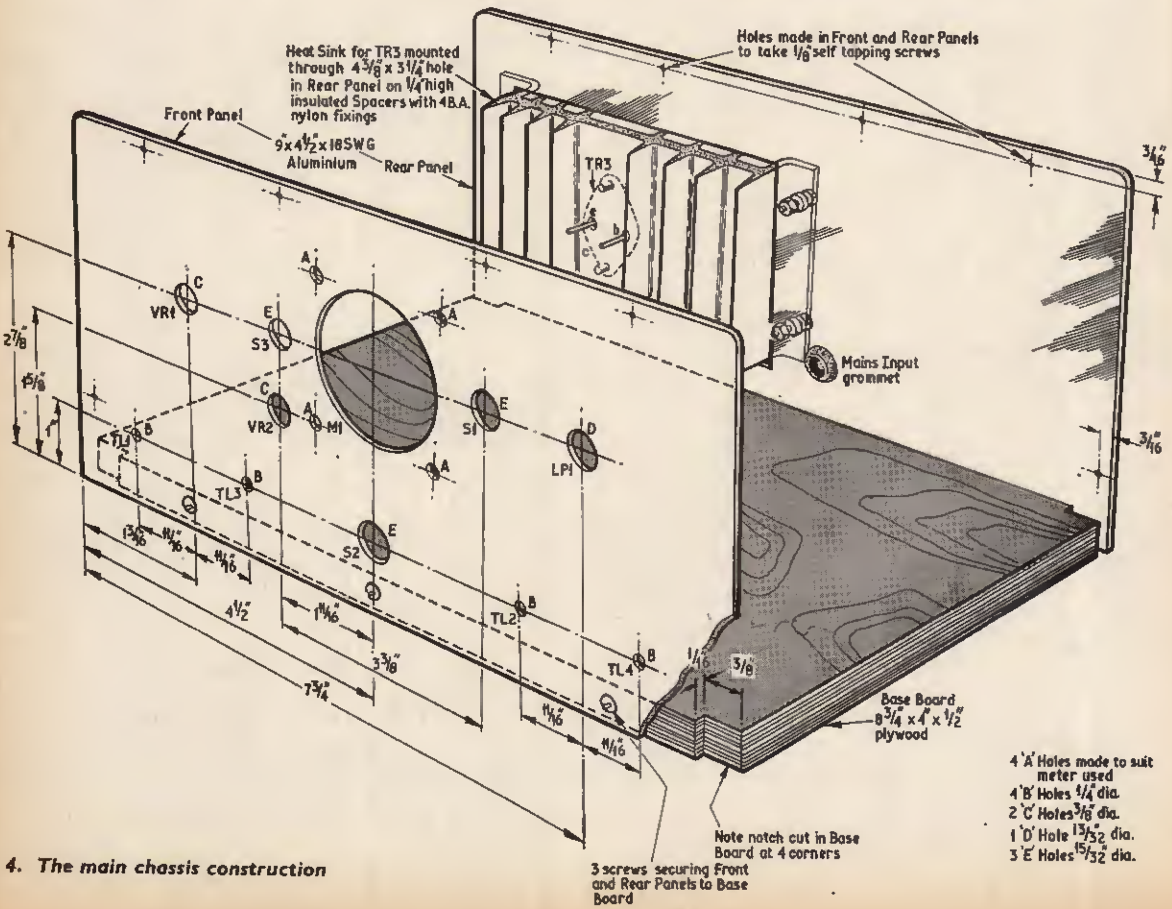
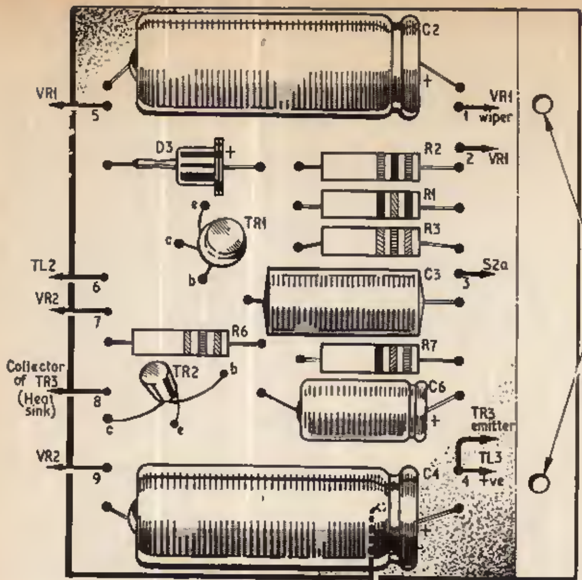
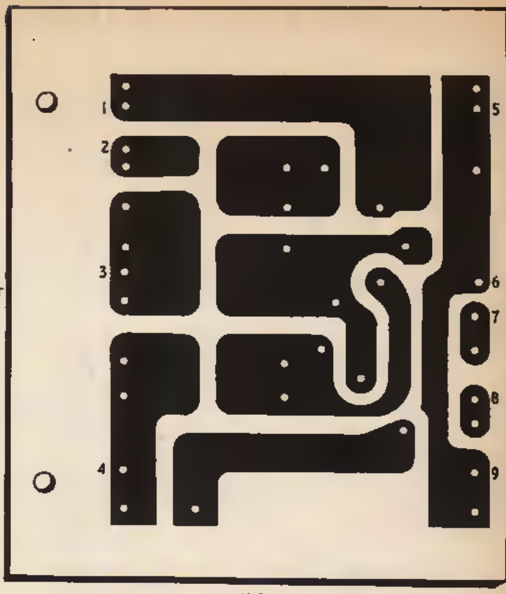


Fig. 4. The main chassis construction



(a)



(b)

Fig. 6. Printed circuit board. (a) arrangement of components on plain, insulated side of board. (b) full size pattern on copper clad side of board

COMPONENTS . . .

Resistors
- R1 220Ω 1W
- R2 47Ω 1W
- R3 5·6kΩ 1W
- R4 5Ω, tapped at 3·4Ω (see text)
- R5 meter shunt (see text)
- R6 270Ω 1W
- R7 1kΩ 1W
- R8 4kΩ meter multiplier

Potentiometers
- VR1 500Ω 3W wire wound (Colvern CLR 4239/264)
- VR2 500Ω 1W wire wound

Capacitors
- C1 4,000μF elect. 25V
- C2 250μF elect. 15V
- C3 0·1μF paper
- C4 1,000μF elect. 25V
- C5 0·1μF paper
- C6 50μF elect. 15V

Transistors
- TR1 AC127
- TR2 OC81
- TR3 OC29

Diodes
- D1, D2 BYZ13 5A 100V peak inverse (Mullard) (2 off)
- D3 OAZ210 Zener 6V (Mullard)

Miscellaneous
- LP1 Indicator lamp 6V, with holder and coloured lens
- M1 Moving coil meter. 5mA f.s.d. modified to read 0–20V, and 0–4A (see text)
- S1–S3 D.P.D.T. toggle switches (3 off)
- T1 Mains transformer. Secondary tapped at 0, 15, 20 and 30V, 2A. (Douglas MT3AT)
- TL1–6 Terminal, chassis mounting, insulated (3 red, 3 black)

Material for chassis and case. Heatsink

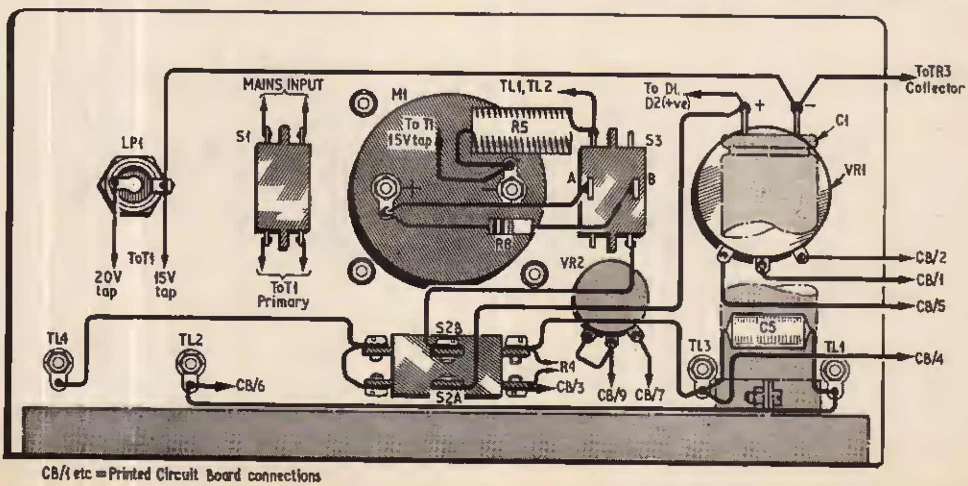


Fig. 7. Rear view of front panel with wiring details

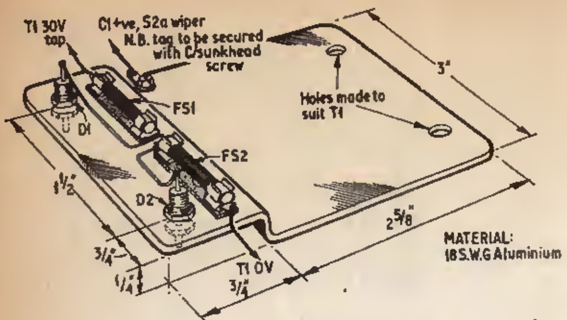
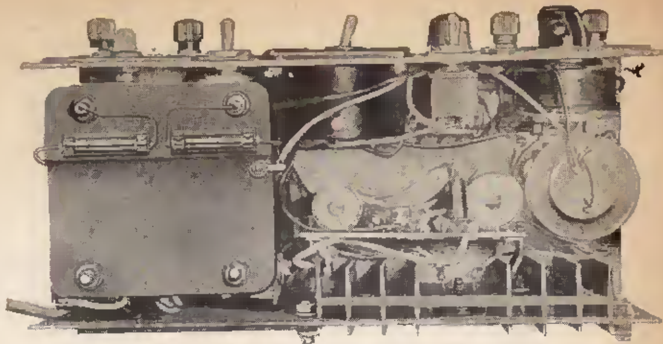


Fig. 8. Details of the heatsink for D1, D2 which is mounted on top of transformer T1



General layout and disposition of components

The diodes D1, D2 are mounted on a heatsink which is bolted to the top of the mains transformer by means of nylon nuts and bolts. The two fuses are also accommodated on this heatsink, but are insulated electrically by their plastics base, see Fig. 8.

The printed circuit can be seen edgewise; it is mounted with an angle bracket onto the wood base board. The large reservoir capacitor C1 is seen on extreme right-hand side.

The separate housing for the power resistor R4 is described in Fig. 9b. Alternatively, six 21 ohm resistors could be distributed throughout the main unit as described under the heading "Power Resistor" to eliminate the need for this additional box.

METER SHUNT (R5)

Heavy gauge resistance wire can be used to make a suitable shunt for the 4A range of the meter. The wire should carry 3A without undue heating. The shunt can be prepared before building it into the circuit in the following manner.

Pass 4A d.c. through 12in of chosen material with the positive end of the méter moving coil connected to the wire intended for joining to S3a. The negative end of the moving coil is now connected to the shunt within some ½in of the other point. Slide the negative wire along the shunt wire until a full scale deflection is obtained on M1. Solder the negative lead at the precise point found. Leave an additional ½in of shunt material in order to solder the heavy, low resistance lead which will connect the shunt to the negative terminal of C1.

POWER RESISTOR (R4)

Fig. 9a shows the construction of the power resistor R4. A ceramic former is wound with 10ft of 23 s.w.g. oxy-ferry wire.

Alternatively, four 21 ohm 10W resistors can be arranged in parallel to produce the required 5 ohms, and two further identical resistors added to give the lower value.

The power resistor is fitted inside a separate housing, made of metal with a perforated top cover, see Fig. 9b. This housing is secured to the top cover of the main unit. The bottom of the housing is open and leads from the main unit are brought up through the perforated metal cover and connected to R4.

continued on page 301

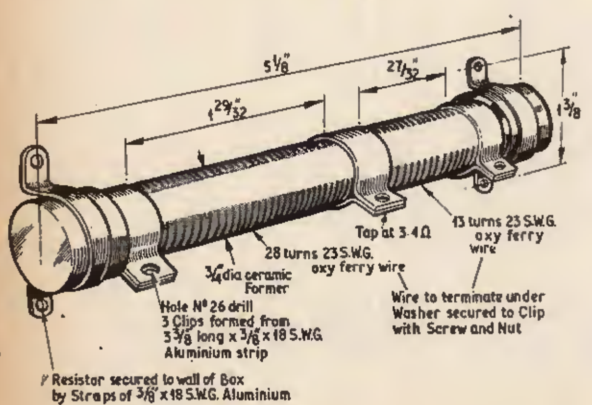


Fig. 9a. The construction of the power resistor R4

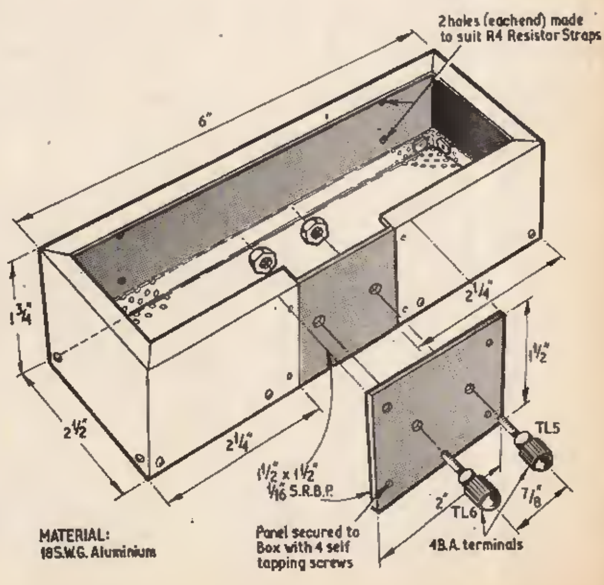


Fig. 9b. Metal housing for the power resistor

nucleonics for the EXPERIMENTER

By M. L. Michaelis M.A.

6—STRACE GAMMA RAY SPECTROMETER UNIT (Continued)

Last month's article terminated with details of the calibration procedure for the bottom and top limit controls VR2 and VR3 of Fig. 5.3.

ENERGY RESOLUTION

The setting accuracy of an ordinary carbon potentiometer calibrated in the manner described is about ± 1 per cent, so that the complete range from 0·1 to 3·6MeV can be resolved into some 100 sequential chanels. It is thus convenient to select any spectrum interval of width 0·5MeV, and to record this in 12 steps of about 0·05MeV each, although this need be no hard and fast rule.

This degree of resolution, which has proved very stable and reproducible with the prototype, is well matched to the other limiting factors, such as the inherent resolution of the specified detector and circuit gain tolerances, so that there is no point in using improved potentiometer types.

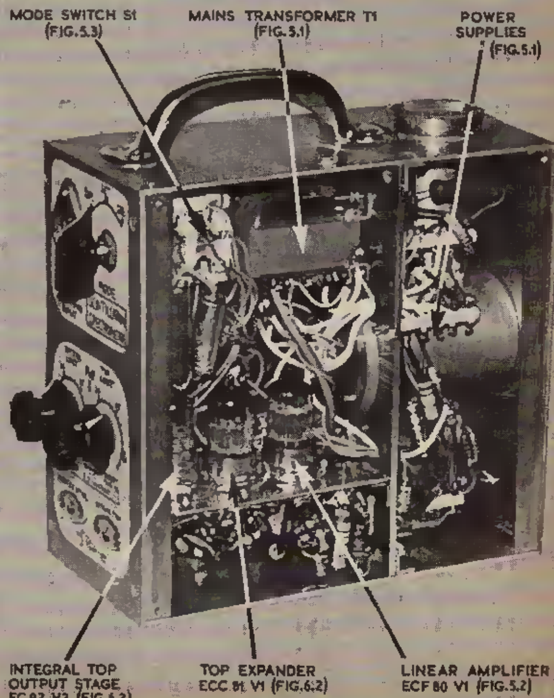
Professional equipments with resolutions of many hundreds of channels employ so-called helical potentiometers. These are spiral-track devices wound with close-tolerance resistance wire. The entire track is covered by several revolutions of the spindle, and suitable gearing and a cyclometer-type counter mechanism show the actual setting. Such potentiometers are expensive, and unnecessary for the amateur design here described.

OVERALL COUNTING RATE

The overall counting rate, apart from the peak counting rates at the respective energy levels, drops logarithmically with increasing energy. Thus typical samples as recommended for this work give counting rates of thousands per minute for peaks falling around 0·5MeV, hundreds per minute for peaks falling around 1·5MeV, and only a few dozen per minute for peaks at still higher energies. This is because the proportion of incident quanta of nuclear radiation which are absorbed totally in the crystal becomes smaller at higher energies, since some of the energetic radiation can escape again.

With a linear scale radiation meter, the entire range of the main potentiometers can thus not be recorded properly anyway, and although logarithmic scaling is often found in professional equipment, it adds unnecessary complexity to an amateur design.

Whilst the entire available energy range from 0·1MeV to 3·6MeV will be required at different times for various experiments with various substances, any *particular* experiment is usually interested only in radiation falling within a quite narrow energy band. For this reason, it is also quite unnecessary in this type of equipment to use an automatic scanner with more than the 12 steps as shown in Fig. 5.3. For a particular experiment, VR2 and VR3 of Fig. 5.3 will be set to select the band of about 0·5MeV width around the energy level of interest, and the radiation meter will be set to a counting range appropriate for the mean pulse repetition frequencies encountered in this energy band.



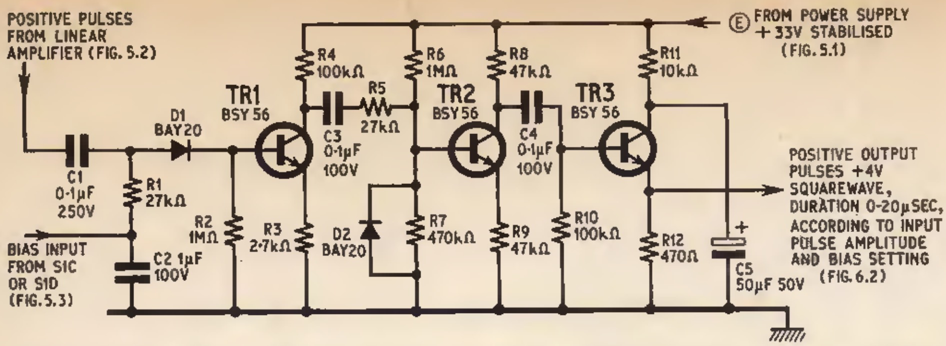
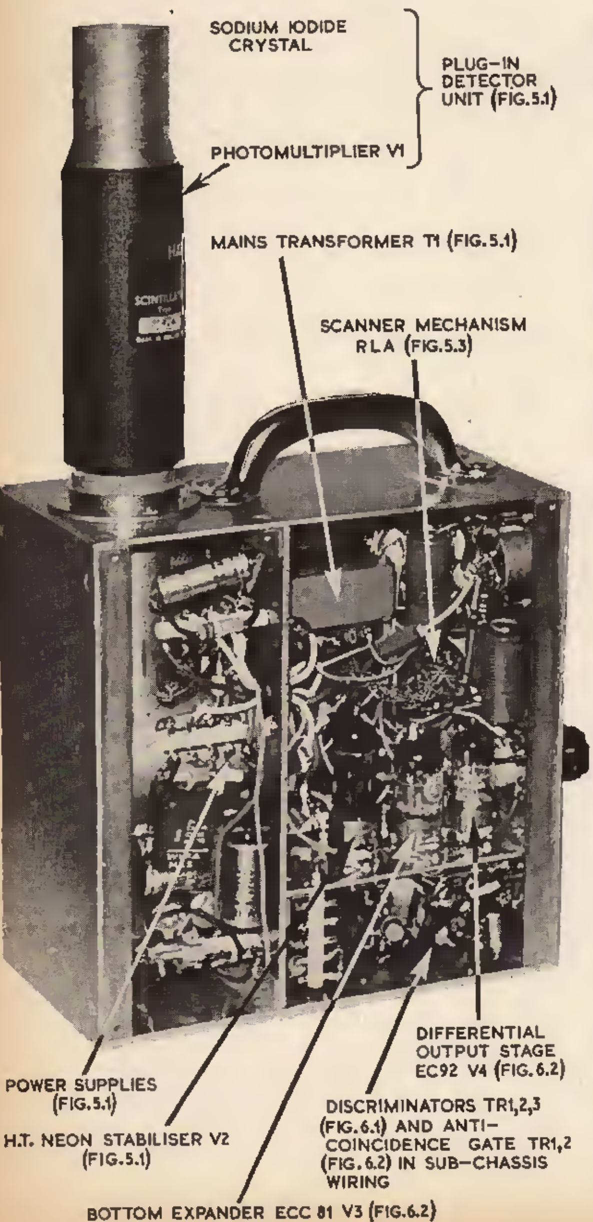


Fig. 6.1 STRACE Gamma Ray Spectrometer: Circuit diagram of the amplitude discriminator (there are two such units in STRACE—"bottom" and "top" discriminators repectively—and they use this identical circuit)



RADIOACTIVE SAMPLES

Suitable radioactive samples may be purchased from the Radiochemical Centre, Amersham, Bucks. The Caesium-137 solution specified for the energy calibration should have a volume of about 4ml, in a sealed glass ampule fitting the sample well in the sodium iodide crystal, and it should contain a total activity of about 350nCi. Similarly for the specified Cobalt-60 solution. These amounts of these particular substances are less than those permitted to be sold without special permit, and are quite safe with reasonable care. They should never be carried on the person, e.g. in pockets.

AMPLITUDE DISCRIMINATOR

The circuit of the STRACE amplitude discriminator is given in Fig. 6.1. D1 is the actual discriminator. The inverse bias is applied via R1 from the scanner to the anode of the diode, whilst the pulse mixture from the linear amplifier is fed in via C1 and establishes a positive pulse voltage spectrum across R1 as load resistor. Only those pulses greater than the applied bias can cause D1 to conduct on their tips, causing TR1 to conduct in turn. Due to the very large collector load R4 of TR1, this transistor saturates already with a very slight excess of pulse voltage above the bias threshold of D1.

R5 and D2 prevent blocking, TR2 is a polarity inverter to restore positive polarity of the pulses, and finally TR3 is an emitter follower to produce low output impedance for driving the next functional stages.

The overall function of the circuit is thus that of a diode gate feeding a high-gain amplifier which normally rests cut off. A very slight excess above the gate threshold already saturates the amplifier and produces full output of 4V. Thus we have now obtained *constant* amplitude output pulses which carry a "yes/no" information. The presence of an output pulse implies "yes, the input pulse was greater than the chosen threshold", whilst the absence of an output pulse implies "no, the input pulse was not greater than the chosen threshold".

However, the output pulses are still not of uniform duration, since their duration depends upon the time spent by the input pulse above the bias threshold, which is obviously a function of the pulse amplitude in relation to the bias level. The energy information, which was originally contained in the amplitude of the input pulses to Fig. 6.1, has been transferred to the width of the output pulses. Some professional circuits make use of this feature, but in our case it is unwanted; we desire discriminator output pulses which are strictly identical in amplitude and duration, carrying solely the yes/no threshold information.

THE EXPANDERS

Turning now to Fig. 6.2, we see that the unwanted pulse width information is "killed" by feeding the output of each discriminator to a respective expander. Each expander is fired by an input pulse to produce a standard

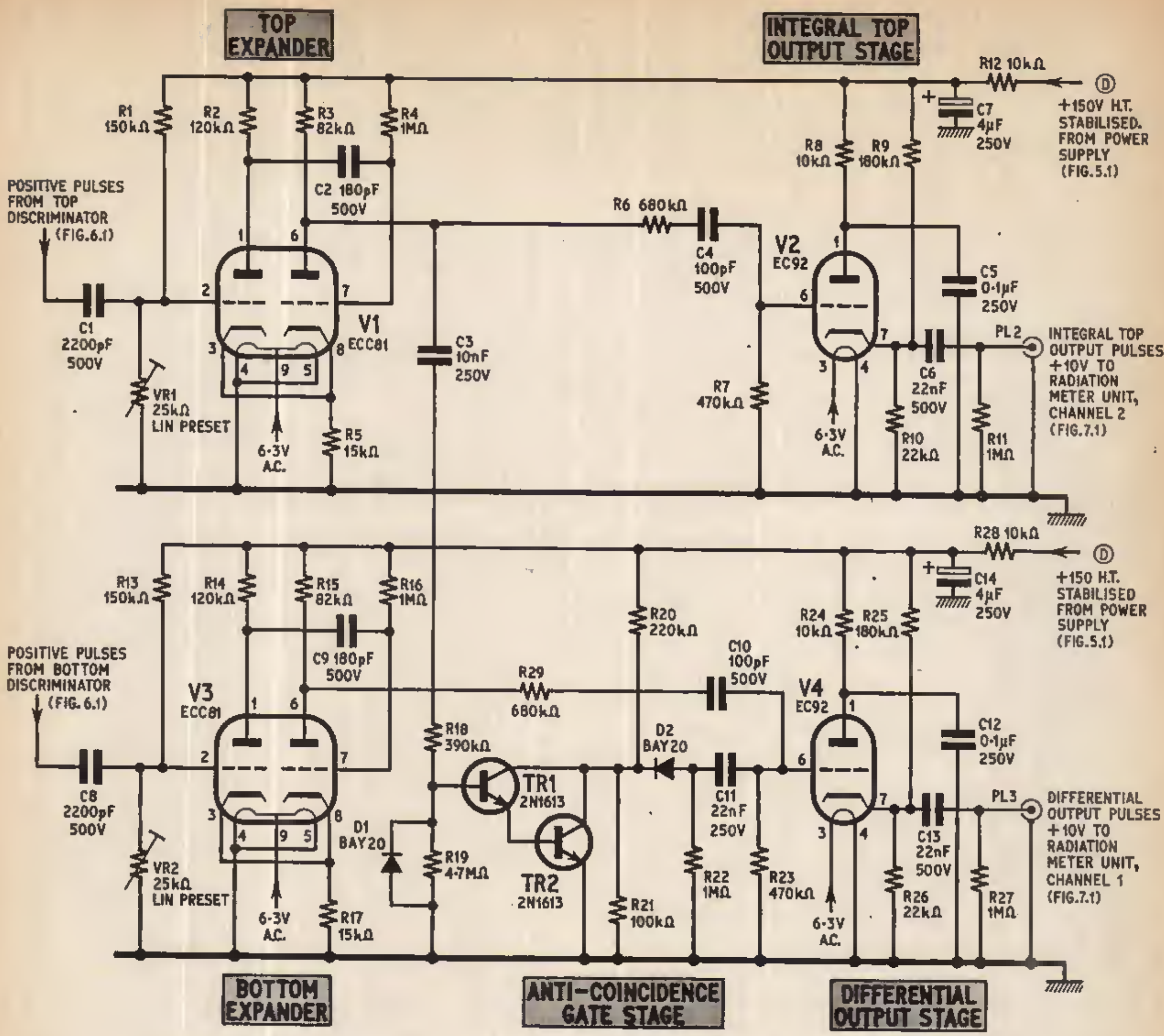


Fig. 6.2. STRACE Gamma Ray Spectrometer: Circuit diagram of the pulse channel amplifiers

response pulse of fixed amplitude and duration determined solely by the characteristics of the expander circuit. It is called an expander because the standard response pulse is longer than the longest input trigger pulse.

The section pins 1, 2, 3 of each double triode rests cut off, whilst the other triode section rests conducting. A positive input pulse greater than a certain threshold amplitude determined by the setting of VR1/VR2 in Fig. 6.2, changes over the roles of the two triode sections by cumulative multivibrator action, for a brief time determined by C2, R4 and C9, R16. After the elapse of this relaxation time, the circuit drops back into its former resting state of its own accord. Positive square pulses of about 70μs duration thus appear at the respective anode pins 6. These are fed to respective conventional cathode follower output stages, V2 and V4, via the voltage dividers R6/R7 and R29/R23.

ANTI-COINCIDENCE GATE

The anti-coincidence gate simply shorts-out the bottom end R23 of the voltage divider feeding the bottom cathode follower, if the top discriminator has also produced a pulse simultaneously.

The diode D2 is normally cut off by the standing bias on the bleeder R20, R21. A pulse from the top expander is fed via C3 to make TR1, TR2 conduct and thus effectively remove the bias from D2, so that D2 then shorts-out the pulse voltage across R23 from the bottom expander, giving no output from V4. Any residual pulse voltage at V4 grid is suppressed by the positive bias applied to the cathode via R25.

V4 thus gives an output pulse only when the bottom, but not the top discriminator has responded. It is thus called the differential output stage. The output from V2 contains all pulses greater than the upper limit of the differential interval of V4, whilst original pulses smaller than the lower limit of the differential interval of V4 are entirely suppressed.

SOME GENERAL FEATURES

The diode D2 is necessary in Fig. 6.2 in addition to the two transistors, because the collector capacitance of transistors is too high in the resting state, distorting the wanted pulses from the bottom expander. It is common practice to use low-capacitance silicon diodes for the actual gating and discriminator functions in nucleonic equipment, with separate drive stages.

The expanders V1 and V3 in Fig. 6.2 are theoretically complete amplitude discriminators in themselves, and one may ask why they are not used as such and fed directly from the linear amplifier and scanner. Some circuits do actually work on this principle, but then at higher pulse amplitude ranges of about 100V peak from the linear amplifier. Numerous other derivatives of multivibrators and paraphase amplifiers can also be used as high-level amplitude discriminators. In our equipment concept, this is inconvenient, because the lower pulse peak values of 15V are too small compared with drifts of the trigger threshold level of the expanders with valve ageing and other factors. A multivibrator type amplitude discriminator is also prone to erratic performance on trigger pulses much greater than the trigger threshold level, as would be the case when working near the bottom end of the spectrum.

This brings us to the question of signal level planning for the complete kick-sorter amplifier, which is intimately connected with the adoption of hybridisation (mixed valves and transistors).

HYBRID DESIGN

Whilst modern professional equipment increasingly tends to be fully transistorised in all stages, hybridisation often permits a better compromise between stability and complexity, if no extreme demands are placed on accuracy. This is best illustrated by the underlying ideas in the present STRACE design.

The most vulnerable point is the discriminator voltage stability. Using biased semiconductors, this stability is determined solely by precision resistors in the scanner and a stabilised voltage supply, irrespective of the active devices as long as the pulse amplitude levels are large compared to silicon barrier layer threshold voltages (the latter being some hundreds of millivolts). This must hold for the smallest pulse voltages, so that the input pulse spectrum to the discriminator is required to be inconveniently large compared to the linear drive range of transistor amplifiers. But it is very easily provided by a valve amplifier. Hence a valve was used for the simple linear amplifier.

Similar considerations led to the adoption of valves for the expanders and output stages, but transistors for the anti-coincidence gate. Sufficiently fast response of the gate is difficult to obtain in a simple circuit, except by brute force of driving it with massive pulse amplitudes readily obtainable only from a valve circuit.

CONSTRUCTIONAL DETAILS

The entire kick-sorter circuitry of Figs. 5.1, 5.2, 5.3, 6.1 and 6.2 can be accommodated in an aluminium casing measuring 8in × 8in × 4in with a carrying handle and the socket for the plug-in scintillation detector on the upper side, as shown in the photographs. Layout is not critical, and constructors can use any convenient form, larger if necessary.

Almost any type of silicon *npn* transistor is suitable in all positions, provided the voltage rating is adequate. The pulse diodes may be any silicon type with at least 100 p.i.v. rating and at most 4pF self-capacitance.

The narrow face panel carries the threshold potentiometer controls VR2, VR3, and the mode switch S1 of Fig. 5.3; the power and command input plug PL1 of Fig. 5.1 and the two pulse output plugs PL2 and PL3 of Fig. 6.2. The latter are coaxial, for feeding the processed pulses through coaxial cables to the radiation meter unit.

IMPORTANT

ADDENDA AND CORRECTIONS TO DIAGRAMS IN PART 5

Fig. 5.1 Power supply and scintillation detector.

The Zener diode voltages of D9, D10, D11 and D12 are equal to the nominal output voltages of their respective circuits. The Zener diode voltage of D13 is 120V, and of D14 to D23 inclusive, 60V each.

The correct value of C16 is 47nF (0.047μF).

The correct value of C17 is 10nF (0.01μF).

Fig. 5.3. Sequential scanner circuit diagram

The correct voltage rating for C3 is 9V and not as shown.

Next month: Radioactivity measurement; a ratemeter design

SOUND EFFECTS: WIND AND RAIN

continued from page 269

The transformer used here is not critical and can be a 3 : 1 intervalve type with a centre-tapped secondary winding. Due to the connections of the transformer there may be some loss of bass frequencies, but this can be minimised by using one of high primary inductance.

The transistors can be types C424 or ME4103 or any similar *npn* types.

SETTING UP AND OPERATION

To achieve the effects intended it is necessary to have a white noise generator; the simple unit described in the January issue was designed specifically for this purpose. The output signal from the white noise generator is connected to the input of the electronically controlled "wind and rain" filter. The filter output is connected to an audio amplifier.

Switch on the amplifier and generator; a loud hiss should be heard at this stage. Now turn the bias controls VR1 to VR7 to minimum (wiper nearest chassis tag) and VR8 to VR14 to maximum resistance. No bias is connected to the switches (or sockets) as yet.

Set up each stage one by one, first connecting a bias voltage source (for example, 9V) to stage 7. Adjust VR7 so that, as the voltage on TR7 base approaches 0·5V, the transistor will begin to conduct and the output volume will drop to a low level. Disconnect the bias (or switch off S7), and the output will rise to its previous level at a rate determined by the discharge of C13 through VR7. VR14 is described later.

Connect the bias supply to stage 6 and adjust VR6. As the voltage on TR6 base approaches 0·5V the transistor will begin to conduct, bringing in the 0·047μF capacitor (C6) to function as part of the filter. When this occurs, the output will change in character to a low pitched "moaning" sound, due to the attenuation of high frequencies. If the bias is disconnected or switched off by S6 the audio output will revert to normal.

The other five stages are set up exactly as for stage 6 above, but remember that the pitch of the output will be different for each one. Having set up each stage as described, the scope of tonal effects can be realised. The bias switches can be operated individually or in any combination to provide a wide range of effects likened to various weather conditions.

So far no mention has been made of the other seven controls VR8 to VR14. These can be replaced by fixed resistors of like values, but it will be to great advantage to use these controls to alter the "attack" when each switch is closed. "Attack" is the term used to describe the speed at which the sound is initially affected by applying the bias.

To achieve controlled "decay" (the reverse action of attack) a large value capacitor can be connected across the bias control, the higher capacitance will give longer decay. Some experiment may be necessary here to get the effects required. Examples given in the circuit (C7–C13).

The "attack" and "decay" controls are only effectively achieved by using the electronic circuit.

The electronically controlled filter can be used for a variety of applications including stage sound, music background, and even psychedelics, where the sound can be associated with a system of lighting effects.

Next month: Percussion Effects

By
D. BOLLEN

PEAC ANALOGUE COMPUTER

THE constructional details for UNIT "A" were completed last month. UNIT "A" is, itself, a complete, self-contained computing equipment, and the method of operation, with practical examples, is described in this article.

PATCHING LEADS

The best plugs to use for patching the computer are those of "split-pin" construction, as they can quickly be attached to wires without the aid of a screwdriver. It is a help if plugs are obtained in various colours, and are mated to different coloured wires to allow easy identification.

For the majority of problems capable of solution by UNIT "A", certain patching leads may be left in position on the front panel. For example, coefficient potentiometers are almost always used with the "0" end of their resistance track connected to earth (link SK3 to SK4 for CP1, CP2, CP3, and CP4, Fig. 2.7).

Similarly, until such time as integrator mode switching is brought into use, the integrator sockets depicted in Fig. 2.9 are joined together by means of a special three-way patching lead consisting of two short lengths of wire joined by a plug, with a plug at each end. Looking at Fig. 2.9, OA1/SK4, SK9, and SK10 are linked, and repeat for OA2 and OA3. Three more semi-permanent patching leads are made up to link each operational amplifier to its companion summer network. Connect OA1/SK8 to S1/SK5, and do the same for OA2/SK8–S2/SK5, and OA3/SK8–S3/SK5.

The rearrangeable patching leads should be of assorted lengths and colours, the longest to patch from, say, CP4/SK2 to S3/I1/SK1, diagonally across the UNIT "A" front panel, and the shortest to link nearly adjacent sockets.

COMPUTING RESISTORS

If a comprehensive range of ± 1 per cent high stability computing resistors was purchased all at once, to meet every requirement, the cost would probably exceed £20. There are after all 101 preferred values in a ± 1 per cent range covering resistors from only 10 kilohm to 100 kilohm. Nevertheless, in the period when the computer operator is learning how to handle PEAC, and a high degree of accuracy is not essential, the majority of ordinary problem set-ups can be catered for by a small number of ± 1 per cent and ± 2 per cent plug-in resistors. A resistor selection list, with suggested values of R_f and R_{in} for standard op-amp closed-loop gains, is given in Table 4.1. Also, a component list included in this article sets out minimum quantities, with tolerances, of computing resistors.

Computing capacitors will be discussed later, in connection with integration.

SETTING UP THE VOLTAGE SOURCE

To set up all voltage source outputs, first remove the dials from VR6 to VR10 (Fig. 2.2), and turn the potentiometer spindles fully anticlockwise. If the potentiometers have flats on their spindles, make up blanking pieces consisting of small segments of hardwood or plastic, so that control knobs can be conveniently located at a selected position on each spindle. Connect the positive lead of a sensitive d.c. voltmeter (0–1V, 20 kilohm/V) to VS1/SK1, and the negative voltmeter lead to VS1/SK4 (Fig. 2.6), then set slide switch S1 for a positive voltage output. Switch on the computer power supply and S6.

Carefully rotate VR6 spindle clockwise until a very small voltage appears, just sufficient to slightly deflect the meter pointer away from zero. Now place a dial knob on VR6 spindle, without disturbing the potentiometer setting, and align so that the "0" division on the dial is vertical and opposite the pointer mark on the surface of the front panel. Tighten the dial knob grub screw.

Switch off S6 and replace the 0–1V meter with the 0–10V d.c. meter which has been chosen to serve as a voltage standard for the computer, while retaining the same meter lead polarity. Rotate VR6 dial until the "10" division is opposite its pointer, and switch on S6. Now adjust slider resistor VR1 from the back of the UNIT "A" box, for a precise reading of 10V on the "standard" meter. Repeat the above procedures for outputs VS2, VS3, VS4, and VS5, and remember to adjust only the particular slider (VR1–VR5) which is associated with the output being set up.

When all the voltage source dials are aligned, return to VS1 and make sure that its output is still +10V. Switch off S6, reverse the "standard" voltmeter leads, and set S1 for a negative output. Switch on S6 again and check the voltmeter reading; if it is not exactly 10V, go to the back of the UNIT "A" box and trim the power pack control VR2 (Fig. 3.4), this ensures that voltage source negative and positive outputs are equal.

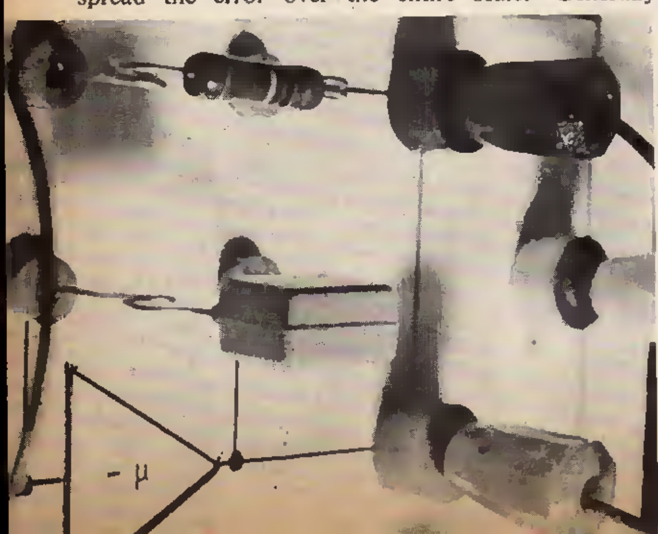
SETTING UP THE COEFFICIENT POTENTIOMETERS

Insert a patching lead to link CP1/SK3 to CP1/SK4 (Fig. 2.7), and do the same for CP2, CP3, and CP4. Take a long patching lead from VS1/SK1 to CP1/SK1. Remove the dial from VR11 (Fig. 2.5) and rotate spindle fully clockwise. With the negative lead connected to any earth socket, insert the "standard" meter positive lead into CP1/SK2 after first setting S1 for a positive output. Adjust VS1 dial for a meter reading of 10V. Rotate CP1 spindle carefully anticlockwise until the meter pointer just beings to drop below the 10V division. Replace CP1 dial knob on VR11 spindle, align the "10" division with the pointer, and tighten the grub screw. Repeat for CP2, CP3, CP4.

With a 10V input to CP1/SK1, and a 0–10V meter connected to CP1/SK2, it is a simple matter to check the agreement between dial divisions and voltage output from the coefficient potentiometer. If there are serious discrepancies between voltage output and dial reading this will indicate that the effective electrical rotation of the potentiometer differs from the 270 degree dial calibration. Errors can often be minimised by slight readjustment of the dial knob on its spindle, to spread the error over the entire scale. Generally speaking, the dial setting error should not be worse than 5 per cent at all settings between "1" and "10" dial divisions. The whole question of computing potentiometer accuracy will be raised later, in connection with the Master Potentiometer of UNIT "B".

TABLE 4.1
SUGGESTED VALUES OF COMPUTING RESISTOR FOR STANDARD CLOSED-LOOP GAINS

Op-amp gain $\frac{R_f}{R_{in}} = -G$	All resistors ±2% unless otherwise stated R_{in}	R_f
0·1	100kΩ	10kΩ
0·2	100kΩ	20kΩ
0·3	33kΩ	10kΩ
0·4	40kΩ ± 1%	10kΩ
0·5	20kΩ	10kΩ
0·6	33kΩ	20kΩ
0·7	13kΩ	9·1kΩ
0·8	20kΩ	16kΩ
0·9	20kΩ	18kΩ
1·0	10kΩ	10kΩ
	100kΩ	100kΩ
2·0	10kΩ	20kΩ
3·0	3·3kΩ	10kΩ
	33kΩ	100kΩ
4·0	4kΩ ± 1%	10kΩ
	40kΩ ± 1%	100kΩ
5·0	20kΩ	100kΩ
6·0	3·3kΩ	20kΩ
7·0	13kΩ	91kΩ
8·0	2kΩ	16kΩ
9·0	2kΩ	18kΩ
10·0	10kΩ	100kΩ
20·0	5kΩ ± 1%	100kΩ
30·0	3·3kΩ	100kΩ
40·0	4kΩ ± 1%	100kΩ
50·0	2kΩ	100kΩ



SETTING UP THE OPERATIONAL AMPLIFIERS

It is usual to check operational amplifiers either before the start of a computation, or at the beginning of the day, but the computer builder may wish to assure himself that his amplifiers are all that they should be when first brought into service. The zero-setting procedure given at the end of Part 3 of this series will have eliminated all but obscure faults. The front panel balance controls (VR15, VR16, and VR17, Figs. 2.4 and 2.9) are deliberately designed to have a limited range of adjustment, so that an amplifier fault will be clearly indicated as an inability to zero-set from the front panel.

To quickly check each amplifier, insert 10 kilohm feedback resistors into miniature sockets SK11 and SK12 for OA1, OA2, and OA3 (Fig. 2.9), and ensure that the operational amplifiers are already linked to their summing networks. Insert 10 kilohm input resistors into S1/I1/SK3–SK4, S2/I1/SK3–SK4, and S3/I1/SK3–SK4 (Fig. 2.8). Patch VS1/SK1 to S1/I1/SK1 (Figs. 2.6 and 2.8) and connect the negative lead of a voltmeter to OA1/SK13, with the positive lead going to any convenient earth socket.

Check that OA1 output is exactly zero when S6 is off. If not, zero-set by means of balance control VR15. Obtain a positive voltage from VS1 by switching on S6 and setting S1 and VR6, and monitor VS1 output with a second voltmeter connected to SN1/SK2 red, and an

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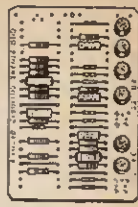

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200μA	32/6	1·0-1mA	25/–	500mA	25/–	300V d.c.	25/–
500μA	27/6	1mA	25/–	750mA	25/–	500V d.c.	25/–
50-0-50μA	35/–	2mA	25/–	1A d.c.	25/–	750V d.c.	25/–
		5mA	25/–	2A d.c.	25/–	15V a.c.	25/–
		10mA	25/–	5A d.c.	25/–	50V a.c.	25/–
		20mA	25/–	3V d.c.	25/–	150V a.c.	25/–
		50mA	25/–	10V d.c.	25/–	300V a.c.	25/–
		100mA	25/–	20V d.c.	25/–	500V a.c.	25/–
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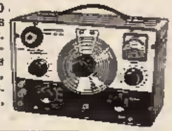

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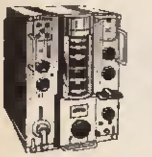

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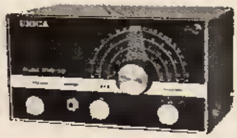

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5 off 10kΩ ±2%
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3 off 20kΩ ±2%
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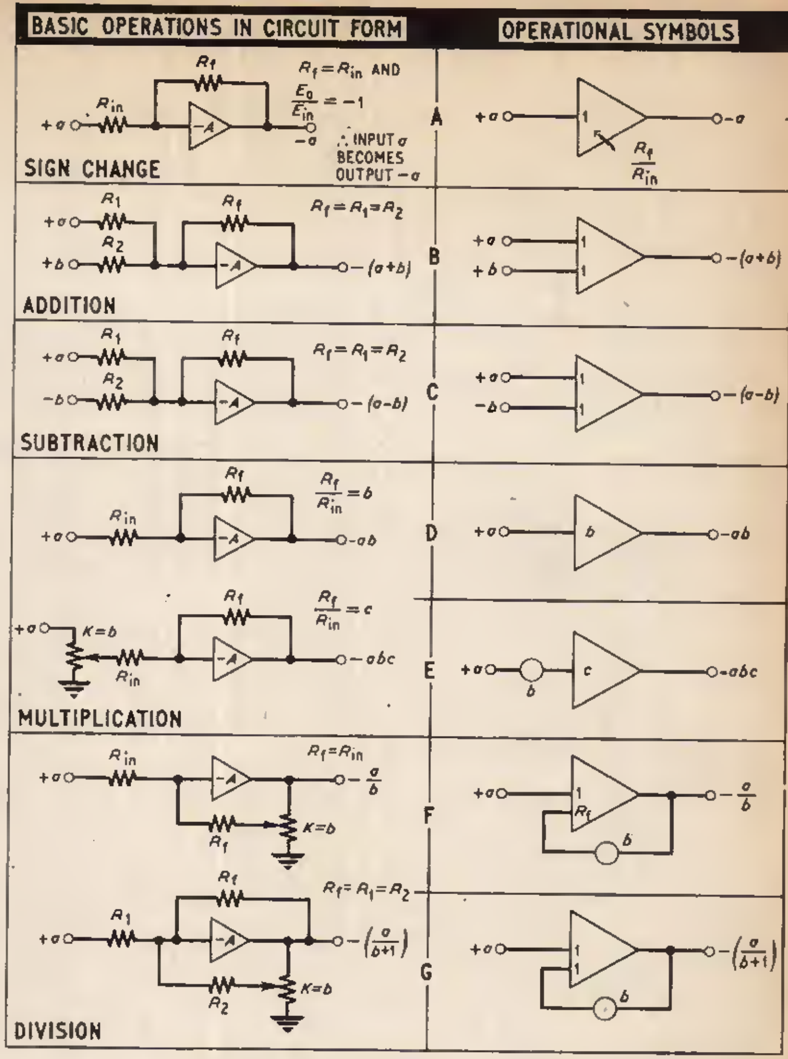

Fig. 4.1. (right) These diagrams indicate how the operational amplifier can be used to solve various algebraic equations

earth socket. Remember that a positive input voltage results in a negative operational amplifier output voltage.

Since input and feedback resistors are both 10 kilohm, the operational amplifier gain will be unity, and both voltmeters should give precisely the same readings. Double check by interchanging voltmeters. Now see that the operational amplifier will faithfully "track" any input voltage of ±10V or less when a temporary output load of 2 kilohm is connected from OA1/SK7 to earth.

The above tests are repeated for OA2 and OA3 by transferring the patching lead from VS1–S1/I1/SK1 to S2/I1/SK1, and then to S3/I1/SK1, and at the same time reconnecting voltmeters to the appropriate summer and operational amplifier sockets.

SOFTWARE

Under the heading of "software" comes all the paperwork associated with drawing up a programme for the computer. The time spent on preparing a programme for PEAC can vary from a few minutes to several days, depending on the skill of the programmer and the nature and complexity of the problem.

The intention is to give a few typical programme examples as an introduction to using the computer. They will consist of a short written *routine*, plus programme layouts. The layouts will be in a duplicated form, of symbolised diagram and patching circuit, so that the reader can compare analogue computer symbols with actual circuits and patching procedures. A newcomer to analogue computers will best learn programming techniques by working with PEAC, and this will also help to increase his knowledge of more advanced mathematics.

ROLE OF THE OPERATIONAL AMPLIFIER IN EQUATION SOLVING

Now that the time has come to consider UNIT "A" as a computer, instead of as a collection of circuits handling voltages, it is appropriate to adopt a slightly different approach. Voltages will now be replaced by the letters or numbers of an algebraic equation, *a, b, c, d, x, y,* 2, 3, 4, 5, and so on. Computing resistors loose their individual identity and are considered only as ratios $\frac{R_f}{R_1}$, $\frac{R_f}{R_2}$, etc., which are also denoted by equation letters or numbers. The same applies to coefficient potentiometer settings.

Sign change. In the circuit of Fig. 4.1a, an input voltage classified as term *a*, reappears at the op-amp

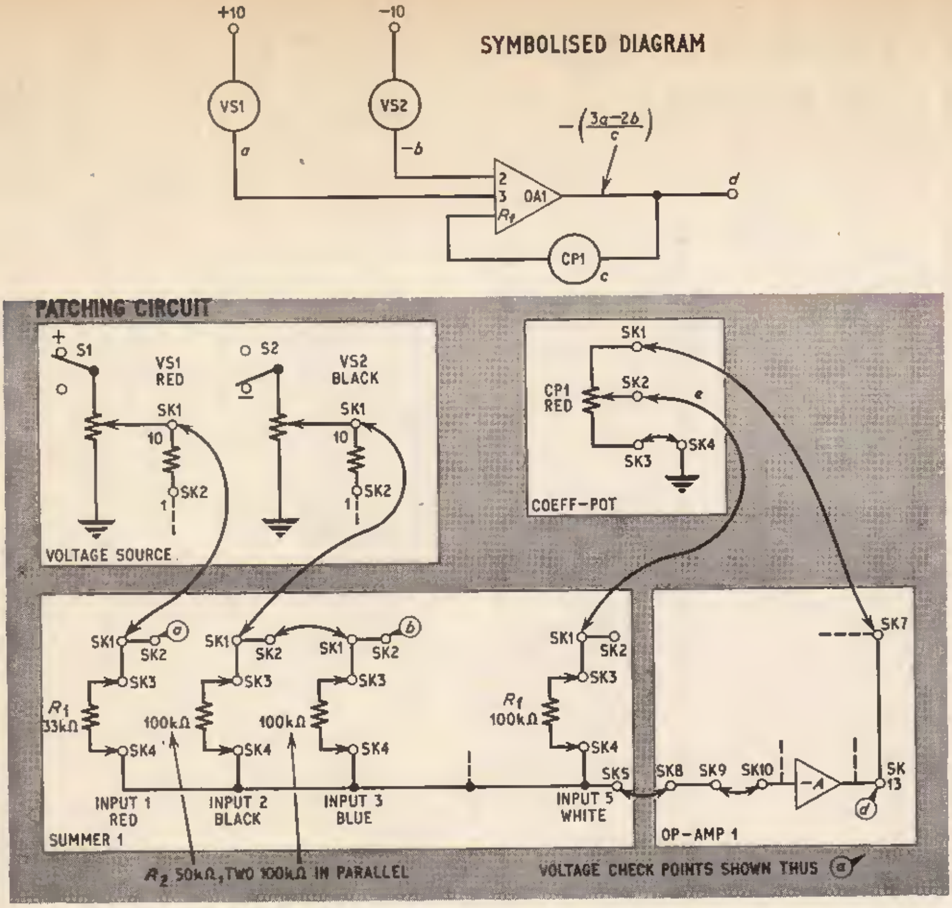

Fig. 4.2 Programme layouts for $\frac{3a-2b}{c} = d$

output as term $-a$, when the $\frac{R_f}{R_{in}}$ ratio is unity. One way of looking at this operation, which is common to all single operational amplifier configurations, is to assume that a has been multiplied by -1, hence $\frac{R_f}{R_{in}} = -1$. In effect, to multiply by -1 is to move a mathematical term from one side of its equation to the other, so sign change can be used to transpose.

The operational symbol of Fig. 4.1a avoids the bother of inserting resistors and their values when drawing up a programme layout on paper. The figure inside the triangle—in this case "1"—merely indicates that the computing resistor ratio, or alternatively the operational amplifier gain, is unity.

Addition. In Fig. 4.1b, positive terms a and b are added to yield an output $-(a + b)$, which can also be written $-a - b$. If $-(a + b)$ is applied as an input to a second unity gain operational amplifier, to give two sign changes, it will be converted to $a + b$. Note that the figures in the operational symbol triangle show that $\frac{R_f}{R_1} = 1$, and $\frac{R_f}{R_2} = 1$.

Subtraction. The only difference between Fig. 4.2b and Fig. 4.2c is that term b has been made a negative quantity. The operational amplifier output is therefore $-(a - b)$ or $-a + b$.

Multiplication. In Fig. 4.1d, R_f and R_{in} are adjusted so that $\frac{R_f}{R_{in}} = b$. Hence, a is multiplied by factor b to become an output $-ab$. The letter inside the operational symbol triangle shows that the $\frac{R_f}{R_{in}}$ ratio is b.

Fig. 4.1e gives an alternative method of achieving multiplication. A computing potentiometer is connected to the op-amp input to multiply a by a factor b. Therefore, with an input ab, and $\frac{R_f}{R_{in}}$ adjusted to equal c, the result is an output $-abc$.

Division. When a computing potentiometer is wired as in Fig. 4.1f, with R_f connected to its slider, term a will be divided by constant b when $R_f = R_{in}$. Note that R_f is written inside the symbol triangle to show that b is a divisor.

It can sometimes happen that a feedback resistor is inadvertently left plugged into an operational amplifier when it is re-programmed for a division operation, and this will result in the circuit of Fig. 4.1g. Instead of an output $-\frac{a}{b}$ the operational amplifier will yield $-\left(\frac{a}{b+1}\right)$.

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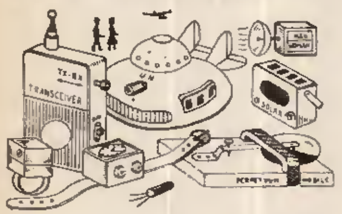

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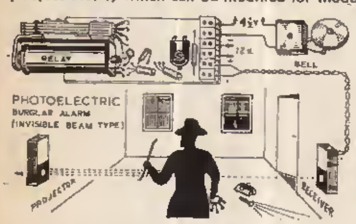

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2μF	150 volt	10μF	25 volt	200μF	3 volt
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2·5μF	25 volt	20μF	6 volt	250μF	2·5 volt
3μF	3 volt	20μF	9 volt	250μF	9 volt
3μF	25 volt	20μF	15 volt	320μF	2·5 volt
3·2μF	6·4 volt	25μF	6 volt	350μF	9 volt
3·2μF	64 volt	25μF	12 volt	350μF	10 volt
4μF	4 volt	25μF	15 volt	400μF	2·5 volt
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ECH81	5/9	PCF806	13/6	UCH21	9/6	6D4	15/-	801	6/-	OC72	6/-
ECH83	8/-	PCL82	7/9	UCH42	10/6	6DK6	9/-	803	35/-	OC74	6/-
ECL80	7/-	PCL83	9/3	UCH81	6/9	6F23	13/6	807	7/-	OC75	6/-
ECL82	7/-	PCL84	7/9	UCL82	8/-	6F24	13/-	811	30/-	OC76	6/-
ECL83	10/3	PCL85	9/3	UCL83	10/-	6F25	12/-	813	75/-	OC77	8/-
ECL86	9/-	PCL86	9/-	UF41	10/-	6F28	11/6	866A	13/6	OC78	6/-
EF9	20/-	PENB4	20/-	UF89	7/6	6J5G	2/6	872A	57/6	OC81	4/-
EF37A	7/-	PEN45DD	12/-	UL41	9/6	6J6	3/-	5651	7/6	OC81D	4/-
EF39	6/-	PFL200	14/-	UL84	7/-	6J7G	4/9	5654	8/-	OC81M	5/6
EF41	10/-	PL36	10/-	UY41	7/-	6K7G	2/-	5672	7/-	OC81DM	6/-
EF80	5/-	PL81	8/-	UY85	6/6	6K8G	3/-	5687	10/-	OC82	6/-
EF86	6/9	PL82	7/6	VP4B	25/-	6L6G	7/6	5691	26/-	OC82D	6/-
EF89	5/-	PL84	6/9	VR105/30	5/-	6Q7G	6/-	5749	10/-	OC83	6/-
EF91	3/6	PL500	15/-	VR150/30	5/-	6SG7	5/-	5763	10/-	OC169	5/-
EF92	2/6	PX4	14/-	W81	6/-	6SJ7M	7/-	5842	65/-	OC170	7/-
EF98	10/-	PX25	12/6	Z66	15/-	6SL7GT	4/9	5963	10/-	OC171	8/-
EF183	6/6	PY32	8/6	Z319	25/-	6SN7GT	4/6	6057	10/-	OC200	7/6
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EFP60	10/-	PY82	6/-			6X5G	4/6	6060	6/-	XA111	3/6
EH90	7/6	PY83	6/6			6X5GT	6/-	6061	12/-	XA112	4/6
EL33	12/6	PY800	10/-			7B6	11/6	6062	14/-	XA125	5/-
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COMBINED OPERATIONS

The configurations of Fig. 4.1 have many similarities, which lead naturally to the combination of several operations. In fact, it is possible to perform, say, ten additions or subtractions, three multiplications, and one division operation all at once using a single operational amplifier with several inputs and coefficient potentiometers.

PROBLEM EXAMPLE 1.
SOLVING A SIMPLE EQUATION

UNIT "A" can solve a linear algebraic equation consisting of more than ten unlike terms, but a simple example with only four terms will serve as an adequate practical introduction to programming.

Take $$\frac{3a-2b}{c}=d \qquad \text{(Eq. 4.1)}$$

the letters *a, b,* and *c* are regarded as known quantities, and *d* is the unknown, but the equation can be transposed to solve for any unknown.

Eq. 4.1 is implemented on the computer as shown in the Fig. 4.2 patching circuit. Two voltages corresponding to a and $-b$ are taken from the voltage source to summer S1, where a is multiplied by $\frac{R_f}{R_1}=3$, and $-b$ is multiplied by $\frac{R_f}{R_2}=2$.

The machine equation for the problem is,

$$\frac{\frac{R_f}{R_1}a-\frac{R_f}{R_2}b}{c}=d \qquad \text{(Eq. 4.2)}$$

and if R_f is made 100 kilohm the equation will take the form of

$$\frac{\frac{100}{33}a-\frac{100}{50}b}{c}=d \qquad \text{(Eq. 4.3)}$$

Computing resistor values could equally well be $R_f=10$ kilohm, $R_1=3{\cdot}3$ kilohm, and $R_2=5$ kilohm, to yield the same multiplication ratios. Since a 50 kilohm resistor is not included in the short list of Table 4.1, two 100 kilohm resistors are patched together in parallel in the patching circuit Fig. 4.2.

Routine. To set up Eq. 4.1 on UNIT "A", first of all ensure that the voltage source switch S6 is off. Insert computing resistors into the positions shown in Fig. 4.2 patching circuit, and connect the computing elements together with patching leads. Set VS1 and VS2 dials to zero, and CP1 to "10", corresponding to a divisor of 1. Wire a voltmeter to OA1/SK13 and zero-set the operational amplifier by means of VR15. Next connect a voltmeter to S1/I1/SK2, and switch on S6. Set VS1 dial for a trial value of $a=2$V. Transfer the voltmeter from S1/I1/SK2 to S1/I3/SK2, and set VS2 dial for a trial value of $b=-2$V.

UNIT "A" will now be computing

$$\frac{(3\times 2)-(2\times 2)}{1}=2 \qquad \text{(Eq. 4.4)}$$

with $a=2$, $b=-2$, $c=1$, and therefore $d=2$. When a voltmeter is linked to OA1/SK13 it will be discovered that the output voltage d is actually -2V, due to the operational amplifier sign change. Remedy by reversing the readout meter leads. If the output voltage is not exactly -2V, recheck voltages for a and $-b$. To check the exact setting of CP1 dial for any value of c, temporarily remove the patching lead from CP1/SK1. Patch CP1/SK1 to a precise $+10$V from a

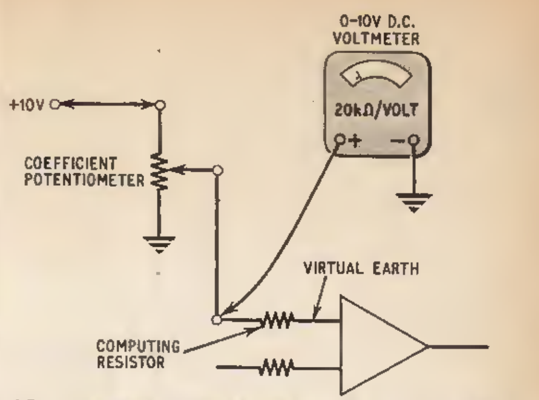


Fig. 4.3. Voltmeter method of determining coefficient potentiometer settings

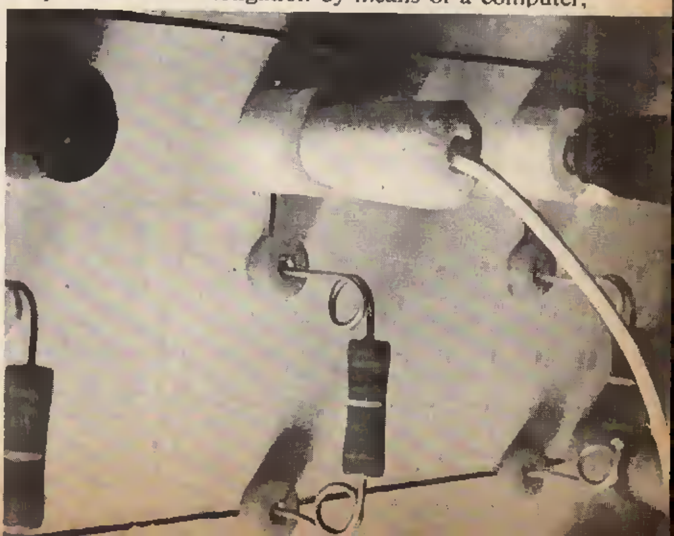
spare voltage source output, and connect a voltmeter to S1/I5/SK2. The voltmeter will then indicate the potentiometer coefficient while taking into account the loading effect of R_f (see Fig. 4.3). A voltmeter reading of 4·75V is equivalent to a coefficient of 0·475. CP1 can now be patched back into the problem set-up. With a 100 kilohm resistor for R_f, CP1 will be dividing by numbers equal to or less than unity. If R_f is changed to 10 kilohm, the range covered by CP1 will become 0–10. Therefore, increasing c by a factor of 10 can be seen quite clearly to be the same as decreasing computing resistor ratios by a factor of 10.

With UNIT "A" now programmed for Eq. 4.1, it is possible to investigate fully the problem for all reasonable values of *a, b, c,* and *d*, and for any unknown without the need for transposing terms or altering the problem set-up. For example, to find a when *b, c,* and *d* are known, set b and c and adjust a for an operational amplifier output equal to d. Always monitor an input voltage with a voltmeter when it is being adjusted.

To see how serious computing errors can occur at extreme limits, set VS1 and VS2 so that terms $3a$ and $-2b$ are virtually equal, and $d \simeq 0$. Also, set CP1 to near zero and observe that d will pass beyond the 10V operational amplifier maximum output swing.

PROBLEM EXAMPLE 2.
ANALYSIS OF VOLTAGE DIVIDER CIRCUIT

The voltage divider of Fig. 4.4a is often encountered in electronic circuits. At first sight, a network consisting of only two resistors might be considered far too simple to merit investigation by means of a computer,



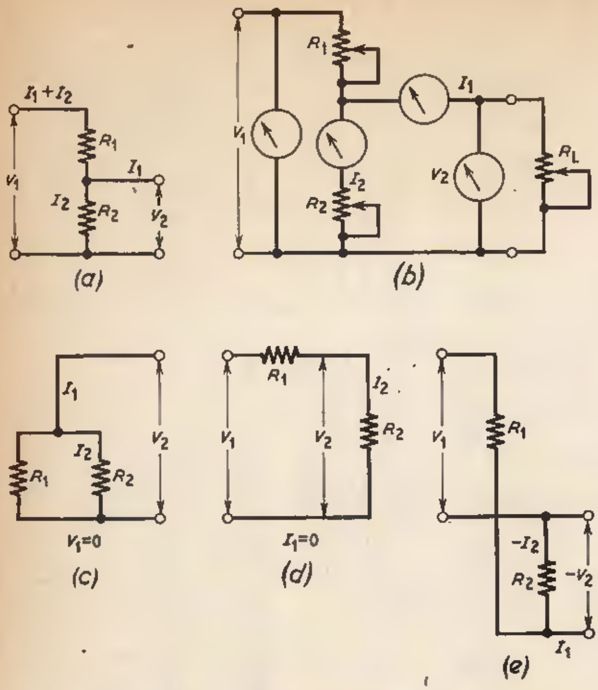


Fig. 4.4. (a) voltage divider circuit; (b) direct simulation of (a); (c), (d) and (e), three variations on (a)

but it does involve at least six variable quantities V_1, V_2, I_1, I_2, R_1, and R_2, and to solve a problem for any unknown, one of six equations would be required, based on

$$R_1 = \frac{V_1 - V_2}{I_1 + I_2} \qquad \text{(Eq. 4.5)}$$

and

$$R_2 = \frac{V_2}{I_2} \qquad \text{(Eq. 4.6)}$$

Thus, although it would be ridiculous to use the computer to find one specific answer to one particular voltage divider problem, the paperwork involved in solving six equations for several sets of variables could become surprisingly laborious. What the computer does in fact allow is the solution to literally any voltage divider problem under any conditions, without the need for re-programming.

To solve Eq. 4.5 and Eq. 4.6 simultaneously on UNIT "A", the equations are first transposed for terms V_2 and I_2, which are common to both.

$$V_2 = V_1 - R_1(I_1 + I_2) \qquad \text{(Eq. 4.7)}$$

and

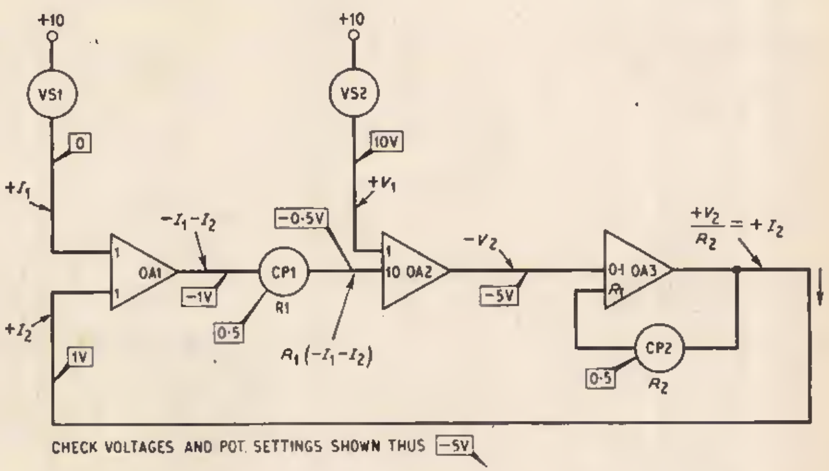
$$I_2 = \frac{V_2}{R_2} \qquad \text{(Eq. 4.8)}$$

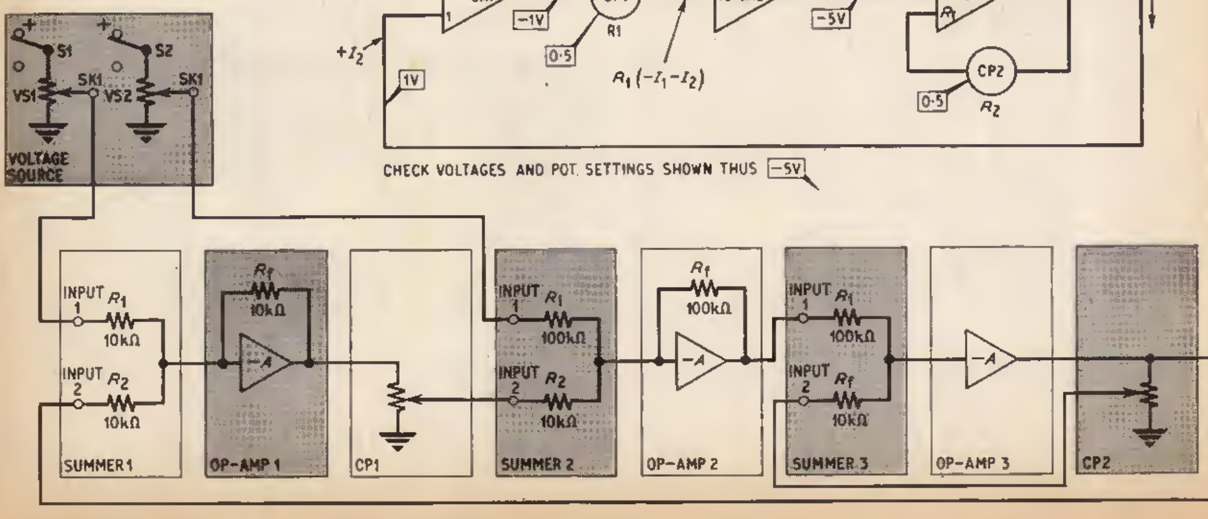
Next, both equations are linked to give a self-enforcing systems, shown diagrammatically as,

$$V_1 - R_1(I_1 + I_2) = V_2 \longrightarrow \frac{V_2}{R_2} = I_2$$

where the answer to Eq. 4.5 is one of the terms of Eq. 4.6 (V_2), and the answer to Eq. 4.6 is one of the

Fig. 4.5. Programme layouts for voltage divider analysis (a) (right) symbolised diagram, (b) (below) patching circuit





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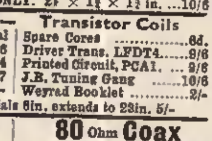

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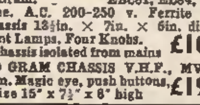

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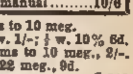

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terms of Eq. 4.5 (I_2). To see how the problem is set-up on the computer, refer to Fig. 4.5, and note the changes of sign involved.

Routine. Switch off S6 and insert all computing resistors and patching leads, except the link between OA3 output and OA1 input, which carries the voltage analogue of I_2. Zero-set OA1, OA2, and OA3 in that order, using a voltmeter applied to each operational amplifier output socket in turn. Now patch the link between OA3 output and OA1 input into circuit. Set VS1 to "0", and VS2 to "+10". The voltmeter method of Fig. 4.3 is employed to set CP1 and CP2 both for a coefficient of 0·5. Temporarily remove the patching leads from CP1/SK1 and CP2/SK1, and connect the "top end" of the potentiometer tracks to a 10V reference voltage. Adjust CP1 and CP2 for outputs of 5V. Exactly the same procedure is adopted when it is necessary to "read off" values for R1 and R2, although approximate readings can be taken from CP1, CP2 dials.

The check voltages in the diagram of Fig. 4.5 correspond to the above voltage source and coefficient potentiometer settings, and provided that there is general agreement with Ohm's law, any desired values can be given to the voltages, currents, and resistances in Fig. 4.4a. The check voltages could apply to actual voltage divider quantities of, say, $V_1 = 10V$, $V_2 = 5V$, $I_1 = 0mA$, $I_2 = 1mA$ (1 machine volt = 1mA), $R_1 = 5$ kilohm, and $R_2 = 5$ kilohm, where VS1 covers the range 0–10mA, VS2 0–10V, CP1 0–10 kilohm, and CP2 0–10 kilohm. Suppose instead that V_1 had been assigned the value of 1,000V, when R_1 and R_2 were both only 5 ohms. One machine volt would now be equivalent to 100A, and V_2 would equal 500V. The ranges covered by computing potentiometers in the latter case would then be VS1 0–100A, VS2 0–1,000V, CP1 0–100, and CP2 0–10 ohms.

Unless informed otherwise, the computer assumes that V_1 is an ideal voltage which originates from a source of infinitely small resistance. Hence, if $V_1 = 0$, this corresponds to a short-circuit, and gives the variation of Fig. 4.4c. Alternatively, if I_2 is made equal to nought, the voltage divider circuit is transformed into a load resistor R_2 in series with a source resistor R_1, given by Fig. 4.4d.

One further variation will serve to show the flexibility of the programme. In Fig. 4.4e the resistance network R_1 and R_2 is made to couple two sources of voltage V_1 and $-V_2$, and this occurs when I_1 is made larger than $I_1 + I_2$, or in other words, when I_2 swings negative.

The layout of Problem Example 2 is an instance of indirect simulation, where the computer solves equations and imitates the behaviour of the simulated circuit. In this indirect "model" of a voltage divider, relationships between governing equations and actual circuit parameters are made obvious, and the abstractions of mathematics are brought to life as tangible voltmeter and dial readings.

Another way of simulating the Fig. 4.4a circuit is by a direct "model", shown in Fig. 4.4b, which employs coefficient potentiometers for R_1, R_L, and R_L, voltmeters for V_1 and V_2, and current meters for I_1 and I_2. Although feasible, the direct model is less elegant, is not so adaptable to extreme cases, and is subject to errors which do not occur when the voltage divider is simulated indirectly.

Next month: Using UNIT "A" to solve a second order differential equation. Indirect simulation of LC circuits, spring pendulums, and servomechanisms by means of integrators.

REGULATED POWER SUPPLY

continued from page 284

	VOLTS						mA	A
	A	B	C	D	E	F	I_2	I_1
No load current	1·0	0·17	14·2	0·68	0·47	2	65	2·7
	2·88	0·145	11·4	0·5	0·38	6	40	2·1
	5·8	0·12	7·0	0·36	0·28	12	18	1·4
1A Load	0·99	0·165	14·1	0·61	0·40	2	36	1·9
	2·86	0·143	11·3	0·41	0·30	6	18	1·3
	5·78	0·119	6·9	0·23	0·17	12	3·5	0·32

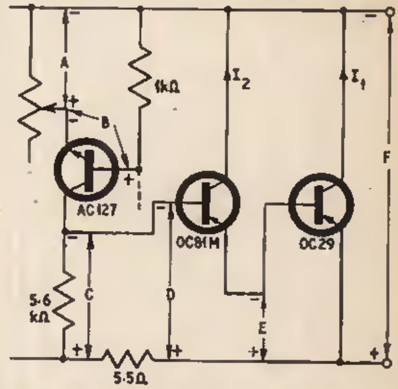

Fig. 10. Test measurements for fault-finding

CALIBRATION OF OUTPUT VOLTAGE

After checking the voltmeter accuracy against an AVO or similar instrument known to have good accuracy itself, the Regulated Volts dial should be adjusted as follows.

Switch S2 to "Regulated" and S3 to "Volts" and turn VR1 until 1V is obtained at the output (best seen on the AVO). Loosen the knob and rotate to indicate 1V on the calibrated dial. Lock the pointer knob grub screw while indicating the correct 1V. Rotate VR1 until the dial indicates 12V output. Now adjust VR2 until 12V output (measured) is obtained.

VOLTAGE CHART

Fig. 10 gives typical voltages at six points in the d.c. amplifier circuit for three different output voltages. Reference to these voltages and to the currents of the super-alpha pair TR2, TR3 should assist in any fault-finding. ★

Readout—
A SELECTION FROM OUR POSTBAG

Taken to task . . .

Sir—Regarding the *Car Anti-Theft Alarm* (February 1968) the device described is only a small part of a comprehensive scheme and by itself seems rather like being offered the protection of an umbrella with a large hole in it.

One of the pre-requisites that is never mentioned is that the device should not only be thief-proof but also fool-proof as far as the driver is concerned. It should automatically test itself when the vehicle is vacated and warn the driver if it is at fault. If it is in working order, it should then automatically set itself, so that there is no onus on the driver to press switches or turn keys—which may get forgotten!

A simple combination of a door switch and a pressure switch beneath the driver's seat could control this testing and setting up.

The actual device has to counter the thief's activities which are carried out in two separate stages. Firstly he has to gain access to the inside of the vehicle and only then can he carry out the second stage of driving it off.

While it is a fact that no vehicle can be rendered completely thief-proof, the usual door designs could well be improved by arranging for the driver's door to have a cylinder night latch lock, interlocked so that the door could not be closed unless all the other doors and windows were secured.

The interlocking could take the form of door and window switches connected in series, the circuit being tested as already described.

If the thief can be scared off soon enough, he will not even test the security of the doors and windows and the only device to discourage him from even touching the vehicle is the familiar system of flashing the headlamps and intermittently sounding the horn. It is absolutely essential that this is triggered by a proximity switch.

If the vehicle were parked out in the wilds and the thief were unperturbed by the Son et Lumière display, he could raise the bonnet, cut the wires to the horn—because of their easy accessibility—and finally disconnect the battery. A jumper wire from the battery to the coil and the thief is ready to force the windows and then drive off. That is, unless he can be held by the last line of defence—the immobiliser.

Two points are clear. It is no use immobilising the ignition since the thief is now master of the electrics and for the same reason any electrically powered device would have to employ a separate battery—unless it locked with the power off. Devices fitted to the steering gear, gear lever or clutch pedal and brakes will produce varying degrees of immobilisation.

It has been shown that an electronic alarm is only part of the answer, and that for complete protection, equipment has to operate as follows:

(1) Driver opens door and vacates seat.
(2) Electronic device checks that doors and windows are closed and tests the alarm.
(3a) In the case of a fault it operates the alarm to warn the driver.
(3b) In the case of everything being all right it sets the alarm for an intruder.
(4) On approach of a thief the alarm is set off, triggered by a proximity switch.
(5) If the thief gains entrance he is confronted by mechanical immobilisation of the steering and clutch.

A. J. Nicholls,
Perry Barr,
Birmingham.

Do you know what you are suggesting? Aren't we in enough trouble already—see letter below!

. . . and again

Sir—I have subscribed to PRACTICAL ELECTRONICS since its inception and must say that the majority of articles are interesting and useful. However I am surprised that you published the article *Car Anti-Theft Alarm*. Surely this is akin to using a computer to calculate two times two.

Whilst it might offer an exercise in transistor circuit construction I feel that the use of transistors, especially germanium types, is misguided, since an inherently easy electro-mechanical problem is solved by semi-complicated electronic circuitry.

As a Senior Electronics Technician employed in the medical field I am often called upon to find effective solutions to problems encountered in this profession, and I am sure you would subscribe to the view that the best solutions are the simplest ones which *adequately* cover the specification.

With your wide circulation I am sure you must be acutely aware of your responsibilities to readers, especially the younger ones, in guiding their thoughts along sound, logical and practical lines, and I feel this article offends these principles in offering a complicated solution to a simple problem.

The much simpler and cheaper circuit enclosed covers all the points raised, and has been fitted to my own vehicle for a number of years. It has proved perfectly reliable (to my own discomfort I might add when in a forgetful mood), can be used on positive or negative earth systems without modification, and is virtually unaffected by temperature location.

Peter S. Stinton,
West Drayton,
Middlesex.

Thank you for forwarding your circuit. Unfortunately we do not feel able to publish this since (1) it is not electronic, (2) the general idea is fairly well known.

Following from point (2) we also thank all those other readers who sent us circuit diagrams of similar electro-mechanical systems.

Hair raising

Sir—I would like to build a "high frequency" unit for use on my hair as a "massage" could you help at all in the supply of any constructional or circuit details on this subject.

G. W. Sheppard,
Stourbridge,
Worcestershire.

We are afraid that this subject is somewhat out of our normal sphere, and cannot assist you on this occasion.

Perhaps a member of the medical profession can give you a lead concerning the availability of such equipment.

If you are successful in your search our Editor will be glad to receive any information.

BAEC news

Sir—I am enclosing a copy of our latest *Newsletter* which is now being sent out to our members, and I hope that you will find it of interest.

As you can see, Mr Cullen, our Hon. Secretary, has resigned due to commitments at work and studies, and our Hon. Secretary is now Mr J. H. Hooper, 5 Cwrt-y-Vil Road, Penarth, Glamorgan, and I would appreciate it if you would kindy mention this change in a future issue.

C. Bogod,
Chairman,
British Amateur Electronics Club,
"Dickens",
26 Forrest Road,
Penarth, Glamorgan.

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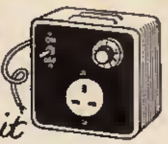

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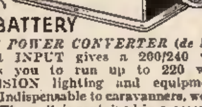

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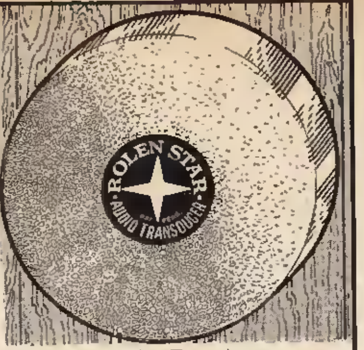

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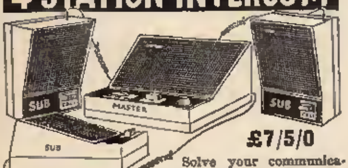

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Range change is manual.
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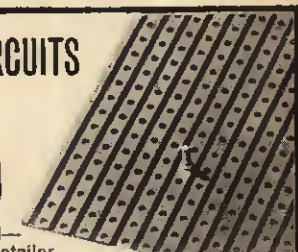

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