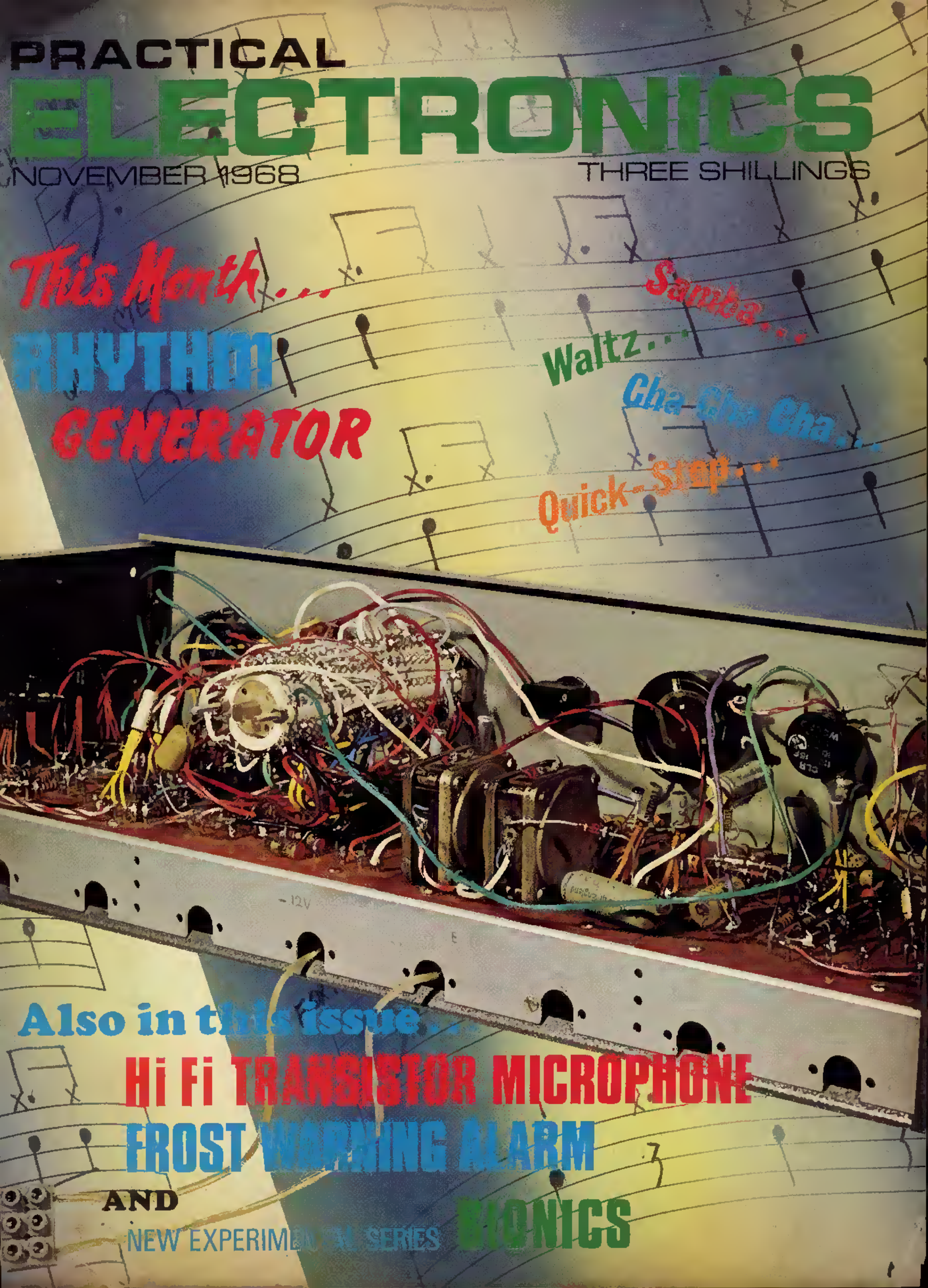
PRACTICAL
ELECTRONICS

NOVEMBER 1968

THREE SHILLINGS



This Month . . .
RHYTHM GENERATOR

Also in this issue . . .

Hi Fi TRANSISTOR MICROPHONE
FROST WARNING ALARM

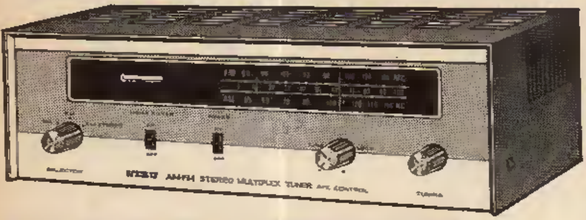
AND

NEW EXPERIMENTAL SERIES **BIONICS**

Lasky's Radio

SPECIAL INTEREST ITEMS!

OUTSTANDING HI-FI BARGAIN



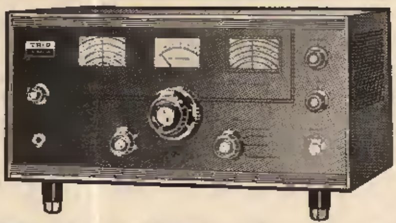
AFX-3U AM/FM STEREO TUNER

Superbly engineered by world famous manufacturer, the Model AFX-3U is an ultra sensitive AM/FM stereo multiplex tuner using 14 valves and 9 diodes. The extra wide bandwidth of the tuner and unique multiplex circuitry ensures the finest possible FM reception with optimum stereo separation of over 38dB. Stereo signal beacon with special circuitry unaffected by external noise, simplifies FM stereo broadcast selection. 3 gang variable condenser provides highly sensitive reception on both bands. The multiplex circuit is completely free from subcarrier leakage and permits direct tape recording without any beat noise interference. An MPX noise filter is also fitted. **Brief specification:** 14 valves, 2 Germanium diodes and 2 Silicon diodes. Frequency range: FM—80–108Mc/s, AM—535–1,605kc/s. Sensitivity: FM—1·9μV/98Mc/s, AM—2μV/100kc/s. Output FM/FM Stereo 2V, AM—3V. Frequency response: FM—20–20,000c/s. Distortion less than 1%. Special Circuits: FM Stereo indicator, AFC, Noise filter. Output for direct tape recording. Hammer enamel and brushed alloy finish. Cabinet size 14¾ × 5 × 9¼in. For 220/240V a.c. Mains (50 or 60c/s) operation. Complete with operating manual. **List Price 55 Gns.**

Lasky's Price 26 Gns. Carriage and Packing 7/6

COMMUNICATION RECEIVERS

TRIO



MODEL 9R-59DE

Brief spec.: 4 band receiver covering 550kc/s to 30Mc/s continuous and electrical band spread on 10, 15, 20, 40 and 80 metres. 8 valve plus 7 diode circuit. 4/8 ohm output and phone jack. **Special features:** SSB-CW ● ANL ● Variable BFO ● S meter ● Sep. band spread dial ● IF frequency 455kc/s ● Audio output 1·5W ● Variable RF and AF gain controls. For use on 115/250V a.c. Mains. Beautifully designed control layout finished in light grey with dark grey case, size 7 × 15 × 10in. Weight 19lb. Fully guaranteed, complete with instruction manual and service data.

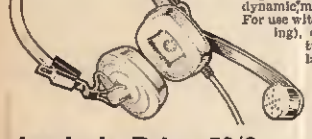
Lasky's Price £39.15.0 Carriage and Packing 12/6

MODEL JR-500SE

Brief spec.: Covers all the amateur bands in 7 separate ranges between 3·5 and 29·7Mc/s. Circuit uses 7 valves, 2 transistors and 5 diodes plus 8 crystals; output 8 and 500 ohm and 500 ohm phone jack. **Special features:** Crystal controlled oscillator ● Variable BFO ● VFO ● AVC ● ANL ● S meter ● SSB-CW ● Stand-by switch ● Special double gear dial drive with direct reading down to 1kHz ● Remote control socket for connection to a transmitter. Audio output 1 watt. For use on 115/250V a.c. Mains. Superb modern styling and control layout—finished in dark grey. Cabinet size 7 × 13 × 10in. Weight 18lb. Fully guaranteed, complete with instruction manual and service data.

Lasky's Price £68.0.0 Carriage and Packing 12/6

FOSTER HF-204 COMBINED MICROPHONE/HEADSET



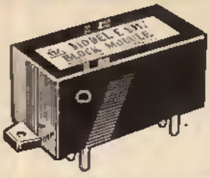
High quality moving coil headphones and sensitive dynamic microphone combined in one lightweight unit. For use with tape recorders (provides constant monitoring), communications equipment, PA (crowd or traffic control), stage direction, language labs, etc. Extremely comfortable to wear for long periods—adjustable foam padded cushions, vinyl covered headband. Headphone imp. 8Ω, max. input 100mW. Microphone imp. 25Ω. Weight 8·8oz. Single cable contains both headphone and microphone leads. **List Price 7 Gns.**

Lasky's Price 59/6 Post 2/6

GET YOUR LASKY'S CATALOGUE

FREE **Second Great Reprint Issue Now Ready. Twelve 16 × 11½in pages — over 1,500 items! Just send your name, address and 1/- for post only**

CONSTRUCTORS BARGAINS



LASKY'S ENCAPSULATED SOLID STATE MODULES

8 completely new special function circuit modules. Size of each module only 2½ × 1½ × ¾in. Ready for immediate use—just connect to power source (usually 9V batt.), input and output. Encapsulated modules are shockproof and almost indestructible. Comp. with full ins. **Post 1/6 each.**

E-1311 Phono Pre-amp Module—max. output 3V. RMS, input 50mV, input imp. 100kΩ, gain 28dB, RIAA compensation.	29/6
E-1312 Tape Head Pre-amp Module—max. output 3V, RMS, input 50mV, input imp. 100kΩ, gain 25dB, NARTB compensation.	29/6
E-1313 Microphone Pre-amp Module—max. output 4V, RMS, input 50mV, input imp. 100kΩ, gain 28dB, response 10-50kc/s.	29/6
E-1314 Power Amplifier Module—max. output 300mW, input imp. 1kΩ, gain 20dB, response 50-10k/cs, distortion 3% at 20mW.	29/6
E-1315 Electronic Organ (tone oscillator) Module—frequency 200–1,000c/s, output 80mW. For use with keyboard, variable resistors and 8Ω speaker.	25/-
E-1316 Morse Code Practice Oscillator Module—frequency 400c/s, output 80mW. For use with morse key and speaker.	25/-
E-1317 Modulated Wireless Signal Transmitter for use in test bench fault finding—frequency 400c/s–30Mc/s, tone freq. 400c/s. For use with any AM receiver.	25/-
E-1318 Lamp Flasher Module—flashes two miniature lamps alternately. For use with 6V, 100/200mA bulbs and 6V power supply.	25/-

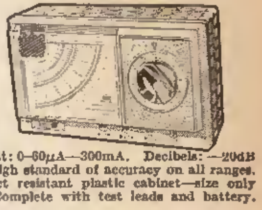
TEST EQUIPMENT

NEW LASKY'S EXCLUSIVE MIDLAND Model 10-502 VHF AIRCRAFT BAND CONVERTER

An entirely new item for the radio enthusiast bringing instant reception of the ground-to-air, air-to-ground waveband. For use with any standard AM or FM radio covering 535 to 1,605kc/s, 88 to 108Mc/s respectively—with no electrical conversion or connection required. The Model 10–502 (self powered by one 9V (PP3 type) battery) is merely placed close to the receiving set and then tuned over 110 to 135Mc/s which covers the whole aircraft communications band. Volume and reception effectiveness is adjusted by moving both sets to the most favourable position and balancing the volume controls of each accordingly. The Model 10–502 has a smartly designed black plastic cabinet with brushed metal front panel and 18in chrome telescopic antenna, size only 4 × 2½ × 2½in (inc. knobs). Complete with battery and full instructions.

Lasky's Price 79/6 Post 3/6

TTC Model C-1051



A completely new design 20,000 O.P.V. pocket multimeter with mirror scale circuit and built-in thermal protection. Exceptionally large easy to read meter with D'Arsonval movement. Colour coded scales. Single positive click-in, recessed selection switch for all ranges. Ohms zero adjustment. Range spec. a.c. volts: 0–6–30–300–1,200V at 10K/ohms/V. D.c. volts: 0–3–15–150–300–1·2KV at 20K/ohms/V. Resistance: 0–60K–6megs. D.c. current: 0–60μA—300mA. Decibels: —20dB to +17dB. Hand calibration gives extremely high standard of accuracy on all ranges. Uses one 1½V penlight battery. Strong impact resistant plastic cabinet—size only 4¾ × 3¼ × 1⅛in. Two colour buff/green finish. Complete with test leads and battery. **Orig. list price £5.5.0.**

LASKY'S PRICE 75/- Post 2/6

CLEAR PLASTIC PANEL METERS

Precision made in Japan by TTC. Each meter boxed and fully guaranteed with all fixing nuts and washers. Sizes are of front panel. Add 1/6 P. on each. (Quotes for quantities.)

Type KR-52 3 × 2½in (illustrated).

1mA	38/6	50μA	56/-
5mA	38/6	1mA S Meter	39/6
100mA	38/6	100μA	52/6
300V	35/-	500μA	45/-

Type MK-38A 1⅝in square

1mA	29/6
5mA	27/6
100mA	27/6
300V	27/6
50μA	37/6
1mA S meter	29/6
100μA	37/6
500μA	29/6

Type MK-45A 2in square

1mA	29/6
5mA	28/6
100mA	28/6
300V	28/6
50μA	49/6
1mA S meter	32/6
100μA	42/6
500μA	35/-

Type KR-65 3½ × 3in

1mA	38/6
5mA	37/6
100mA	39/6
300V	35/-
50μA	59/6
1mA S meter	45/-
100μA	58/-
500μA	46/-

Type MK-65A 3in square

1mA	39/6
5mA	36/-
100mA	39/6
300V	36/-
50μA	59/6
1mA S meter	30/6
100μA	52/6
500μA	42/-

Branches

207 EDGWARE ROAD, LONDON, W.2 Tel.: 01-723 3271
Open all day Saturday, early closing 1 p.m. Thursday

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Open all day, 9 a.m.—6 p.m. Monday to Saturday

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Open all day Thursday, early closing 1 p.m. Saturday

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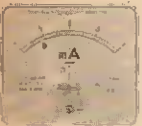
ALL MAIL ORDERS AND CORRESPONDENCE TO: 3-15 CAVELL ST., TOWER HAMLETS, LONDON, E.1 Tel.: 01-790 4821

SEW PANEL METERS

Send S.A.E. for full lists. Other ranges available. Please include postage. Special quotations for quantities.

CLEAR PLASTIC METERS



Type MR.52P. 2½in square fronts

50µA	59/6	100mA	37/6	300V a.c.	37/6
50-0-50µA	49/6	500mA	37/6	S Meter 1mA	39/6
100µA	49/6	1 amp.	37/6	VU Meter	59/6
100-0-100µA	45/-	5 amp.	37/6	1 amp. a.c.*	37/6
500µA	42/6	10V d.c.	37/6	5 amp. a.c.*	37/6
1mA	37/6	20V d.c.	37/6	10 amp. a.c.*	37/6
5mA	37/6	50V d.c.	37/6	20 amp. a.c.*	37/6
10mA	37/6	300V d.c.	37/6	30 amp. a.c.*	37/6
50mA	37/6	15V a.c.	37/6		

Type MR.38P. 1 21/32in square fronts

50µA	37/6	750mA	25/-
50-0-50µA	35/-	1 amp	25/-
100µA	35/-	2 amp	25/-
100-0-100µA	32/6	5 amp	25/-
200µA	32/6	3V d.c.	25/-
500µA	37/6	10V d.c.	25/-
500-0-500µA	25/-	20V d.c.	25/-
1mA	25/-	50V d.c.	25/-
1-0-1mA	25/-	100V d.c.	25/-
2mA	25/-	150V d.c.	25/-
5mA	25/-	300V d.c.	25/-
10mA	25/-	500V d.c.	25/-
20mA	25/-	750V d.c.	25/-
50mA	25/-	15V a.c.	25/-
100mA	25/-	50V a.c.	25/-
150mA	25/-	150V a.c.	25/-
200mA	25/-	300V a.c.	25/-
300mA	25/-	500V a.c.	25/-
500mA	25/-	S meter 1mA	29/6
		VU meter	39/6

Type MR.45P. 2in square fronts

50µA	42/6	10V d.c.	27/6
50-0-50µA	39/6	20V d.c.	27/6
100µA	39/6	50V d.c.	27/6
100-0-100µA	35/-	300V d.c.	27/6
500µA	29/6	15V a.c.	27/6
1mA	27/6	300V a.c.	27/6
5mA	27/6	S meter 1mA	35/-
10mA	27/6	VU meter	42/6
50mA	27/6	1 amp a.c.*	27/6
10mA	27/6	5 amp. a.c.*	27/6
500mA	27/6	10 amp. a.c.*	27/6
1 amp.	27/6	20 amp. a.c.*	27/6
5 amp.	27/6	30 amp. a.c.*	27/6

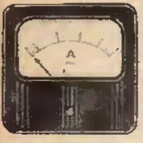
Type MR.85P. 4½in × 4¼in fronts

50µA	69/6	15 amp.	49/6
50-0-50µA	59/6	30 amp.	49/6
100µA	59/6	20V d.c.	49/6
100-0-100µA	59/6	50V d.c.	49/6
200µA	55/-	150V d.c.	49/6
500µA	52/6	300V d.c.	49/6
500-0-500µA	49/6	150V a.c.	49/6
1mA	49/6	300V a.c.	49/6
1-0-1mA	49/6	S Meter 1mA	55/-
5mA	49/6	VU meter	69/6
10mA	49/6	1 amp. a.c.*	49/6
50mA	49/6	5 amp. a.c.*	49/6
100mA	49/6	10 amp. a.c.*	49/6
500mA	49/6	20 amp. a.c.*	49/6
1 amp.	49/6	30 amp. a.c.*	49/6
5 amp.	49/6		

Type MR.65P. 3½in × 3¼in fronts

50µA	65/-	50V d.c.	39/6
50-0-50µA	52/6	150V d.c.	39/6
100µA	52/6	300V d.c.	39/6
100-0-100µA	49/6	15V a.c.	39/6
500µA	45/-	50V a.c.	39/6
1mA	39/6	150V a.c.	39/6
5mA	39/6	300V a.c.	39/6
10mA	39/6	500V a.c.	39/6
50mA	39/6	S meter 1mA	45/-
100mA	39/6	VU meter	65/-
500mA	39/6	50mA a.c.*	39/6
1 amp.	39/6	100mA a.c.*	39/6
5 amp.	39/6	200mA a.c.*	39/6
10 amp.	39/6	500mA a.c.*	39/6
15 amp.	39/6	1 amp. a.c.*	39/6
20 amp.	39/6	5 amp. a.c.*	39/6
30 amp.	39/6	10 amp. a.c.*	39/6
50 amp.	39/6	20 amp. a.c.*	39/6
10V d.c.	39/6	30 amp. a.c.*	39.6
20V d.c.	39/6		

BAKELITE PANEL METERS

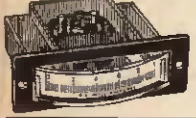


***Moving iron, all others moving coil.**

Type MR.65. 3½in square fronts

25µA	67/6	500mA	32/6	30V a.c.*	32/6
50µA	45/-	1 amp.	32/6	50V a.c.*	32/6
50-0-50µA	42/6	5 amp.	32/6	150V a.c.*	32/6
100µA	42/6	15 amp.	32/6	300V a.c.*	32/6
100-0-100µA	42/6	30 amp.	32/6	1 amp. a.c.*	32/6
500µA	39/6	50 amp.	32/6	5 amp. a.c.*	32/6
1mA	32/6	5V d.c.	32/6	10 amp. a.c.*	32/6
1-0-1mA	32/6	10V d.c.	32/6	20 amp. a.c.*	32/6
5mA	32/6	20V d.c.	32/6	30 amp. a.c.*	32/6
10mA	32/6	50V d.c.	32/6	50 amp. a.c.*	32/6
50mA	32/6	150V d.c.	32/6	VU meter	59/6
100mA	32/6	300V d.c.	32/6		

NEW RANGE OF "SEW" EDGEWISE METERS



MODEL PE70. Dimensions 3 17/32 × 1 11/32 × 2¾ deep overall. Available as follows:

50 microamp	57/6	500 microamp	49/6
50-0-50 microamp	55/-	1 milliamp	45/-
100 microamp	55/-	300V a.c.	45/-
100-0-100 microamp	52/6	VU meter	62/6
200 microamp	52/6		

Post extra

TE-20D RF SIGNAL GENERATOR

Accurate wide range signal generator covering 120kc/s to 500Mc/s on 6 bands. Directly calibrated. Variable RF attenuator, audio output. Xtal socket for calibration. 220/240V a.c. Size 140 × 215 × 170mm. Brand new with instructions. **£15.**

Carr. 7/6.

TY 75 AUDIO SIGNAL GENERATOR

Sine Wave 20c/s to 200kc/s. Square Wave 20c/s to 30kc/s. High and low impedance output. Output variable up to 6 volts. 220/240 volts a.c. Size 210 × 150 × 120mm. Brand new with instructions. £16. Carr. 7/6.

T.M.C. 1000 SERIES KEY SWITCHES

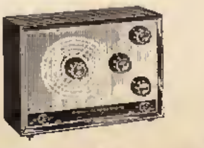
Brand New with knobs as follows.

1 way, 2 c/o 7/6; 1 way, 2 c/o 2b, 7/6; 1 way, 4 c/o. 8/-; 2 way, 3m., 3m. 8/6; 2 way, 2 c/o., 2 c/o 8/6; 2 way, 2 c/o., 4 c/o. 10/-.

Post extra. Quantities available.

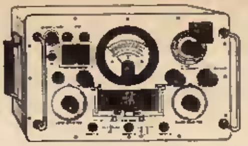
NOMBREX TRANSISTORISED TEST EQUIPMENT

All Post Paid with Battery



Model 22. Power Supply 0–15V d.c.	£14.10.0
Model 30. Audio Generator.	£19.10.0
Model 31. R.F. Signal Generator.	£12.10.0
Model 32. C.R. Bridge.	£10.10.0
Model 33. Inductance Bridge.	£20.0.0
Model 66. Inductance Bridge.	£18.0.0
Model 61. Power Supply.	£6.10.0

AVO CT.38 ELECTRONIC MULTIMETERS

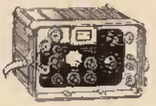


High quality 97 range instrument which measures a.c. and d.c. Voltage, Current, Resistance and Power output. Ranges d.c. volts 250mV–10,000V. (10megΩ–110megΩ input). D.c. current 10µA 25 amps. Ohms: 0–1,000megΩ. A.c. volt 100mV–250V (with RF measuring head up to 250Mc/s). A.c. current 10µA–25 amps. Power output 50 micro-watts–5 watts. Operation 0/110/200/250V. C. Supplied in perfect condition complete with circuit lead and RF probe **£25.** Carr. 15/-.

TYPE 13A DOUBLE BEAM OSCILLOSCOPES

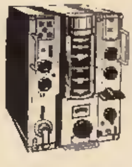
An excellent general purpose D/B oscilloscope. T.B. 2c/s–750 kc/s. Bandwidth 5·5 Mc/s. Sensitivity 33mV/CM. Operating voltage 0/110/200/250V a.c. Supplied in excellent working condition. **£22.10.0.** Or complete with all accessories, probe, leads, lid, etc. **£25.** Carriage 30/-.

AM/FM SIGNAL GENERATORS



Oscillator Test No. 2. A high quality precision instrument made for the ministry by Airmec. Frequency coverage 20–80Mc/s. AM/C.W./FM. Incorporates precision dial, level meter, precision attenuator 1µV-100mV. Operation from 12V d.c. or 0/110/200/250V a.c. Size 12 × 8¼ × 9in. Supplied in brand new condition complete with all connectors fully tested. **£45.** Carr. 20/-.

ADMIRALTY B.40 RECEIVERS



Just released by the Ministry. High quality 10 valve receiver manufactured by Murphy. Coverage in 5 bands 650kc/s – 30Mc/s, I/F 500 kc/s. Incorporates 2 R.F. and 3 I.F. stages, band-pass filter, noise limiter, crystal controlled B.F.O., calibrator I/F, output, etc. Built-in speaker, output for phones. Operation 150/230V a.c. Size 19½ × 13¼ × 16in. Weight 114lb. Offered in good working condition, **£22.10.0.** Carr. 30/-. With circuit diagrams. Also available B.41 L.F. version of above 15kc/s–700kc/s. **£17.10.0** Carr. 30/-.

MARCONI CT44/ TF956 AF ABSORPTION WATTMETER

1 µ/watt to 6 watts

£20. Carr. 20/-.

AVOMETERS

Supplied in excellent condition, fully tested and checked. Complete with prods, leads and instructions.
Model 47A **£9.19.6.**
P. & P. 7/6 each.

CLASS D WAVEMETERS

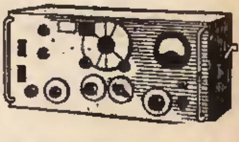
A crystal controlled hetrodyne frequency meter covering 1·7–8Mc/s. Operation on 6 volts d.c. Ideal for amateur use. Available in good used condition **£5.19.6.** Carr. 7/6. Or brand new with accessories **£7.19.6.** Carr. 7/6.

AUTO TRANSFORMERS

0/115/230v. Step up or step down. Fully shrouded.

150 W.	**£1.12.6,**	P. & P. 3/-
300 W.	**£2.7.6,**	P. & P. 3/6
500 W.	**£3.10.0,**	P. & P. 6/6
1,000 W.	**£5.10.0,**	P. & P. 7/6
1,500 W.	**£6.10.0,**	P. & P. 8/6
3,000 W.	**£7.10.0,**	P. & P. 12/6
7,500 W.	**£15.10.0,**	P. & P. 20/-

MARCONI TEST EQUIPMENT



EX-MILITARY RECONDITIONED.
TF 144G STANDARD SIGNAL GENERATORS, 85kc/s–25 Mc/s, **£25,** carr. 30/-. TF.885. VIDEO OSCILLATOR. 0-5Mc/s, **£45.** Carr. 30/-. T.F. 195M. BEAT FREQUENCY OSCILLATOR 0–40kc/s, 200/250V a.c. **£20,** carr. 30/-; TF.142E. Distortion Factor Meter, **£20,** carr. 20/-. All above offered in excellent condition fully tested and checked. TF. 1100 VALVE VOLTMETER, Brand New, **£50.** T.F. 1267 TRANSMISSION TEST SET, Brand New, **£75.** TF.1371. Wide Band Millivolt Meter, **£50.**

Variable Voltage TRANSFORMERS

Brand new, guaranteed and carriage paid.
High quality construction. Input 230V 50-60 cycles.
Output full variable from 0-260V. Bulk quantities available.
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Type 1035 general purpose, a.c. coupled. **Type 1049 L. F.** d.c coupled **£35 each.** Carr. 30/-.

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Postage 2/-, Over £3 post paid.

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C60-60 mins. **12/6.** C90-90 mins. **17/6.** Over £2 post paid.

EVERSHED VIGNOLES SERIES II 500 VOLT MEGGERS. Perfect condition **£21.** P. & P. 10/-.

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LAFAYETTE DE-LUXE 100 KΩ/VOLT "LAB TESTER"

Giant 6½in. scale. Built-in meter protection. 0/·5/2·5/10/50/250/500/1,000V d.c. 0 / 3 / 10 / 50 / 250 /500 /1,000V a.c. 0/10/100μA /10 / 100 / 500 MA / 2·5 / 10A. 0/1K / 10K / 100K / 10M / 10MΩ. —10 to 49·4dB **£18.18.0.** P. & P. 5/-.

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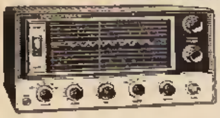

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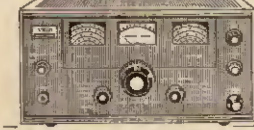

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19 transistors, 8 diodes, IHF music power, 30W at 8Ω. Response 30-20,000 ±2dB at 1W Distortion 1% or less. Inputs 3mV and 250mV. Output 3-16Ω. Separate L. and R. volume controls. Treble and bass control. Stereo phone jack. Brushed aluminium, gold anodised extruded front panel with complimentary metal case. Size 10½ × 3⅞ × 7⅞in. Operation 115/230V. A.V. **£28.** Carr. 7/6.

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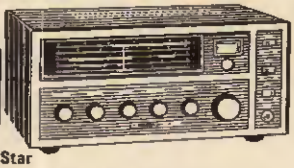
Combined Stereo S.M. Receiver and amplifier with 25 watts I.H.F. channel. Frequency response ± 1 dB, 18 to 30,000 Hz. Tuning range 88 to 108 MHz. Speaker outputs for 4 – 16 ohms. £55 3s. 6d. Teak case extra £5 1s. 6d. plus 14s. 0d. tax. Tuning Heart £6 6s. 4d. plus £1 12s. 8d. tax.



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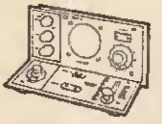

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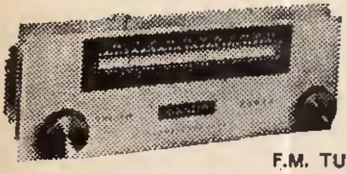

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Load impedance	3 to 15 ohms.
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The circuit diagram of the IC-10 is shown on the right. The first three transistors are used in the pre-amp and the remaining 10 in the power amplifier. The output stage operates in class AB with closely controlled quiescent current which is independent of temperature. A high level of overall negative feedback is used round both sections and the amplifier is completely free from cross-over distortion at all supply voltages. Thus battery operation is eminently satisfactory.

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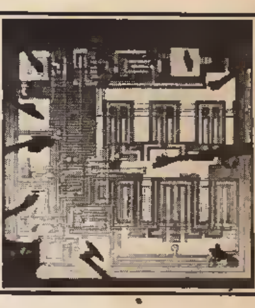
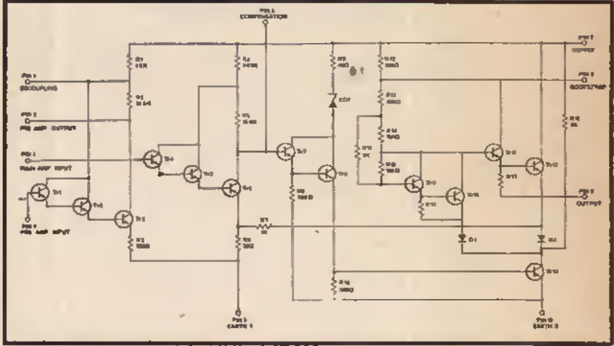
ABOVE SHOWS ACTUAL SIZE OF IC-10. TO RIGHT, VIEW OF AMPLIFIER MAGNIFIED 625 TIMES.





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Each IC-10 is sold with a very comprehensive manual giving circuit and wiring diagrams for a large number of applications in addition to high fidelity uses. These include public address, loud-hailers, use in cars, inter-com., stabilised power supplies, electronic organs, oscillators, volt meters, tape recorders, solar cell amplifier, radio receivers.
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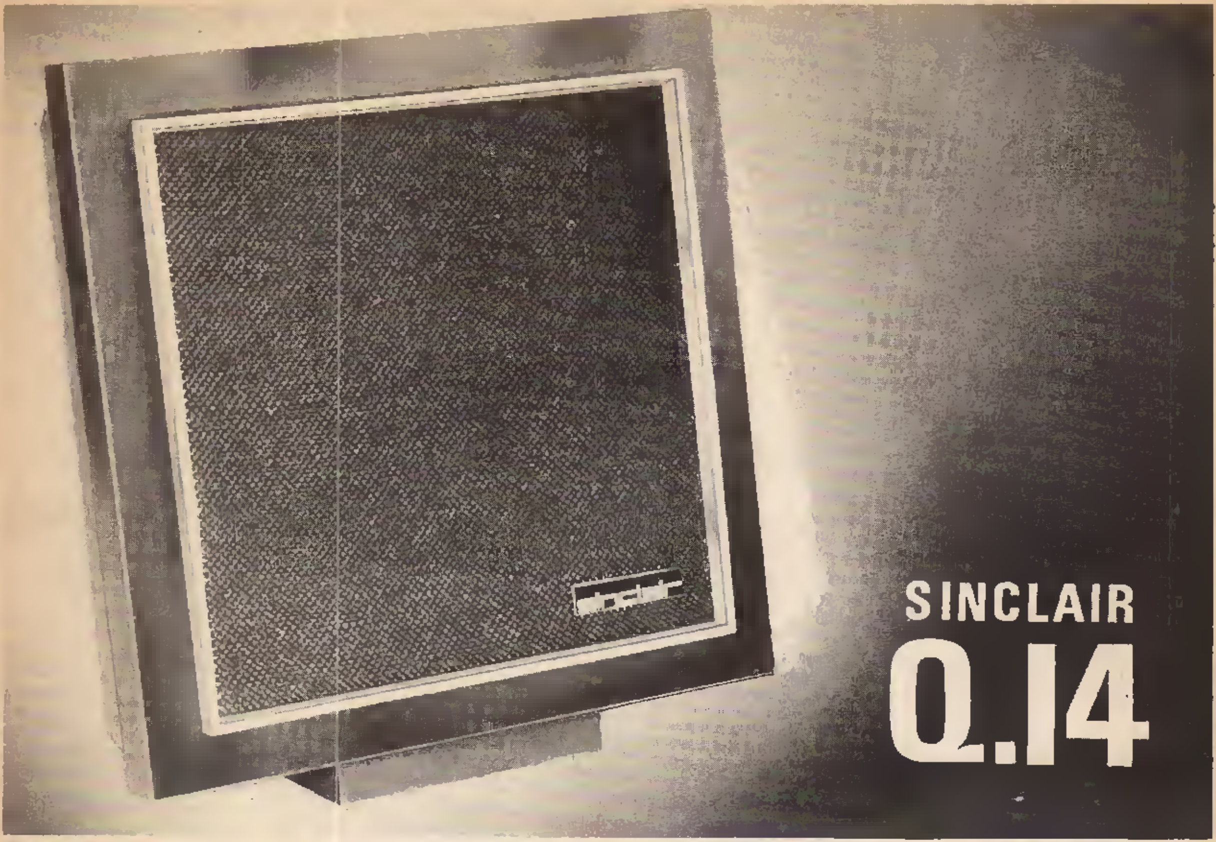

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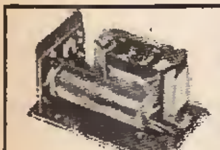

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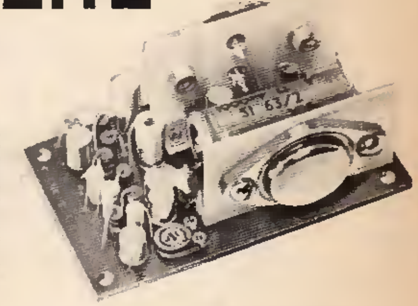

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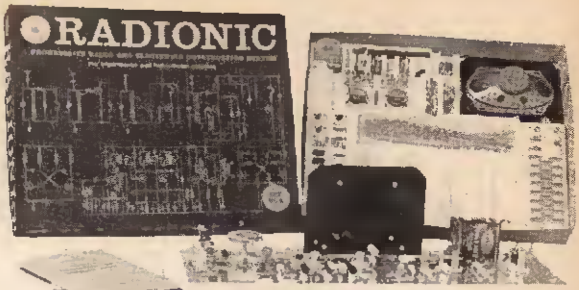

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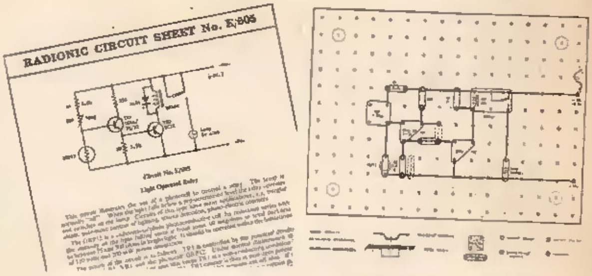

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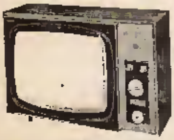

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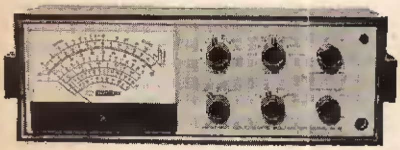

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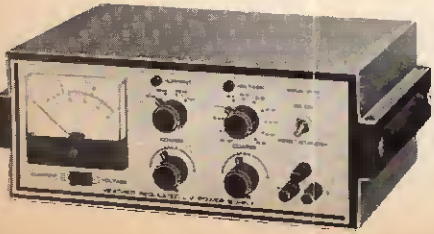

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VOL. 4 No. 11
November 1968

PRACTICAL
ELECTRONICS

ELECTRONS AND NEURONS

Down the ages mathematicians, philosophers, scientists, and other great minds have expended thought and effort in attempts to devise machines with some kind of artificial intelligence. Numerous artifacts, automata, or robots (name them what you will) that imitate, albeit in a crude way, some of the characteristic attributes of man have been built at various times. The techniques employed have been equally varied in character.

Since the advent of electronics, the crude efforts of earlier days have been put in the shade. Much more is possible now. The intelligent machine is now a reality. But it is well to separate fact from fancy.

The affinity between electronic circuit systems and living systems is generally well known. The creation of an electronic system analogous in many ways to the human nerve system can be achieved. But even so, the electronic automata will fall short of its human counterpart in many important respects. Present techniques do not permit the assembling of anything like the electronic equivalent of the 10,000 million cells or neurons contained in the human brain. Despite this limitation, some truly amazing results have already been achieved in simulating certain human faculties. Assuredly great advances will continue to be made.

Scientists have explored electronic circuit techniques for biological and other research purposes. Their technological interests overlap those of industrial engineers who specialise in the field of control systems and automation. Apart from this, however, the philosophical approach of the scientist intent upon building working models that closely resemble a living cell or whole animal will be in contrast with the more materialistic approach of the engineer engaged in designing systems for strictly utilitarian purposes.

Now, can the amateur do anything purposeful and creative in this rather exotic field? We think he can, and for this reason have launched this month a fascinating series entitled "Bionics". In one sense, the experimenter will be on familiar ground, working with the normal electronics stock-in-trade; but he will need to reorientate his thinking to a considerable extent.

Experimenting in this field of "electrons and neurons" will lead to a wider appreciation of other branches of science, particularly biology. It could be a stimulating change from more mundane applications of electronics.

F. E. Bennett—*Editor*

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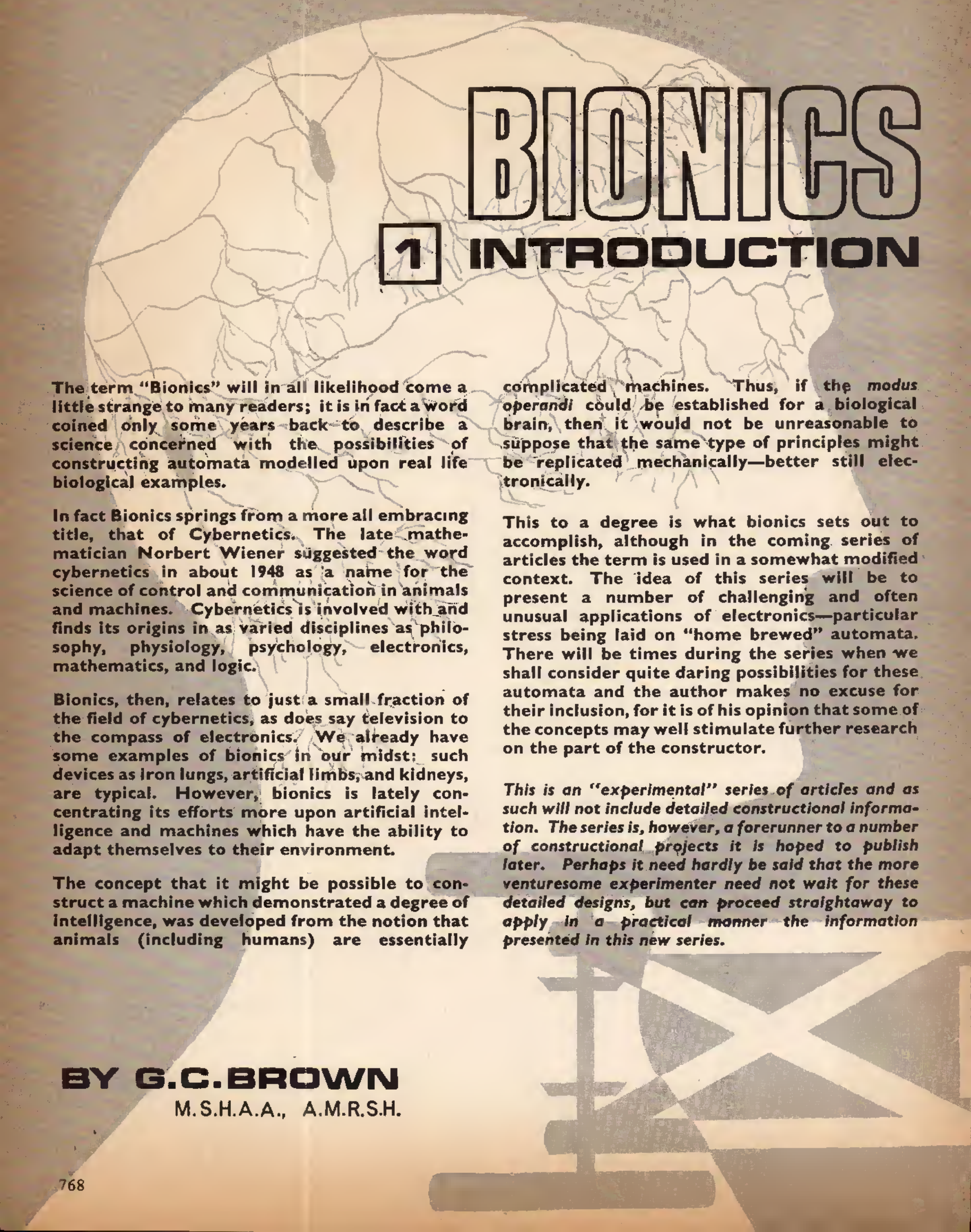
Our December issue will be published on Friday, November 15

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, 42s.



BIONICS

1 INTRODUCTION

The term "Bionics" will in all likelihood come a little strange to many readers; it is in fact a word coined only some years back to describe a science concerned with the possibilities of constructing automata modelled upon real life biological examples.

In fact Bionics springs from a more all embracing title, that of Cybernetics. The late mathematician Norbert Wiener suggested the word cybernetics in about 1948 as a name for the science of control and communication in animals and machines. Cybernetics is involved with and finds its origins in as varied disciplines as philosophy, physiology, psychology, electronics, mathematics, and logic.

Bionics, then, relates to just a small fraction of the field of cybernetics, as does say television to the compass of electronics. We already have some examples of bionics in our midst: such devices as iron lungs, artificial limbs, and kidneys, are typical. However, bionics is lately concentrating its efforts more upon artificial intelligence and machines which have the ability to adapt themselves to their environment.

The concept that it might be possible to construct a machine which demonstrated a degree of intelligence, was developed from the notion that animals (including humans) are essentially complicated machines. Thus, if the *modus operandi* could be established for a biological brain, then it would not be unreasonable to suppose that the same type of principles might be replicated mechanically—better still electronically.

This to a degree is what bionics sets out to accomplish, although in the coming series of articles the term is used in a somewhat modified context. The idea of this series will be to present a number of challenging and often unusual applications of electronics—particular stress being laid on "home brewed" automata. There will be times during the series when we shall consider quite daring possibilities for these automata and the author makes no excuse for their inclusion, for it is of his opinion that some of the concepts may well stimulate further research on the part of the constructor.

This is an "experimental" series of articles and as such will not include detailed constructional information. The series is, however, a forerunner to a number of constructional projects it is hoped to publish later. Perhaps it need hardly be said that the more venturesome experimenter need not wait for these detailed designs, but can proceed straightaway to apply in a practical manner the information presented in this new series.

BY G.C.BROWN

M.S.H.A.A., A.M.R.S.H.

The design and construction of electronic "animals" or machines with artificial intelligence

In nearly every one of us there is a latent desire to create. Not only to create, but to create something unique. It is therefore not surprising that since time immemorial man has made numerous (relatively unsuccessful) attempts to devise machines that might imitate himself.

Probably one of the first examples we can find is the lever; not in fact an actual imitation of man, but a device that could aid his physical strength. As time continued, so he produced more and more powerful "muscle amplifiers" (this is, after all what they are), and so if we stop to consider say a huge jib crane capable of lifting some tons, the amplification factor involved may well be in the order of several million. No mean feat, for a man!

AMPLIFICATION OF MENTAL ENERGY

The foregoing examples serve to indicate the "stepping stones" from which man began his attempts to synthesise certain characteristics of himself and other animals. It was not long, however, before it occurred to him that if *muscular* energy could be amplified, so indeed the same should apply to *mental* energy, and so we have the abacus or bead board which certain Asiatic countries are still using with great success.

With the advent of electronics it was at once realised that more rapid and yet more powerful machines could be built; and so we see the giant abaci of today: we call them computers. When electronic computers came into existence the popular press of course tended to over glamourise the machines' capabilities using such anthropomorphic terminology as "brains", "thought", etc. What the press lost sight of was that a basic digital computer however powerful or rapid, is still none-the-less a rather more sophisticated version of a mechanical desk calculator.

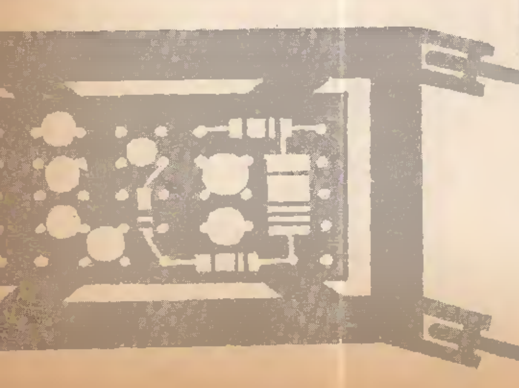
THOUGHT AND LEARNING PROCESSES

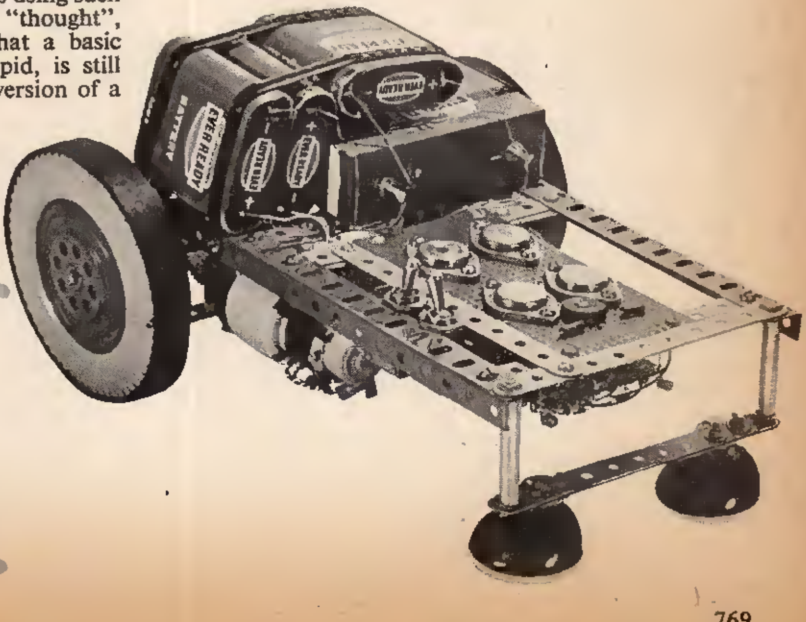
Unfortunately, although thought is a very intimate part of us we remain, ironically enough, unable to specify exactly what it is. However, we can say what it is not, and in no wise does any characteristic of a computer (save perhaps memory) qualify the right to be called a thought process. Before a computer can operate at all on the complex mathematics that it must handle, a programme often taking months to prepare and containing very precise orders, must accompany any calculation. If this were not enough, the computer must have all its instructions written in machine language.

It was not until about two decades ago, that man even began to "scratch the surface" of what appear to be the underlying principles of "thought" and learning processes. Although little is still understood, it is now possible to synthesise certain characteristics of the biological brain, albeit crudely, by applying the wealth of electronic principles we now have at our elbow. It is with this in mind, and with the almost limitless possibilities that it suggests that we shall discuss, and even construct, artefacts which will have "memory" and the ability to "learn".

MOBILE BREADBOARD

However, prior to considering rather more exotic devices, from a practical point of view it is a pre-requisite that we design and build some type of mobile breadboard





upon which we can perform modifications and "surgery". This then will be our first consideration, and at this stage an initial glance at Fig. 1.1 will reveal the main structure and "muscles" of the electronic animal.

Generally speaking, those of us whose interests lie in electronics rarely claim a similar zeal for the field of mechanics. In bionics this state of affairs can be a real handicap, because there are all too often times when a particular item just does not exist and one has no alternative but to fabricate. However, most of the mechanical problems can be largely solved by the use of Meccano, which readily lends itself to adaptation and "grafting". In addition, Meccano produce "ready-made" drive gearboxes which can either be used in conjunction with one of their motors, or a motor of the constructor's choice.

As will be seen from Fig. 1.1, the breadboard is basically of rigid box construction, cross members being incorporated to reduce possible twist along the length and increase its strength. The choice of chassis size was very much an arbitrary one; but in fact, providing readers maintain the general format it may be constructed to personal preference.

GEARBOX AND WHEELS

The original model was shod with plastic tracks, but as these are frequently difficult to come by we have chosen separately driven wheels for the device given here. The motor gearbox units are mounted at the rear end of the chassis, and drive power is transmitted via final bevel gears to the road wheels. The forward end of the chassis is supported by a pair of castors; one at each corner. This was found necessary, since a single castor introduced excessive chassis twist.

The "muscles" selected to power our model are a pair of Meccano E15R motor gearbox units, but in fact any reliable equivalent would do just as well provided that the overall gear ratio is kept lower than 160 : 1. Any higher ratio would tend to make the "animal" rather intractable, and apart from anything else accurate observation would become impossible.

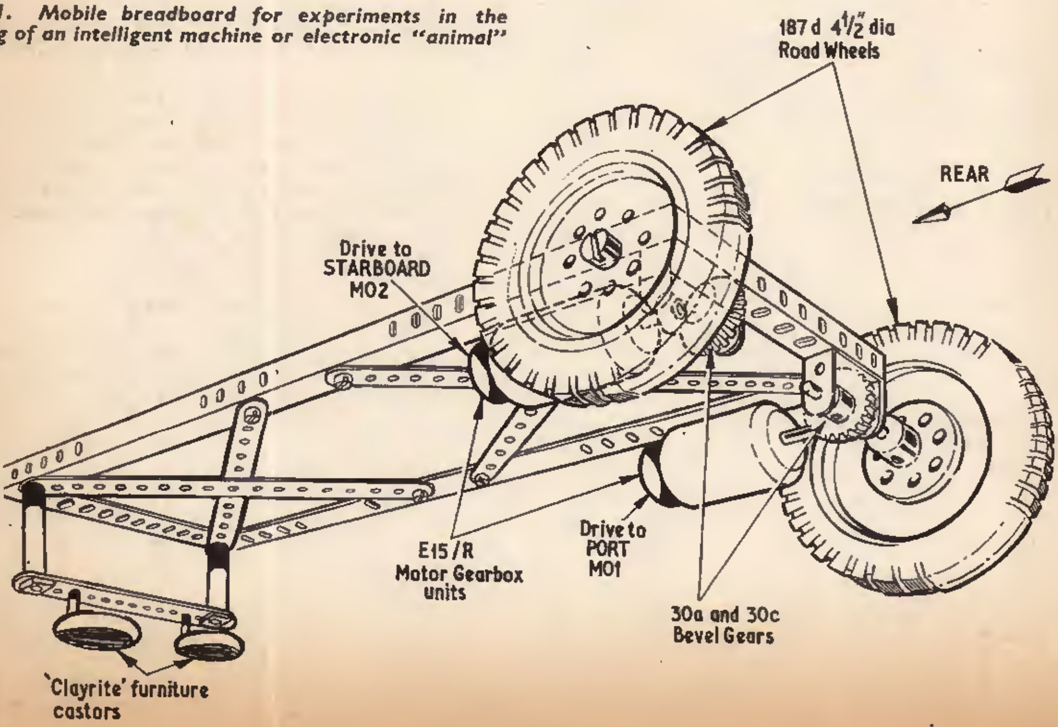
There are, of course, two fundamental methods for controlling the motors: relays and power transistors. As variable (analogue) control of the motors was often required, relays were rejected at an early stage in favour of power transistors. The use of transistors involves somewhat more complex circuit arrangements, but in view of their inexpensiveness and ability to provide more sophisticated control, extra time taken in building the equipment is adequately rewarded.

"MUSCLE" CONTROL CIRCUITS

The "muscle control" circuits are shown in Fig. 1.2. At the risk of causing some slight confusion the right and left hand side motors have been referred to respectively as Port and Starboard—the reason becomes obvious upon reflection because the right hand motor will cause the "animal" to move to port, and vice-versa. Motor Mo1 is therefore Port and Mo2 Starboard: together they drive the animal in forward or reverse directions.

Alternative steering and drive arrangements of course are possible, but owing to various problems that will be apparent as we progress, the present scheme will be retained. In any case there are unlikely to be any actual biological examples which utilise separate steering and motive systems; indeed, steering is usually a function of motivation. In our model steering is achieved as an integral part of the drive functions.

Fig. 1.1. Mobile breadboard for experiments in the building of an intelligent machine or electronic "animal"



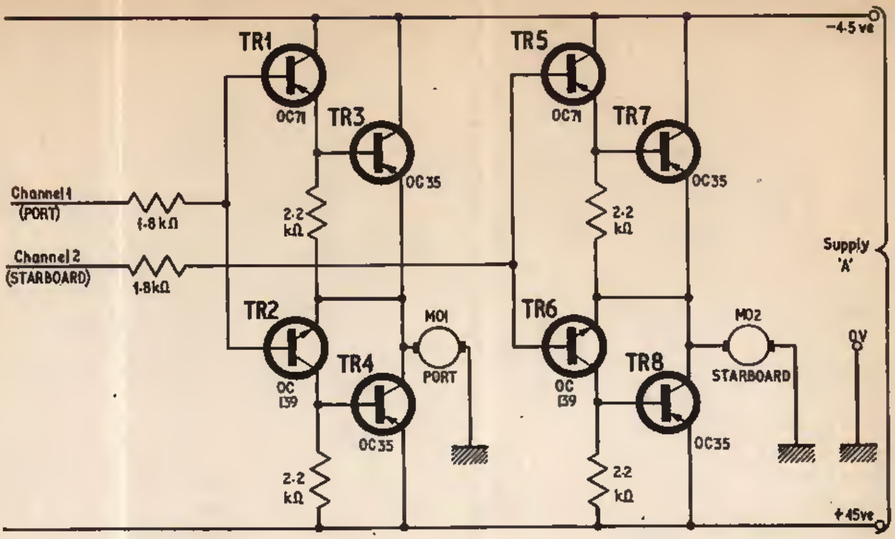


Fig. 1.2. "Muscle control" circuits for a simple electronic animal

TWO CHANNELS

Control over the motors is brought about through two separate channels which can provide facilities for operation in rate of response, scansion, and direction modes. Each channel consists of complementary emitter follower type configurations of *pnp-pnp* and *npn-npn* Darlington pairs. It is essential to ensure that the drive transistors have low leakage, otherwise there will be a pronounced tendency for the motors to rotate even when the inputs are grounded.

Prior to connecting the motors into the muscle control circuit, attention must be paid to establish correct polarity. With a negative input at each channel, TR1 and TR5 will conduct causing their associated power transistors TR3 and TR7 to drive up, thereby bringing Mo1 and Mo2 into operation: these inputs should cause forward rotation of the motors. Reverse rotation results from application of positive inputs, when TR2 or TR6 will conduct to drive up TR4 or TR8.

PRACTICAL POINTERS

All circuits can be built on Veroboard. No difficulties should be experienced in drilling the holes to take mounting bolts for the power transistors. The power transistors for each channel are located side by side and take up very little space; no heat sink being required as even maximum current demands are fairly small.

ANIMAL PSYCHOLOGY AND BEHAVIOURAL THEORY

Up till now, and for quite valid reasons, we have considered only the basic muscle control circuits. Having built and installed them, we shall now be able to concentrate our energies upon somewhat more creative lines.

As discussed previously, we shall consider the feasibility of synthesising electronically certain very limited aspects of memory and learning: these will be eventually incorporated within our mobile breadboard. It is simple enough to build an animal that will react to light and this will be discussed, but before attempting these projects it would at this stage be prudent to re-discover certain basic facts about animal psychology and behavioural theory.

Ostensibly, the problem we are facing appears simple enough: all that seems necessary is to arrange for a design procedure which will fit in with our concept of what a biological animal's psychology is. But then we don't really know completely, even if we examine it. The minute an animal is confronted with the unnatural conditions of a laboratory its responses tend to be artificial. Often, animals are bred in the laboratory, and behavioural tests with these are frequently even more sterile because they have never known a normal environment. On the other hand if an animal is within its normal environment we cannot easily examine it.

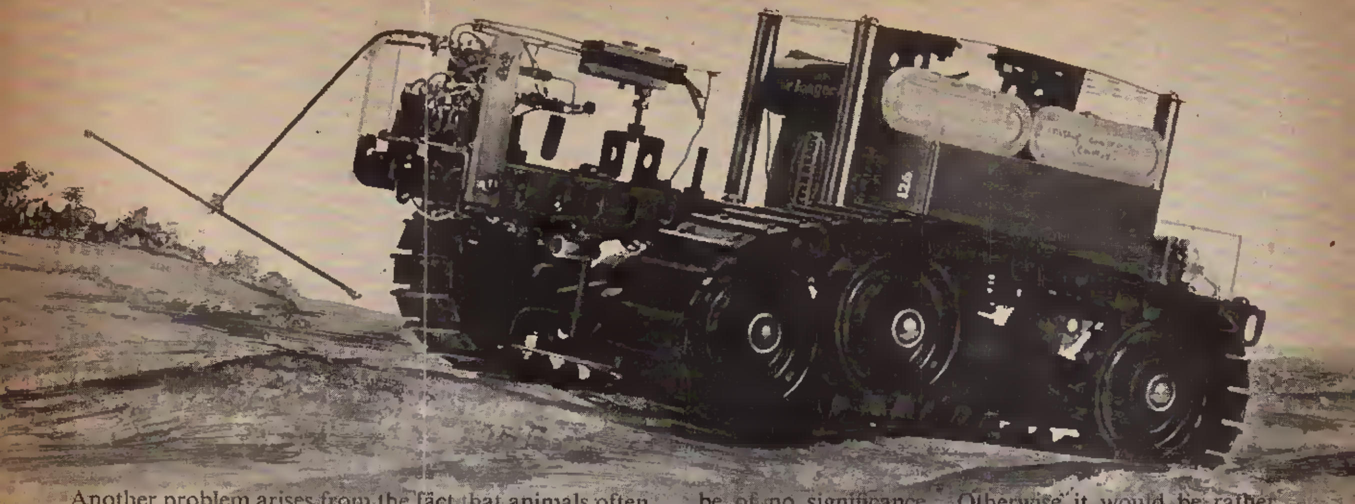
It is gratifying to discover that in our quest for information there are some short cuts that may be taken, so we can, as a cliché suggests "stand on the shoulders of giants". One of these "giants", Pavlov in fact, has already done a lot of ground work for us and it is to a large extent from this and other classical data that we shall draw our inspiration.

BLACK BOX ANALYSIS

In experiments designed to assess the reasons behind certain animal behaviours, "black box" principles have been used. This amounts to qualifying the animal and its brain as an unknown quantity and placing this in a hypothetical box with inputs and outputs. The notion being that if we have known inputs and measurable outputs, a relationship might be established between them which will tell us about the contents of the "box".

This method in principle is a good one, and probably the only one we can safely utilise, because any direct attempts to evaluate the brain and its peripheral equipment by way of surgery necessarily interfere with the animal's behaviour.

However, the black box analysis is not without certain pitfalls. One obvious difficulty is that no matter how many different inputs we apply, there may still remain further modes of response that the animal can produce; thus never giving us a complete look inside the "box".



Another problem arises from the fact that animals often produce responses from what seem to be a whole repertoire of possible actions; it is therefore sometimes impossible to be specific about outputs.

At present then, for our purposes at least, we must be content to base our reasoning along the lines of well tested and easily reproducible features of behaviour. Even then, actual design work must needs be largely based on experiment.

CONDITIONED REFLEX

One aspect of animal behaviour which should show us some rewards upon synthesis, is the conditioned reflex.

Reflexes, or more correctly reflex responses, are due to stimuli exciting certain sensory organs: they may for example be the result of light shone into the eyes, or a touch applied to some area upon the skin. These stimuli having excited a receptor cause nerve impulses to pass along the various neural pathways to the reasoning part of the brain, or cortex. Here they may interact with other types of sensory information either produced simultaneously or stored at some time in the past.

Now the reflex that concerns us is a special condition occurring as a result of the former variety, the conditioned reflex—let us call it R_c. To understand what it is and how it may be evoked, we must hearken back to Pavlov's early experiments.

Pavlov, who performed the conditioning experiments with hungry dogs, used food as a basic drive—this we shall call the "specific" stimulus S_s. The amount of saliva produced upon application of S_s was then measured. When the animals became hungry again, a further stimulus was included which would not normally cause salivation; this was a "neutral" stimulus in the form of sound, i.e. a bell. This we shall designate S_n.

Pavlov found that if S_n was applied shortly before S_s, and the combination repeated a few times, S_n would eventually produce salivation in the same way that S_s did. Hence the animals had *learnt* that the sound of the bell meant food. The neutral stimulus S_n had thus been conditioned to the specific stimulus S_s and so the result of applying S_n at future times was to elicit a conditioned reflex.

There are two important factors to remember if we require the stimulus combination to be successful in producing a conditioned reflex. Firstly S_n should occur *before* S_s *not after*; the reader will appreciate that there is little point in sounding the dinner gong after the meal has been eaten! The second fact is that assuming S_n occurs before S_s, it must be *just* before, or else it will be of no significance. Otherwise it would be rather like announcing lunch, two hours before it was served!

INHIBITION

So far, so good! But we have only considered the excitation mode of conditioning. What if we continue the application of S_n without the reinforcement of S_s? That is, ring the bell without feeding the animal.

The effect of course can be virtually predicted; the bell no longer signifies the coming of food, and so the conditioned reflex is inhibited. The animal therefore no longer responds to S_n. This state of affairs is generally referred to as extinction.

However, an interesting fact emerges from inhibition of this kind, in that it too can be inhibited. One easy way to bring R_c back is to re-establish the reinforcement (S_s).

There are more unexpected ways too: assume we take the case of a dog which, say yesterday, had its conditioned response extinguished. If today we re-apply S_n, back comes the conditioned response as strong as before; even more surprising is the fact that no matter how many times R_c is extinguished it will always re-appear. This "recovery" or disinhibition as it is called, seems to be the result of the inhibition placed upon R_c dissipating with time.

DISTRACTING STIMULI

Disinhibition can occur in an even more striking way, a way which in fact caused Pavlov no end of problems from quite a different point of view. During his experiments there were times when he found it difficult, often impossible, to condition the animals—and it was not long before he realised the cause.

Most of the experiments were conducted in an environment where the ambient noise level was relatively high, resulting in distracting stimuli which either inhibited the conditioning, or caused irrelevant conditioned responses. These strong "external" stimuli whilst inhibiting excitation, will also remove inhibition. Hence, if R_c has been extinguished it can be recalled by the simple expedient of introducing a powerful external stimulus.

With the conditioned reflex mentioned earlier, we considered only two kinds of stimuli. Of course, virtually any stimulus combination could be used, and as we proceed with the design of our electronic "animal" so its need to deal with more and more combinations (some of them quite unusual) will increase.

Next month: "Muscle" control and reflex response.

SENSITIVE D.C. VOLTMETER

This is the third project in our five-part series featuring the integrated circuit linear amplifier Type SL701C

Now that the inexpensive high gain silicon transistors are readily available, very small collector currents in the order of tens of microamps are often encountered in equipment, and a conventional multirange voltmeter may consume sufficient current to make voltage readings inaccurate. This article describes a d.c. amplifier which may be used to increase the sensitivity of a meter by ten or one hundred times.

VALUE OF INTEGRATED CIRCUIT

We could design and build a high gain d.c. amplifier using conventional components, but we might have a problem with drift in d.c. levels with temperature. The best solution would be to use an integrated circuit operational amplifier, where the manufacturer has already done the best he can to minimise offset voltage and drift, and where the very method of construction ensures that components are *inherently* excellently matched.

Until this point in our series on the use of the operational amplifier, we have only considered a.c. circuits, and have suggested that the d.c. level at the output of the amplifier will be almost zero. While this is true, since we now require a d.c. amplifier, we must investigate in more detail the reasons for this offset.

THE OFFSET VOLTAGE

The d.c. offset at the output of the amplifier is due to the following causes.

(a) Mismatch of the electrical characteristics of the amplifier; mainly the difference between base to emitter voltages and current gains of the two transistors which comprise the differential input pair, and also the mismatch between their associated collector resistors.

(b) The finite input current flowing through the series resistor in each input lead.

Since the magnitude of the offset will depend on the closed loop gain of the complete amplifier circuit, the parameters of the integrated circuit itself are always referred back to the input of the integrated circuit. If the amplifier were perfect each input would draw the same current and require the same base to emitter voltage, but in practice this is not so. The difference between the input currents is defined as the input offset current, while the input offset voltage is that voltage which has to be applied between the input terminals to obtain zero output voltage.

For a d.c. amplifier it is obviously important to know what output offset we must expect, and how to trim this out if required, but even for an a.c. amplifier the undistorted peak to peak swing of the output may be restricted if the d.c. steady state level of the output is appreciably unbalanced.

For the Plessey SL701C the parameters we require are:

Input base current (either side) = 3μA maximum
Input offset base current = $1{\cdot}8\mu$A maximum
Input offset voltage = 25mV maximum

These are maximum figures, and typical figures are less. By inserting the appropriate figures in the formulae to be considered next we can obtain typical or maximum values, but we have only used the maximum values for our examples. For completeness we first consider the offset of an a.c. amplifier.

OFFSET VOLTAGE OF AN A.C. AMPLIFIER

For the amplifier it does not matter if we use the inverting or non-inverting configuration, the d.c. conditions are idential. In the example of Fig. 1 we have a 100 kilohm resistor from the non-inverting input to earth and a 10 kilohm resistor from the inverting

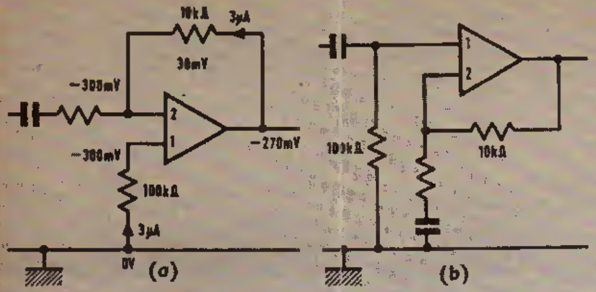


Fig. 1. The offset voltage at the output of a typical a.c. amplifier, due solely to unequal source resistors. (a) inverting, (b) non-inverting configuration

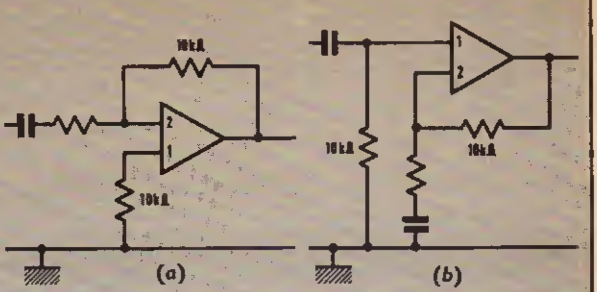


Fig. 2. The method of minimising initial offset by making the input source resistances equal. (a) inverting, (b) non-inverting configuration

input to the output. The output is assumed to be a low impedance point so that the effective source resistance for this input is 10 kilohm.

If we assume for the moment that there is no offset voltage and no offset current for the integrated circuit, we can work out the possible offset voltage. Input 1 draws up to 3μA through 100 kilohms and so can be up to 300mV below earth potential. If there is no offset voltage between the two inputs (in any case the maximum value of 25mV we might have is small compared with 300mV) then input 2 must also be at -300mV.

Since input 2 also draws 3μA, the 10 kilohm resistor will have 30mV across it and the d.c. level of the output will have to be at -270mV to maintain these d.c. conditions. We thus have an output offset voltage of 270mV *solely* due to the different source resistors for the two input. If we now take offset voltage and current into account this could increase or decrease this value depending on the relative polarities.

Unless we specifically need the high input impedance of 100 kilohms for the non-inverting configuration we can minimise this offset due to unequal source resistors by making the resistors equal, as in Fig. 2.

In the inverting configuration it might be advisable to decouple the non-inverting input to earth, both to prevent capacitive pickup which might cause positive feedback and also to help maintain closed loop h.f. stability. This is especially important if a high value of source resistance is used, as in Fig. 3.

INITIAL OFFSET

If the source resistors are made equal so that the effects of input base currents through the input resistors are approximately self cancelling, then the initial offset (it depends now on the offset current and offset voltage) may be calculated. The offset due to current is given by the input offset current multiplied by the source resistance, for our example of Fig. 2, this becomes: Offset due to current $= 1{\cdot}8 \,.\, 10^{-6} \,.\, 10 \,.\, 10^{3} = 18$mV

We are better off with low values for the source resistors rather than high ones.

From the d.c. point of view any offset voltage at the input is amplified unity times, so that the possible total offset is:

$$\text{Total offset} = \text{offset due to current} + \text{offset due to voltage}$$
$$= 18 + 25\text{mV} = 43\text{mV}$$

We can place these results into a general formula for future reference, and need the Fig. 4. The offset voltage has been shown as an addition to the non-inverting input while the current offset has been shown as a current which in effect flows out or into the inverting input and through the feedback resistor. We have equal source resistors for both inputs, and I_d is the current offset and E_d the voltage offset. Total offset = current offset $\times R$ + voltage offset.

$$E_0 = I_d\, R + E_d. \quad \textit{A.C. amplifier}$$

OFFSET VOLTAGE OF A D.C. AMPLIFIER

For a d.c. amplifier we have a similar situation, but the offset voltage of the integrated circuit is amplified by the overall gain of the complete circuit (Fig. 5).

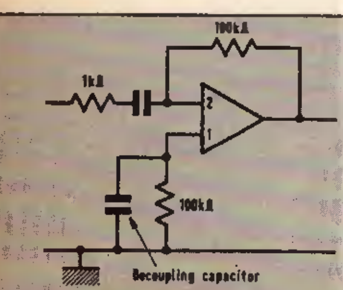


Fig. 3. For the inverting configuration, the non-inverting input may need to be decoupled to prevent instability

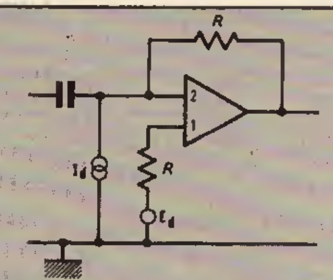


Fig. 4. The circuit diagram for the calculation of offset of an a.c. coupled amplifier, showing conditions of minimum offset

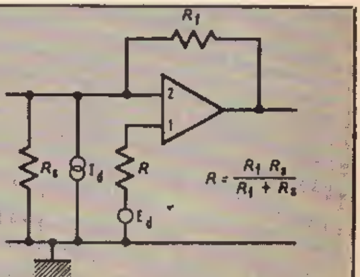


Fig. 5. Theoretical circuit diagram for offset calculations for a d.c. coupled amplifier, showing conditions for minimum offset

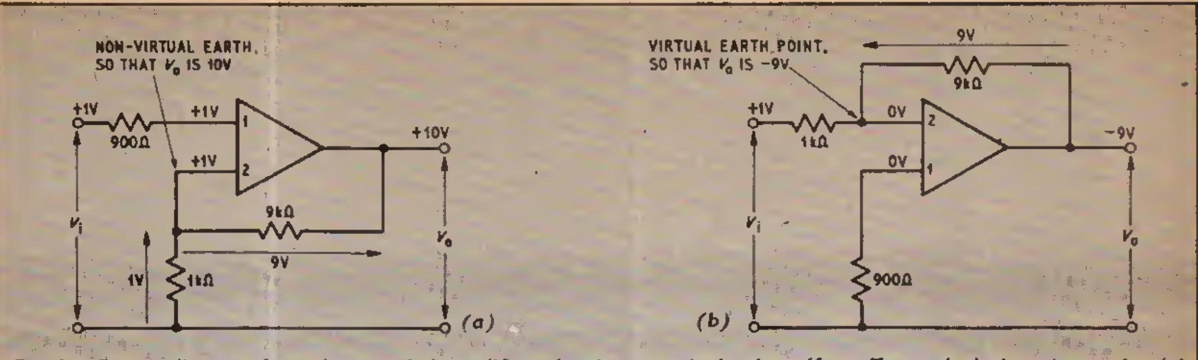


Fig. 6. Circuit diagram for a d.c. coupled amplifier, showing practical values (for offset calculations in text). (a) non-inverting, (b) inverting configurations

In this case to maintain the same source resistance for each input, the resistor R has to be made equal to the resistance of R_s and R_f in parallel.

$$R = \frac{R_f R_s}{R_f + R_s}$$

If we consider the practical d.c. amplifier of Fig. 6, we can arrive at our d.c. offset. From the point of view of the feedback both circuits are identical, but from the signal point of view we obtain different gains because of the slight difference in how the signal is applied. For the non-inverting configuration the input adds to the voltage developed across the feedback resistor, while for the inverting configuration this does not happen.

For Fig. 5 or Fig. 6 the total offset voltage is given by:

$$E_0 = E_d\left(1 + \frac{R_f}{R_s}\right) + I_d R_f \quad \textit{D.C. amplifier}$$

In the case of Fig. 6 this becomes:

$$E_0 = 25(1 + 9) + 1{\cdot}8.10^{-6}.9.10^3$$

$$= 250 + 16{\cdot}2\text{mV} = 266{\cdot}2\text{mV}$$

For a.c. amplifiers where the d.c. offset might reduce the available swing or for d.c. amplifiers where we require 0V out for 0V input, we will wish to balance out any offset.

AMPLIFIERS WITH OFFSET BALANCING

The best type of circuit chosen to balance offset depends on the impedance of the signal source. For low impedance sources (say up to 5 kilohm) the circuits of Fig. 7a or b are suitable.

In Fig. 7a since we have a control to balance offset, the low value resistor from the non-inverting input to earth may be omitted. R3 is chosen to be much greater than R1 and the range on the potentiometer is chosen so that the gain from point X (of R_f over R3) to the output is sufficient to balance out the expected offset. For Fig. 7b VR1 is chosen to be much greater than R1, while the high value resistor to the h.t. line is chosen to give a suitable range.

For a high impedance source acting as a current generator, it would be better to use the circuit of Fig. 8. To give sufficient range on the potentiometer the values are chosen so that the potentiometer value is 1·5 times R2 while the series resistor is 0·5 of R2. This gives (for R2 of 47 kilohms) a potentiometer value of 70 kilohms and a series resistor of 22 kilohms, so that using 100 kilohms with a series resistor of 22 kilohms should give more than enough range.

Now that we have dealt, in general, with d.c. amplifiers and balancing, we can go on to consider our current amplifier.

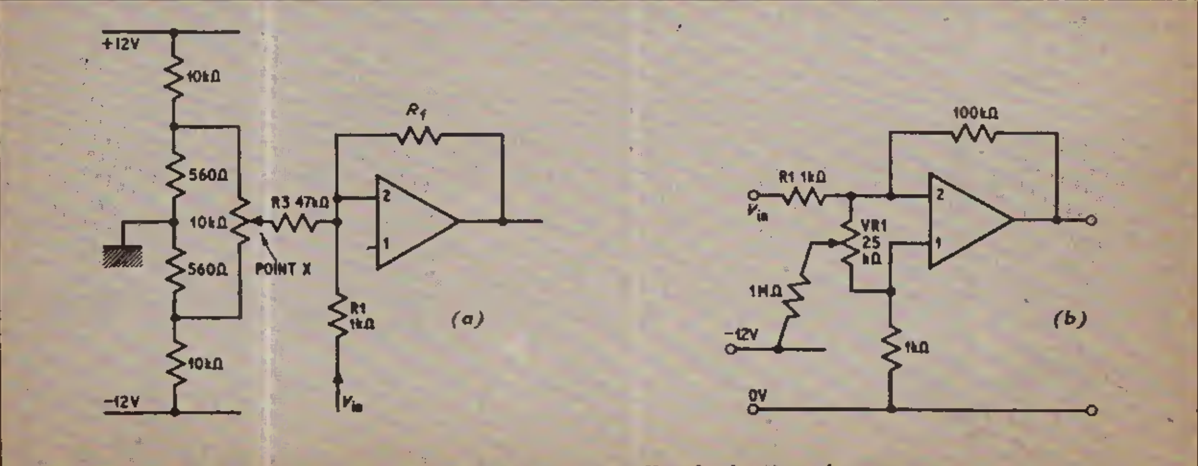


Fig. 7. Two methods of balancing out offset for low impedance sources

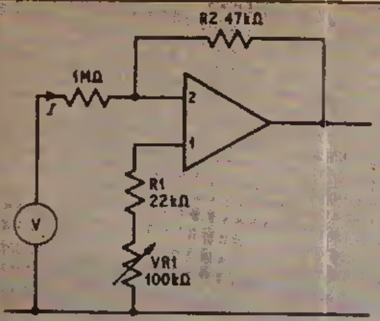


Fig. 8. Balancing method for a high source impedance

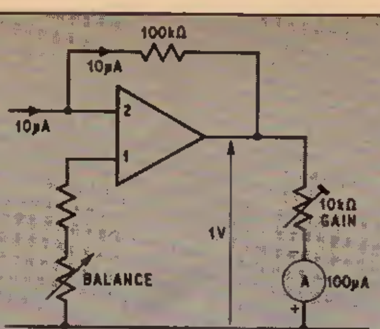


Fig. 9. One possible arrangement for a ten times current amplifier for a meter

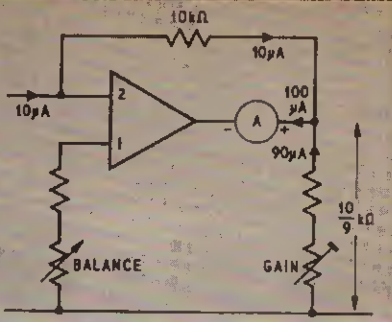


Fig 10. An alternative and less critical arrangement for a current amplifier

THE CURRENT AMPLIFIER

We would use a circuit like Fig. 8 to give us the gain we require, and a suitable circuit for a 100µA meter and times ten gain is given in Fig. 9.

An alternative approach is Fig. 10, and this was adopted because it has the advantage that the meter resistance does not enter into the calculations for current gain, and once the circuit is set up we could replace the 100µA meter by another meter of known sensitivity and still expect its sensitivity to be multiplied by ten times.

The complete finalised amplifier circuit is shown in Fig. 11. R7 is included in series with the meter to limit the maximum current, while R8 is shunted across the meter to complete the d.c. path for the amplifier if the meter is removed. R8 need not be added for a permanently wired in unit. C1 rolls off the amplifier response at a low frequency and prevents any possible difficulties due to h.f. instability.

CONSTRUCTION

The form of construction given in this article follows the pattern set by the previous projects in this series. The integrated circuit IC1 and most of the discrete components are mounted on a piece of perforated s.r.b.p. This board is secured to the die-cast box, using extra nuts or spacers to provide clearance between the metal and live points on the circuit board. The box should have already been drilled to accommodate the sockets, feed-through terminals and the potentiometer VR1. All essential details can be obtained from the diagram Fig. 12 and the accompanying photograph.

Individual constructors may wish to use a larger box so that the meter can be built-in with the electronics. The battery could also be accommodated within such a larger box, thus achieving a single, self-contained piece of test gear.

SETTING UP

For this circuit using a 100µA meter and a times 10 gain (to give 100 kilohms volt sensitivity) the input offset for the amplifier will be up to 1·8µA. When this is multiplied by our gain of 10 times it becomes ±18µA as a maximum value, which is still small in comparison with our f.s.d. of 100µA.

In our instrument we used a balance control of 10 kilohm and suitable series resistor to give a control range of ±6µA. While this was adequate, it is quite small, and it would be preferable to use a 25 kilohm potentiometer to give more range. The series resistor R4 can then be chosen so that the potentiometer gives a control centred about zero.

Since the 10V range is probably the most useful one, the instrument was set up by applying a known voltage

SENSITIVE D.C. VOLTMETER CIRCUIT

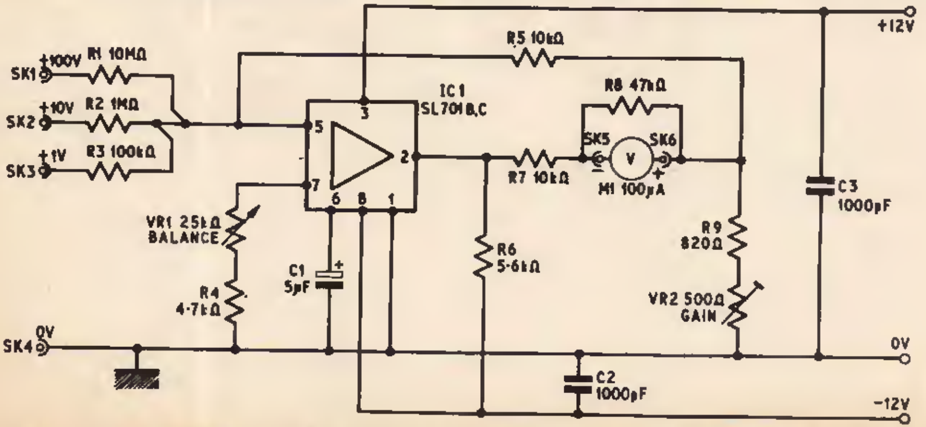


Fig. 11. The complete circuit for ten times current amplifier for a 100mA meter with appropriate resistors to give 1V, 10V, and 100V f.s.d.

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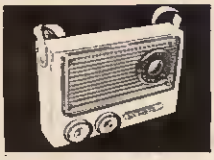

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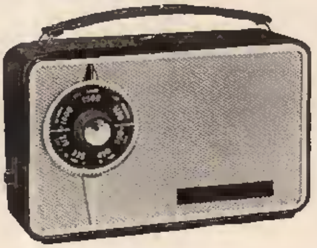

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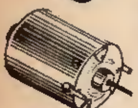

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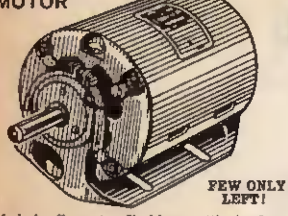

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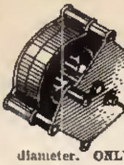

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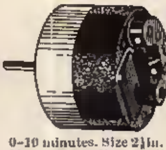

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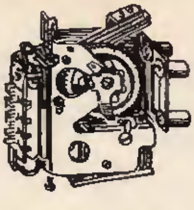

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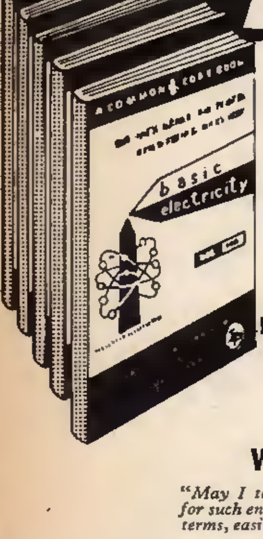

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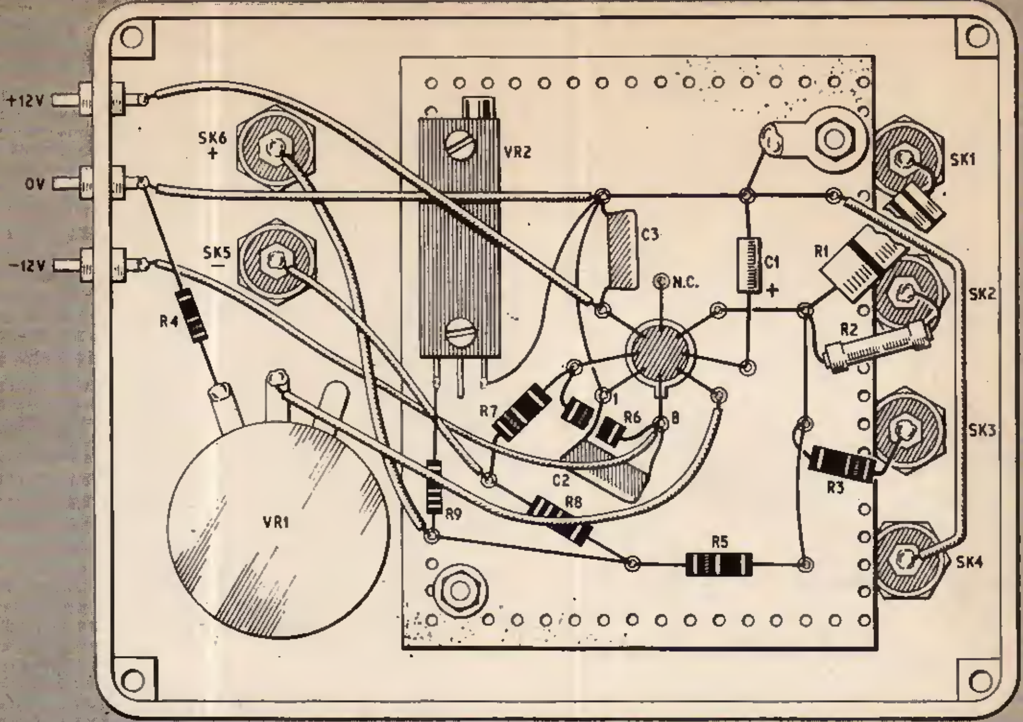
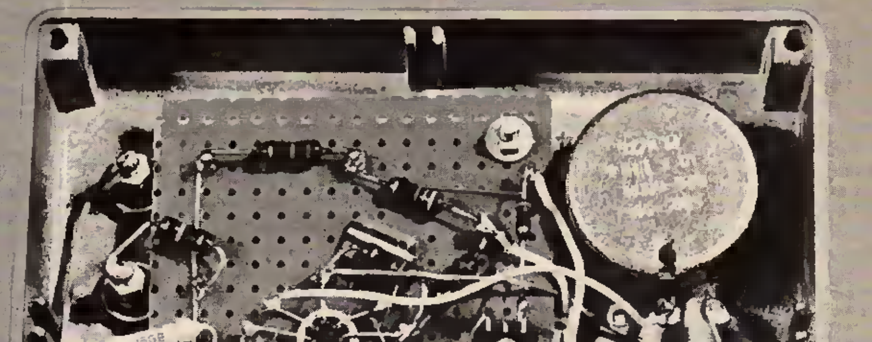


Fig. 12. Layout and wiring of the d.c. voltmeter amplifier

IC1



COMPONENTS . . .

Resistors

R1	10MΩ	5% H.S.
R2	1MΩ	5% H.S.
R3	100kΩ	5% H.S.
R4	4·7kΩ	10% carbon
R5	10kΩ	5% H.S.
R6	5·6kΩ	10% carbon
R7	10kΩ	10% carbon
R8	47kΩ	10% H.S.
R9	820Ω	10% H.S.

Potentiometers

VR1	25kΩ carbon
VR2	500Ω preset (Radiospares)

Capacitors

C1	5μF elect. 12V
C2	1,000pF ceramic
C3	1,000pF ceramic

Miscellaneous

IC1	Linear integrated circuit (d.c. coupled amplifier —SL701C). (Available direct from the makers: The Plessey Co. Ltd., Components Group, Cheney Manor, Swindon, Wiltshire. Price: 18s)
M1	Moving coil meter, 100μA f.s.d.
SK1-6	4mm sockets, and matching plugs (Radiospares) 6 off

Die-cast box 4¾in × 3¾in × 1in (Electroniques 46R.043A, but see text)
Perforated s.r.b.p. 3in × 2⅜in
Three insulated feed-through terminals
Control knob
6B.A. screws and nuts

on this range and adjusting VR2 until the meter read correctly. On the 10V or 100V ranges the instrument can be zeroed with the input open or short circuited since the input resistance (1 megohm or 10 megohm) is high enough in comparison with the 10 kilohm feedback resistance to not affect balance conditions. On the 1V range this is not quite so, and there is a shift of 2 per cent of f.s.d. between open and short circuit conditions. For the most accurate results this range should be zeroed with the leads short circuited.

Once the zero is set, drift is negligible, and only very occasional adjustment is required.

SOME POSSIBLE MODIFICATIONS

(a) Range Extensions

Although the amplifier is intended as an addition to increase the sensitivity of a single or multirange meter, it could be constructed as a complete d.c. voltmeter (see also under "Construction"), and a meter scaled 0–1 and 0–3 could be employed with advantage to give ranges of 1, 3, 10, 30, 100V f.s.d. (making the 300 kilohm resistor up out of 120 kilohm and 180 kilohm in series, and making the 3 megohm resistor up out of 1·2 megohm and 1·8 megohm in series).

(b) 1mA Meter Increased to 100μA f.s.d.

The meter series resistor should be decreased to 1 kilohm and the input resistors chosen at 10 kilohms/volt.

(c) 1mA Meter Increased to 10μA f.s.d.

Again the series resistor should be decreased to 1 kilohm, the input resistors need to be chosen at 100 kilohms/volt. To obtain this current gain of 100 times VR2 has to be reduced to 100 ohms and R9 reduced to about 47 ohms. The maximum offset is 180μA which is ⅕ f.s.d. and the existing balance control values should still be suitable.

(d) 100μA Meter Increased to 1μA f.s.d.

The meter series resistor should be left at 10 kilohm, while the input resistors have to be chosen at 1 megohm /volt. VR2 has to be reduced to 100 ohms with R9 at 47 ohms. The maximum offset is now 180μA, which is well over f.s.d., and there will be some difficulty in zero setting. One solution would be to retain the 25 kilohm potentiometer and series resistor but add an extra 1 kilohm potentiometer in series as well, the former becomes the coarse zero with the latter the fine zero. A more elegant solution would be to use a helical potentiometer of 10 kilohms with a suitable series resistor chosen to give a balance about zero.

Once set, the balance is reasonably stable with temperature, and would only need to be adjusted every (say) ten minutes, the difficulty is that a single turn potentiometer does not have sufficient resolution, rather than that the circuit drifts with temperature!

Next month: A fixed frequency sine wave test oscillator, based on the same type IC.

Hi Fi TRANSISTOR MICROPHONE

By H. E. OWENS

A Hi Fi Microphone that can be used with 100ft of cable without electrostatic or magnetic interference

Crystal microphones are generally viewed with scorn in the hi-fi fraternity, an image well deserved by the majority. For while some of the more carefully designed examples are capable of natural, wide range reproduction and, price for price, can be superior to dynamic types, there remains one serious disadvantage: the capacitative nature of the crystal element limits the length of the output lead to a maximum of about 10ft. More than this will progressively attenuate the signal.

Also, a very high input impedance is required of the associated amplifier to achieve full bass response, and because of this the circuit becomes sensitive to electrostatic hum pick-up and cable-handling noises. To add to our difficulties, the better the acoustic quality of the microphone, the lower will be its output!

F.E.T. PRE-AMPLIFIER

This article describes the construction of a low-noise f.e.t. pre-amplifier designed to do justice to the wide response of a specified crystal microphone insert, and physically small enough to be mounted as an integral unit with the insert and battery in a convenient metal tube.

Used in this way, it completely overcomes hum pick-up and permits the use of a long output cable, but it can alternatively be housed in a larger case and equipped with an input socket for use as a general purpose audio booster having a voltage gain of at least 25 (28dB), suitable for feeding valve or transistor equipment. It will handle inputs of up to 50mV and the frequency response is flat from 10Hz to 100kHz.

CIRCUIT DESCRIPTION

The circuit (Fig. 1) consists of a common-source f.e.t. stage, TR1, having an input impedance of around 5 megohms (recommended value for the insert used), direct coupled to an emitter follower, TR2. This has a voltage "gain" of slightly less than unity but, because of 100 per cent negative feedback, reduces the signal impedance to less than 2 kilohms.

The input series resistor R1, in conjunction with the gate-to-source capacitance of the f.e.t., forms an r.f. stopper. This was found to be necessary when using the prototype next door to a radio taxi base station, when broadcasts persisted in breaking through despite the excellent linearity of the f.e.t. and the screening properties of the tube.

With this potential source of trouble overcome, the microphone is immune to all forms of interference—both electrostatic and magnetic. To prove the point, the prototype has been tested alongside a high-power radio transmitter, sitting on top of a transformer carrying 500W, and feeding a tape recorder through 100ft of unscreened flex.

BATTERY SUPPLY

Current drain is less than 0·5mA and the circuit will operate consistently to a supply end-point of 15V, thus obtaining good service life from the 22½V battery. Resistor R5 provides a charging path for C2.

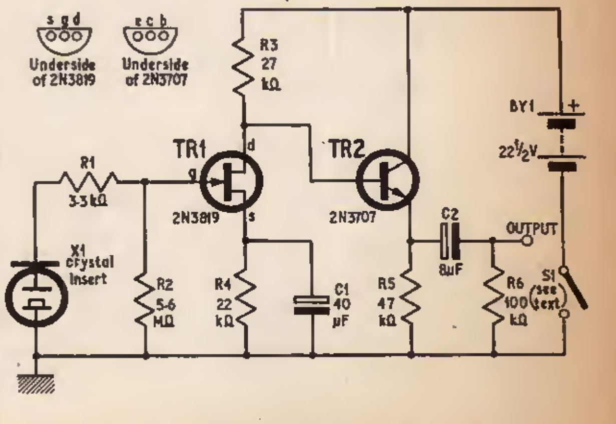


Fig. 1. Circuit diagram of the transistor-amplified microphone. The source, gate and drain of the f.e.t. (TR1) correspond functionally to the emitter, base and collector, respectively, of conventional bipolar transistors

COMPONENTS . . .

Resistors

R1	3·3kΩ	R4	22kΩ
R2	5·6MΩ	*R5	47kΩ
*R3	27kΩ	R6	100kΩ

All 10%, ⅛W carbon. *R3 and R5 should be low noise types

Capacitors

C1	40μF 6V elect.
C2	8μF 12V elect.

Transistors

2N3819 n-channel field effect transistor
2N3707 npn silicon
} Texas Instruments.

Insert

X1 Acos 39/1 crystal (Henry's Radio)

Miscellaneous

Tube: brass, copper or brass-clad steel, ⅞in bore × approx. 4½in long. Steel strip, approx. 8in long × ¼in wide. Cartridge-type connector. Polyshrink tube No. 50 if required (black or white, sold in multiples of 1ft), Home Radio. Piece of Veroboard, 1¼in × ¾in. 4B.A. solder tag. Thin p.v.c. flex.

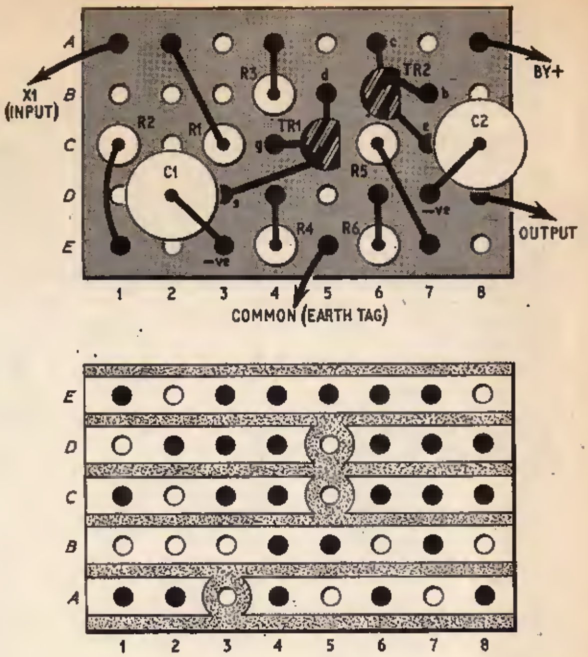


Fig. 2. Component layout and underside of the board with connection details to other components.

From the stability point of view, no capacitor is required across BY1. But as a safeguard against the occasional battery that causes frying noises as it nears the end of its life, a 10μF 25V electrolytic could be connected between holes *A7* and *E8* on the circuit board (see Fig. 2), with the positive end taken to *A7*. This measure was found to be necessary with only one of the large number of batteries that died prematurely while voltage and current adjustments were being made to the prototype, and was therefore omitted.

AMPLIFIER CONSTRUCTION

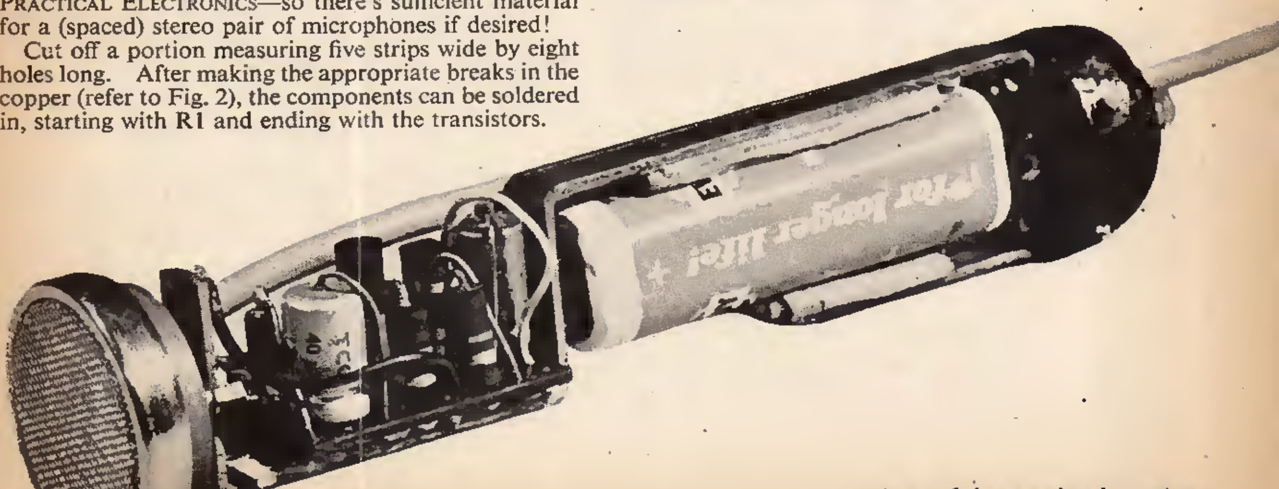
The amplifier occupies exactly half the length of the Veroboard presented with last month's issue of PRACTICAL ELECTRONICS—so there's sufficient material for a (spaced) stereo pair of microphones if desired!

Cut off a portion measuring five strips wide by eight holes long. After making the appropriate breaks in the copper (refer to Fig. 2), the components can be soldered in, starting with R1 and ending with the transistors.

To ensure the finished assembly will go into the tube, all component leads must be cut to the absolute minimum and solder blobs, rough ends, etc. should be filed away from the underside of the board.

It is important that the amplifier board be insulated from the S-shaped sub-frame, this prevents the copper strip on the underside of the board from being shorted out. This is best accomplished by cutting out a piece of cardboard, or any plastics material, the same size as the wiring board and glueing it between the underside of the wiring board and sub-assembly chassis.

If the amplifier is to be tested before making up the rest of the microphone, use an earthed tobacco tin or something similar to screen the input.



View of the completed transistor microphone prior to insertion in the metal tube. It is important to insulate the amplifier board from the metal sub-assembly.

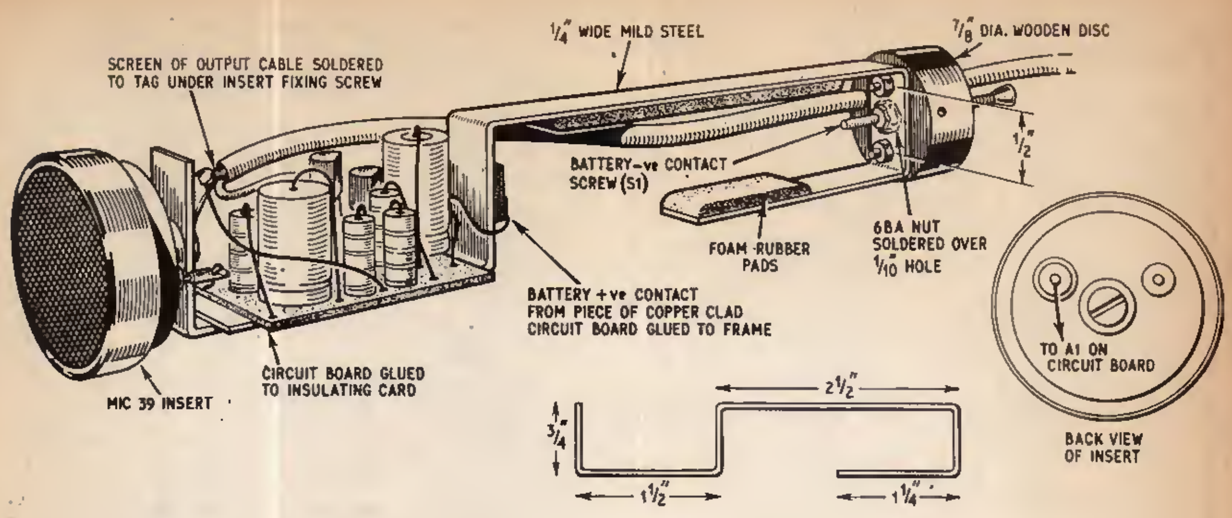


Fig. 3. Construction of the transistor microphone, with battery and metal cover removed

MECHANICAL CONSTRUCTION

The drawings (Figs. 2 and 3) and photographs give most of the constructional information necessary. The amplifier and battery are mounted on an S-shaped sub-frame of mild steel, carrying the microphone insert at one end and a circular block of wood plus a made-up on/off "switch" at the other (Fig. 3). The case is a ⅞in i.d. thin-walled steel or copper tube (it must of course be metallic) secured by two screws into the wood block. The tube is grounded by contact with the rim of the insert.

The length of the sub-frame, and the quantity of strip needed to make it, is a little unpredictable because the radius of the bends will vary from one constructor to the next. Start with slightly more strip than necessary and cut off the excess after making the final bend. After drilling the appropriate holes and attaching the insert and wood disc, the assembly can be measured and the tubular case trimmed to size.

The wood disc in the prototype was cut with a hacksaw from a piece of whitewood ¾in thick and filed to shape, but constructors who take pride in their carpentry or who own a lathe will no doubt use their own methods.

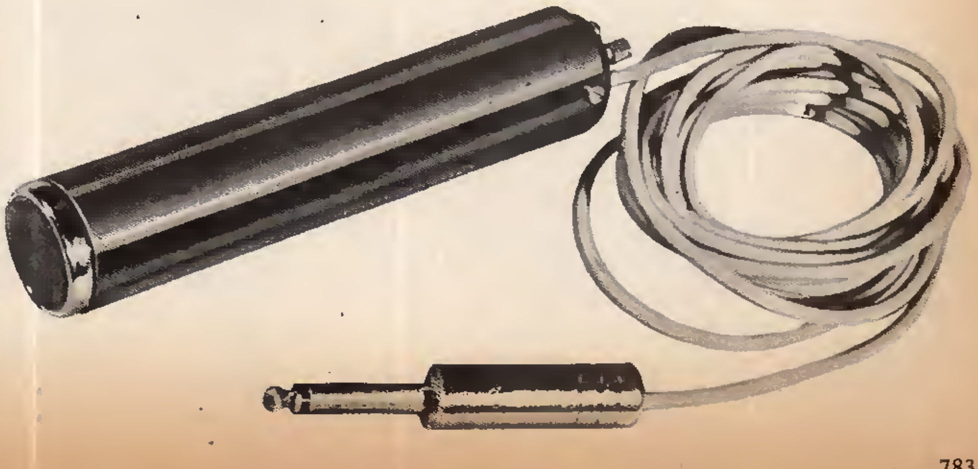
FITTING THE INSERT

When connecting the amplifier to the insert on no account make a direct soldered connection, because the heat will immediately dissolve the crystal. Use a gramophone cartridge type connector, or trap the lead under a piece of plastic sleeve pushed over the "live" post. Note that the "earth" pole is integral with the case and need not be used, as continuity is achieved via the central fixing screw and 4B.A. tag.

FINAL FINISH

Various finishes are possible. The tube can be given a "satin" finish by twisting it in a wad of wire wool and protecting with a couple of coats of clear lacquer, or it can be painted.

For the sake of trying a new material, the prototype was sheathed in black "Polyshrink" (available from Home Radio), which is a soft plastics tubing that shrinks dramatically when heated. The correct size is No. 50, suitable for covering objects of 0·8in to 1·25in diameter. A particular advantage of the material is its ability to damp handling noises.



View of the completed transistor microphone

USING THE MICROPHONE

Before setting up the completed unit for trial one most important point must be noted. The amplifier will not function until the contact adhesive used to attach it to the sub-frame is completely dry. The prototype produced a terrifying rumbling noise caused by leakage through the damp glue from the supply line to the high impedance input, and had to be left overnight for the noise to subside.

The specified insert is "pressure operated" and therefore non-directional over most of the frequency range. At higher frequencies however, it has a greater sensitivity to sounds arriving directly on axis, which can be useful in balancing the "presence" of individual voices or instruments.

Average male speech at a distance of 12in from the microphone produces a peak level of about 70mV at the amplifier output, and at 3ft an upright piano (played forté) produces 400mV, so that normally the microphone will be used in the line, or radio, socket of a recorder or amplifier.

Fig. 4 shows a simple attenuator to prevent overloading the first stage of tape recorders having only a microphone socket. Without the attenuator, the output is sufficient to feed a simple passive mixer.

Although the output impedance of the microphone is effectively 2 kilohms so far as immunity to electrostatic hum pick-up on the line is concerned, it should not be operated into a load of much less than 5 kilohms. Doing so will cause distortion on peaks and bass loss through C2.

Fig. 4. An attenuator to prevent overloading of recorders that have only a low-level microphone socket. With Rb = 2·7kΩ, Ra should be around 22kΩ for valve recorders and 220kΩ for transistor models. Components should be at the recorder end of the microphone output cable, and can probably be mounted inside the plug

PERFORMANCE DETAILS

Judged subjectively the microphone has a most satisfactory performance, with a noise level far lower than could be achieved with the same insert feeding a typical valve pre-amplifier. The maker's literature for the 39/1 insert quotes a frequency response flat from 40Hz to 15,000Hz, with a broad peak of 5dB at about 8·5kHz. Played through wide-range equipment, the peak is noticeable as a slightly metallic quality on orchestral instruments, but this is the only clue to the "economy" nature of the device.

The battery should last at least six months, used for an hour every day or for eight hours each weekend. Expressed another way, 3s worth of energy will allow recording of 120 7in reels of l.p. tape at 7½in/sec. The complete transistor microphone with battery and flex costs less than £2 10s.

★

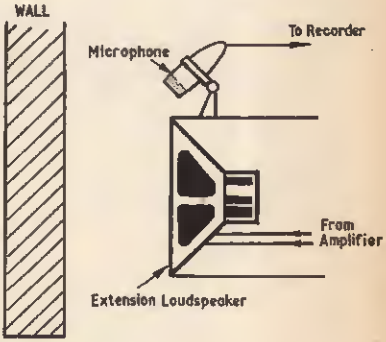
UNLIMITED!

A selection of readers' suggested circuits. It should be emphasised that these designs have not been proven by us. They will at any rate stimulate further thought.
This is YOUR page and any idea published will be awarded payment according to its merit.

PHASE SPEAKER

After reading the article in Practical Electronics on Musical Phase, September issue, I thought my method of making phased recordings may be of interest.

The signal to be phased is amplified in the normal way, but the output is fed into an extension speaker with the microphone of a tape recorder mounted as shown in the diagram below.



With the selected programme playing and the tape recorder on record the speaker and microphone are moved towards and away from a sound reflecting surface.

When the speaker and microphone are one foot away from a wall the microphone picks up sound from the speaker only. But when the two are moved closer to the wall, sound reflected off the wall, which is out of phase, is also picked up.

The only problem with this system is that the recording level on the tape recorder has to be decreased as the gap between the wall and speaker/microphone diminishes.

G. Stratton,
Dawlish, Devon.

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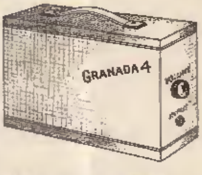

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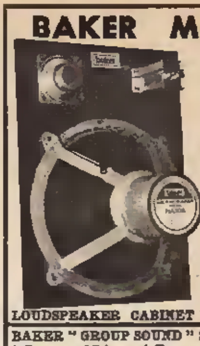

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OTIS KING
SLIDE RULE

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.

NEW HI FI CENTRE

A high quality mains powered integrated transistor stereo amplifier and pre-amplifier has just been introduced by **Audio Components and Services,** Sound Studios, Bell Hill, off Crown Hill, Croydon, Surrey.

A printed circuit board complete with heatsinks and control mounting together with a circuit diagram is available at 50s. Components as required, or the whole project in kit form, are available at £12.

There are six transistors in each channel and an output of 6½ volts into 8 or 15 ohm loads is achieved from 250mV input. Input impedance is 800 kilohm and will accept up to 4 volts without overloading. All measurements are r.m.s.

A selector switch provides for gram., radio and tape positions and there is a tape take-off socket. The tone control circuits are similar to that shown in the P.E. data booklet *Transistor Circuits* (see April issue).

It is claimed that the amplifier can be constructed in six hours using a d.c. voltmeter and the usual constructional tools.

Readers in the Croydon area may also be interested to learn that Audio Components and Services intend to develop the second floor as a large service department specialising in audio service and applications. Also, if there is sufficient interest, space and facilities could be made available for enthusiasts for increasing the scope of their hobby.

NON-WALK FEET!

The term self-adhesive, high friction, and odourless is given by **West Hyde Developments Ltd.,** 30 High Street, Northwood, Middlesex, to their range of small feet for instrument cases. They are made in a non-plasticised, resilient, high hysteresis material, having a high friction coefficient—their description, not ours.

Suitable for instrument cases, domestic equipment, radios, drawer bumpers, etc., these feet are self-adhesive or screw fixing or both and will not mark or discolour the surface they are placed on. The feet measure ⅝in diameter by ⅜in high, with a recessed countersunk hole for a 6BA screw in the centre.

It is claimed that if the feet are fixed to a case which is temporarily placed on a sloping surface it will not slip or walk.

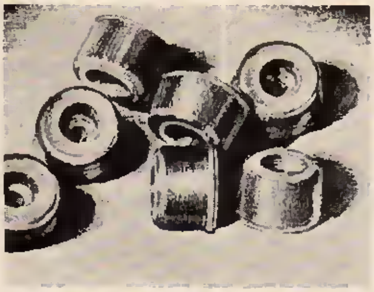
EMERGENCY LIGHT

A portable lamp with bright all-round illumination has a multitude of uses around the home, is indispensable when camping and is a useful accessory for the "shack" in case of power failure.

The Tildawn hurricane lantern, powered by standard dry batteries, provides just such a light from a 5in high virtually unbreakable polypropylene dome. Very stable when standing on its wide base, it will also hang by the handle, body inverted with the globe downwards, or horizontal with the base flat against a wall. Designed to withstand rough treatment, this robust lamp can be dropped or even thrown across the floor without apparent damage. Takes one or two AD28 or similar batteries, giving up to 50 hours illumination.

The Tildawn Lantern retails at 32s 6d plus batteries and is available from electrical stores. In case of difficulty contact the sole distributors, **Harris Marketing,** 16 Hillcroome Road, Sutton.

Belling Lee miniature terminal



Instrument case feet by West Hyde Developments

Hurricane lantern marketed by Harris Marketing

MINIATURE COMPONENT

A series of miniature terminals, no thicker than a pencil, with a current rating of 10 amperes and a breakdown voltage greater than 4kV d.c., is announced by **Belling and Lee Ltd.,** Great Cambridge Road, Enfield, Middlesex.

Known as type L1726, these new terminals are only a quarter the size of standard terminals but have all the same features. These include a captive head available with a choice of six standard colours, a socket in the top for plugging in connections to extra equipment, and a cross-hole in the clamping gap which will accept wires up to 15 s.w.g.

The moulded panel bush is keyed to prevent rotation. The stem terminates in an integral solder pin for rear panel wiring.

LITERATURE

A new Catalogue No. 137 describes the complete range of products manufactured by Arcoelectric Switches Ltd.

Divided into seven sections, covering transformer signal lamps, switches, neon indicators, and signal lampholders, etc., the catalogue lists numerous new styles and the section on car switches and indicators has been expanded.

Copies of the new 76 page catalogue can be obtained from **Arcoelectric Switches Ltd.,** Central Avenue, West Molesey, Surrey.

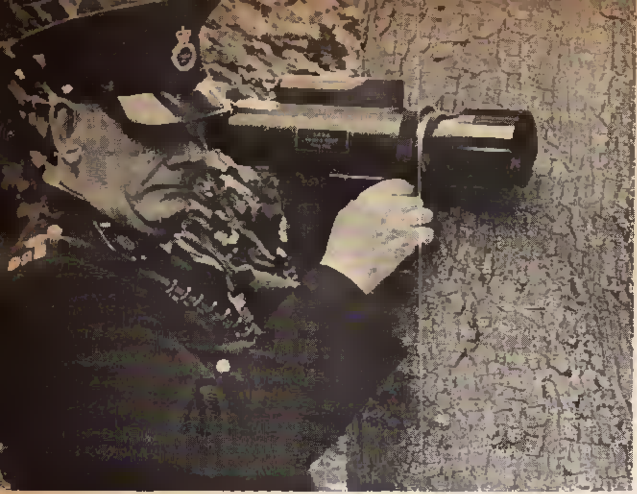
NOTICES

LST Components inform us that due to an enormous response to their advertisement all stocks of Texas reject transistors were exhausted with the publication of the September issue.

Unfortunately, due to an error the advertisement in the October issue was not corrected and the same item was repeated.

The manufacturers of Timac automatic timer switches, **Kangol Ltd.,** have appointed **Electroniques,** Edinburgh Way, Harlow, Essex, as distributors of their timing controls.

Both the 3-pin plug-in types and the permanent wired-in versions are now stocked for immediate dispatch from Electroniques.



A police observer using a hand-portable passive sight infra-red viewer

INFRA-RED COMMUNICATIONS

By M. A. COLWELL

INFRA-RED radiation occurs in similar form as visible radiation, but occurs in that part of the electromagnetic frequency spectrum below visible light (see Fig. 1). Therefore it has the properties of wavelength and frequency just as visible light has, but because its wavelength is longer, it is not visible to the naked eye.

However, light from tungsten filament lamps contains a very high proportion of infra-red (about 90 per cent) and is useful for experimental and industrial work whereby, with the use of filters, the visible light can be made invisible (Fig. 2).

When the wavelength of any kind of electromagnetic radiation becomes very short, i.e. for frequencies above about 3,000 megahertz, it is more convenient to refer to wavelength in microns, micrometers or Ångstroms. The infra-red region lies in the 0·75 to 10^3 microns range, one micron being equal to one 10^{-6} metre, although the division between infra-red and microwave frequencies is not clearly defined.

This region is further sub-divided into "near" (0·75 to 1·5 microns), "intermediate" (1·5 to 10 microns) and "far" (beyond 10 microns) regions, while above 300 microns it is often referred to as the "submillimetre" region.

PROPERTIES OF INFRA-RED

Electromagnetic radiation in the infra-red region is sometimes able to penetrate objects which would otherwise stop visible light. Here it is important to think of it as radio waves which pass through physical obstructions, whereas visible light requires line of site communication.

This property is extremely useful, as we shall see later, in that an infra-red beam can be directed to a given point without being seen. High power lamps can be used here with a black opaque screen to cut off visible light rays. Clear glass will pass all visible light but will only pass near infra-red rays up to about 2·5 microns.

If transmission in the intermediate and far infra-red regions is required certain semiconductor materials can be used. Up to recent times germanium and silicon have been used, but now gallium arsenide is proving very valuable.

It is possible to detect infra-red by absorption and conversion of heat. However, this can be a cumbersome process, as was shown by early experiments where a blackened thermometer was used.

More lately, thermocouple detectors or photoconductive cells were made to respond over a wide frequency range, then perhaps filtered as required. This method is disadvantageous because the response to temperature changes in the transmitting object were too slow.

Current developments illustrated in this article show examples of detection of pure infra-red radiation from natural sources ("passive") and reflected radiation dependent on an infra-red beam being bounced off an object ("active").

CARRIER WAVE

There is now a new line of thinking based on the active system whereby the transmitted infra-red can be used as the carrier wave for pulse code frequency

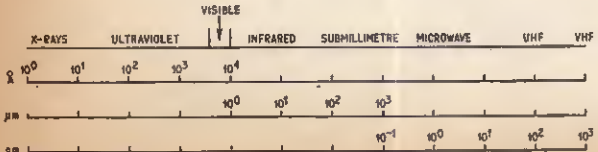


Fig. 1. Electromagnetic spectrum

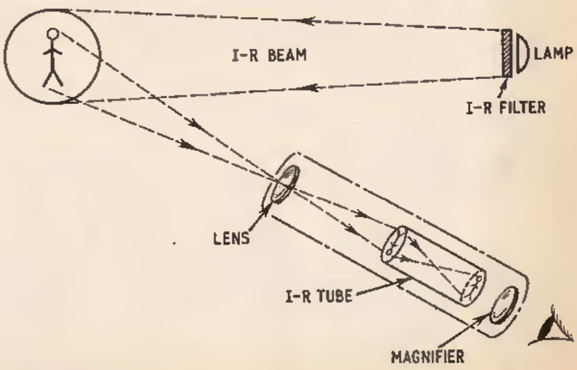


Fig. 2. An active infra-red system consisting of an infra-red source, which is a normal lamp with a filter to remove the visible part of the spectrum, and an optical viewing system incorporating an image converter tube

modulated audio signals. Propagation is by waveguide or line of sight, the waveguide being in the form of 2 micron diameter glass fibre.

This technique (known as "fibre optics") is becoming a commercially viable proposition, although certain difficulties still remain to be ironed out. Much work has been carried at the Ministry of Technology Signals Research and Development Establishment near Christchurch in close collaboration with industry to develop a system of communication in which telephone land lines transmitting at pure audio can be replaced by glass fibre.

GLASS FIBRE OPTICS

The engineering aspect of producing suitable glass fibre is critical, chiefly in the elimination of impurities, particularly traces of iron, which gives ordinary glass the typical green appearance on its cut surface. Glass required for fibre optic communication must be "white" to avoid filtering and unnecessary attenuation, and must be of the correct dimensions.

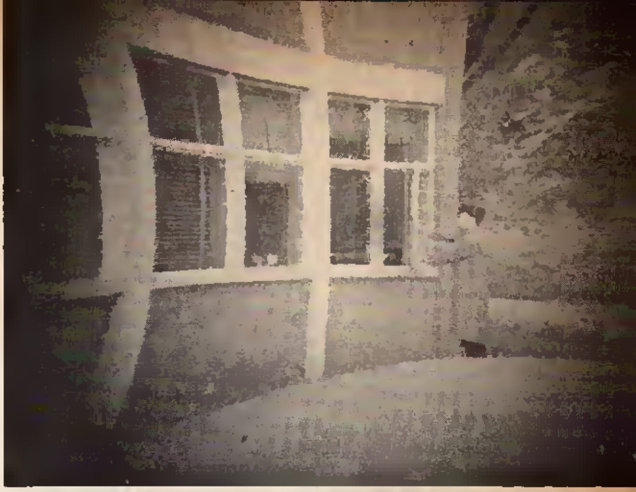
In this, the single-mode or waveguide fibre, there are only a few possible modes of transmission and maximum bandwidth is obtained, typically 10,000MHz over 1km. This type of fibre is most suitable where very wide band, single channel systems are required, such as data or telephone trunk links.

If several fibres are contained in one "cable" no insulation is necessary between each provided the physical conditions of each fibre have been satisfied. This is because the refractive index of the glass ensures that the infra-red or light beam is kept within the bounds of each fibre. Consequently, common experiences such as stray capacitance and l.f. radiation and cross-talk are virtually non-existent in fibre optic communication. On the other hand, attenuation is at present still a problem which can be overcome by using line repeaters.

To minimise attenuation the beam must not be allowed to touch the walls. Early experiments involved the insertion of expensive servo-operated lenses at intervals along the length of fibre. More recently, it has been found that if the core is sheathed with a suitable glass cladding of lower refractive index the light will be adequately contained within the core.

Strange as it may seem, the glass fibre although only about as thick as human hair, has a high tensile strength and is inherently flexible. If suitably protected from crushing and given a protective plastics coating, it can be inserted into cable ducts with the ease of conventional copper wire. So here we now have a 200-core cable with an overall diameter about the same as the conventional plastics covered *single*-core bell wire. Consequently more channels can be fed through underground ducts than with the present copper cable.

An infra-red optical two-way telephone using YIG (yttrium iron garnet) modulator. Frequencies up to 100kHz and a range up to 2km is obtainable (M.E.L. LTD.)



The scene through a passive sight looking at an intruder under overcast, starlight conditions

LASER TRANSMISSION

Having looked at the link between two stations, what about the stations themselves; how does one get the signal into the fibre at one end and out at the other? The answer quite briefly is the laser and a silicon photodiode. The laser must emit a beam which can be injected into such a small diameter, must have high speed and efficiency and operate in the near infra-red region. Gallium arsenide electroluminescent sources are used in the laser which transmits at room temperature, a pulse code modulated signal. The laser beam is injected accurately near the source into the fibre end, which is sheathed in polished Perspex for laboratory convenience, and to reduce scattering on entry. The received signal is picked up by a silicon photodiode, decoded and amplified in the usual way.

By using glass fibre the laser beam is not dependent on straight line-of-sight transmission paths; indeed, there is no reason why the fibre should not be layed haphazardly or even in coil form, provided that bends and kinks are not unnecessarily severe.

TUNING THE LIGHT BEAM

Optical communications systems rely on the usual signal generation as applied to any other form of radio communication. Harmonic generation, frequency mixing and frequency tuning take place at optical frequencies. Tuning is an interesting subject on its own and when applied to laser technology the results can be in the form of pure colour generation.

Experiments at S.R.D.E. have demonstrated the ability to "fire" a pre-tuned colour beam for a fraction of a second on a white screen. Development here is still at the purely experimental stage, but apart from being used in signal transmission, there is the possibility of applying the technique to coloured light displays.

A narrow band source of radiation can be tuned over most of the visible and near infra-red regions of the spectrum. The tunable source results from the selective addition of a laser frequency to a frequency from a continuum of frequencies generated by the laser in a liquid placed immediately in front of a non-linear electro-optical crystal.

NEODYMIUM-GLASS LASER

A high power Q-switched neodymium/glass laser (Fig. 3) is used to generate an intense continuum of frequencies in a 20cm cell of carbon disulphide. As soon as the laser beam enters the liquid, it causes a non-linear increase in the refractive index of the liquid. The laser beam is forced into propagating in a region of relatively high refractive index, and is reflected in on itself at the interface between these two regions.

After a further non-linear increase in the refractive index, the laser is self-trapped and rapidly collapses into a filament, the smallest so far identified having diameters of about 2 to 5 microns. The power density in the filament is very high—about 10^9 watts per square centimetre—leading to efficient stimulated scattering.

On leaving the carbon disulphide cell the intense continuum and unchanged laser radiation are directed into a lithium niobate crystal where frequency addition takes place. Tuning of the sum frequency is achieved by altering the temperature of the lithium niobate. A tunable difference frequency has also been generated so that tunable narrow band frequencies can be generated in practically the whole 0·3 to 13·0 micron spectral range.

A modified pair of binoculars used as an optical transceiver. The range is about half a mile, but the required power is minimal in comparison to conventional systems

ACTIVE LINE-OF-SIGHT

Other methods of active infra-red communication are generally based on line-of-sight transmission paths, although the modulation process is here applied to the transmitting crystal attached to a modified pair of binoculars. This method is limited in range to about half a mile, but the required power is minimal in comparison to conventional systems.

This makes the system particularly useful in environments where reflections from nearby structures would interfere with conventional systems. Examples would be in the building industry, ship's intercom and ship-to-ship radio telephone.

The added attraction is that the two stations, once lined up could be used for viewing as well as speech, forming a visual radio-optical telephone. The speech modulated signal is transmitted by a gallium arsenide lamp through the right-hand lens of the binoculars to the left-hand lens of the receiving binoculars. Inside this the optical picture is passed through to the eye piece in the normal way; while the speech signal is picked up by a silicon photodiode after being deflected by a specially coated prism.

INTERFERENCE FREE

The link uses a pulse frequency modulation system at 20kHz, eliminating the critical factors of heat haze causing signal fluctuations, hand shake or changes in daylight level. A voice operated switch is incorporated to change from receive to transmit; the system is interference free and is completely secure from eavesdroppers.

The gallium arsenide *pn* junction in the lamp is forward biased to emit infra-red light at 0·9 micron wavelength. The range of the instrument is dependent on visibility and increases to about half a mile at a visibility of about 10,000 metres, although it is expected that improvements will be made in due course.

The foregoing principles have now been released for commercial exploitation, having been developed originally for military purpose, and are born out of the concept of using separate infra-red light beams to flood a particular scene or object for viewing with infra-red sensitive viewers.

The current state of the art in infra-red detection is expected to be put to use in industrial or civil espionage control and crime detection.

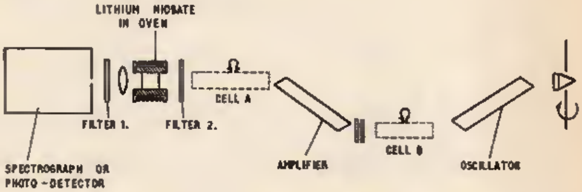


Fig. 3. Block diagram of the neodymium glass tunable laser

A typical example has been cited whereby the Thames river police are finding it increasingly difficult to make an arrest of dockside warehouse prowlers without arousing the attention of the prowler. The "telescopic" infra-red viewer can be used in pitch dark to watch the activities of an intruder. Of course, a lighted match or torch will apparently flood the infra-red scene immediately giving the security patrol an even better picture.

PASSIVE LINE-OF-SIGHT

The passive system relies on the detection of objects by their emission of temperature variance with atmospheric temperature. The photograph of the potential intruder shows up clearly with the building. It is now possible to make devices which can discriminate a 1 degree difference between an object and its background. As a result such a device will detect the presence of an animal, a vehicle or human being.

A more advanced method is the thermal imager, incorporating several detectors and a scanning system. The signal is applied to a cathode ray tube to give a visual picture from heat contrasts rather than colour and brightness contrasts.

IMAGE INTENSIFIER

Although not strictly relevant to infra-red, it is worth looking at recent development of image intensifiers because their applications are similar to those of passive infra-red detectors.

The image intensifier is a passive night vision device which can amplify light directly by 50,000 times. It is a small cylindrical encapsulation with three light intensifying modules each supplied by an e.h.t. of 15kV (Fig. 4).

Each module is a vacuum envelope with fibre optic input and output windows. A photocathode on the inner surface of the input window emits electrons according to the intensity of incidental light. These electrons are electrostatically focused and accelerated on to a phosphor screen on the output window to give a visible image.

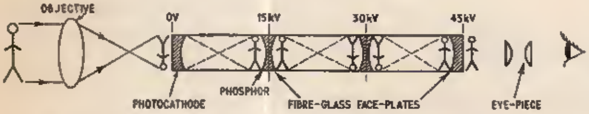


Fig. 4. A three-stage cascade intensifier tube.

A single module is not sensitive enough for poor light conditions; this is why three are usually banked together in a single envelope.

This intensifier needs no special lighting conditions, so true reproduction of natural light can be achieved, even in starlight conditions. The performance is dependent on atmospheric visibility, ambient brightness and contrast.

Applications lay in intensifying x-ray images, night navigation, and microscopy.

FUTURE POSSIBILITIES

Infra-red detection has numerous applications in industry and public life. The Ministry of Technology has released details of the work described in this article and it is expected that the following lines will be followed up on the basis of infra-red experiments already, and still being, carried out.

Tremendous possibilities in the study of wild life and nature conservation seem apparent when one is told that Vampire bats have been successfully bred in this country for the first time under close observation by infra-red.

Automatic fire alarm systems become a much more simple and reliable proposition and can double up as intruder alarms at the same time.

Infra-red radio and television links can be coupled with trunk telephone lines in the laser powered fibre optic system.

Closed circuit broadcasting in a room equipped with a centrally placed gallium arsenide transmitter and infra-red detection equipment overcomes problems of multi-image reflection and absorption experienced from conventional radio devices; no wires are needed.

Telephone tapping is avoided by using the infra-red modulated binocular and fibre optic systems.

Development work is still going on at S.R.D.E. and co-operation from manufacturers including Barr and Stroud, English Electric, E.M.I., Elliott Bros., Hilger and Watts, Marconi Instruments, Mullard, Plessey and 20th Century Electronics, has brought to light some advances that could well place infra-red techniques in its rightly deserved place in civil communications.

Acknowledgement is made to the Ministry of Technology, S.R.D.E. Christchurch, for illustrations used in this article. ★

Rhythm

THE article describes a variable-tempo rhythm generator which can be used to accompany a piano, organ or other musical instrument.

The percussive effects reproduced electronically are high and low bongoes, short and long brushes, and bass drum.

The rhythm selector switches provide instantaneous choice of any one of 12 popular dance rhythms each one being both variable in its tempo and instrumental colour to suit the needs of the music or moods of the instrumentalist.

OPERATION

The principle of operation of the rhythm generator is most easily described by reference to the block schematic diagram shown in Fig. 1. The heart of the system is a twisted-ring counter driven by a variable frequency clock-pulse generator. The counter has eight outputs and is so arranged that positive-going pulses appear on the output leads in sequence and in time with the clock pulse generator. A start switch S1, ensures that, on switching on, the first pulse occurs on output 1, the next pulse on output 2 and so on up to pulse number 8. The ninth pulse appears on output 1 again and the whole sequence is repeated indefinitely.

The positive-going pulses are fed to two sets of eight differentiator circuits which allow short positive pulses to pass via the rhythm selector switch to the various sound generating circuits. The two sets of differentiators, set 1 and set 2, are controlled by a bistable circuit (bistable 5) which changes state for every complete cycle of the ring counter. Thus the first eight pulses are derived from differentiators in set 1 whilst the second eight pulses are derived from set 2.

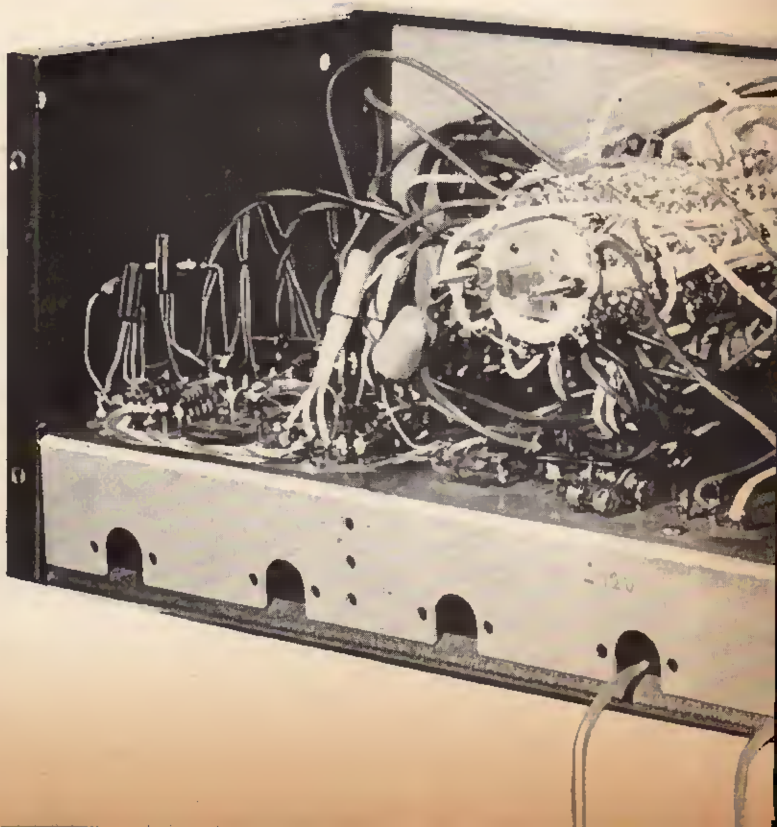
A sequence switch, S2, is connected to the bistable and may be used to over-ride the alternating set 1/set 2 sequence to give either set 1 sequence only or set 2 sequence. It will be seen later that this facility gives a possible total number of rhythms which is greater than the number of positions on the rhythm selector switch.

For certain rhythms involving 3/4 or 6/8 time the basic counter is required to have only 6 pulses for each complete cycle and this is accomplished, when required, by part of the rhythm selector switch, which modifies the counter interconnections.

The arrangement given is that used by the author but the system is easily modified to suit individual constructor's requirements.

CLOCK GENERATOR AND RING COUNTER

The tempo of the selected rhythm is governed by the frequency of the clock-pulse generator shown in Fig. 2. The circuit is a conventional astable multivibrator and control of frequency is obtained by varying the voltage supplied to the base resistors by means of VR1. To



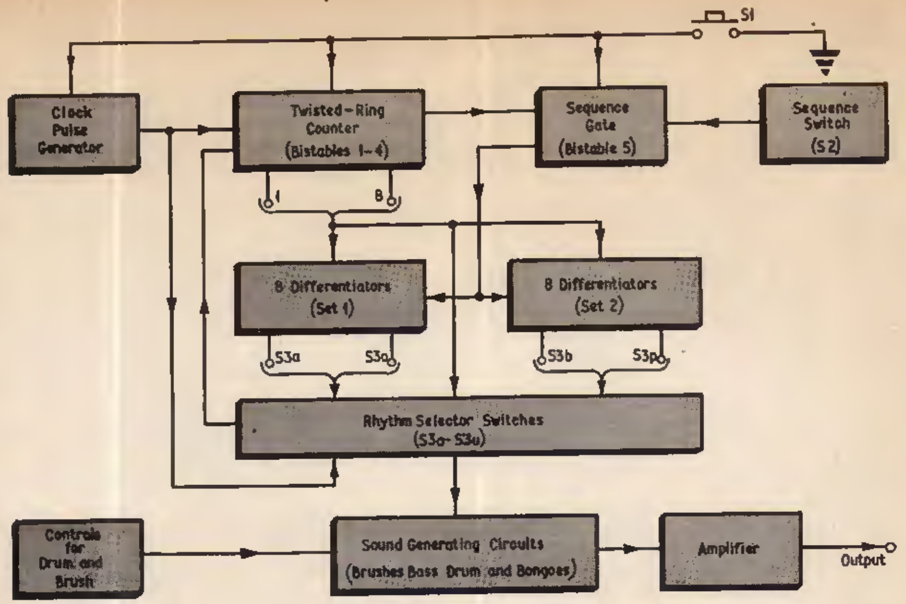


Fig. 1. Block diagram of rhythm generator

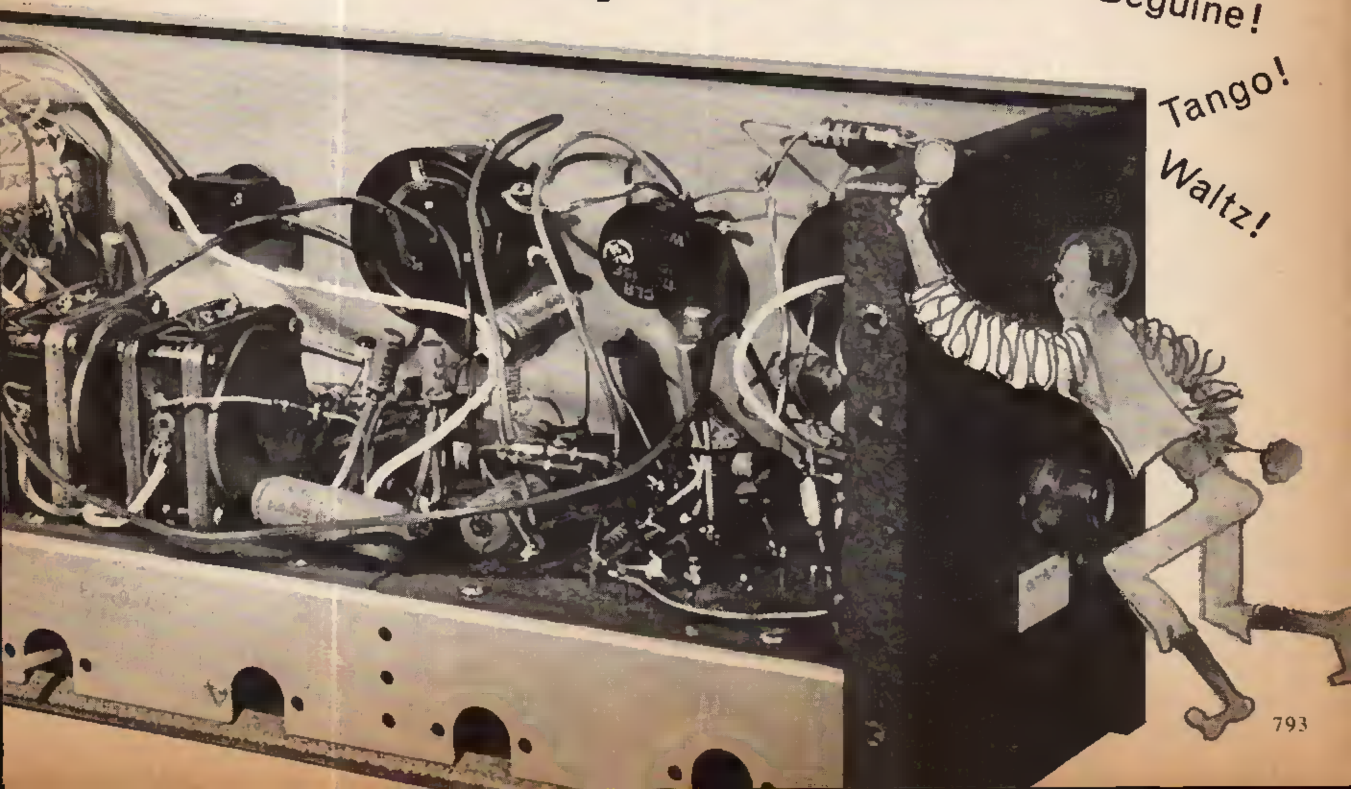
Generator

By P. R. Allcock

Beguine!

Tango!

Waltz!



BOARD A CIRCUIT

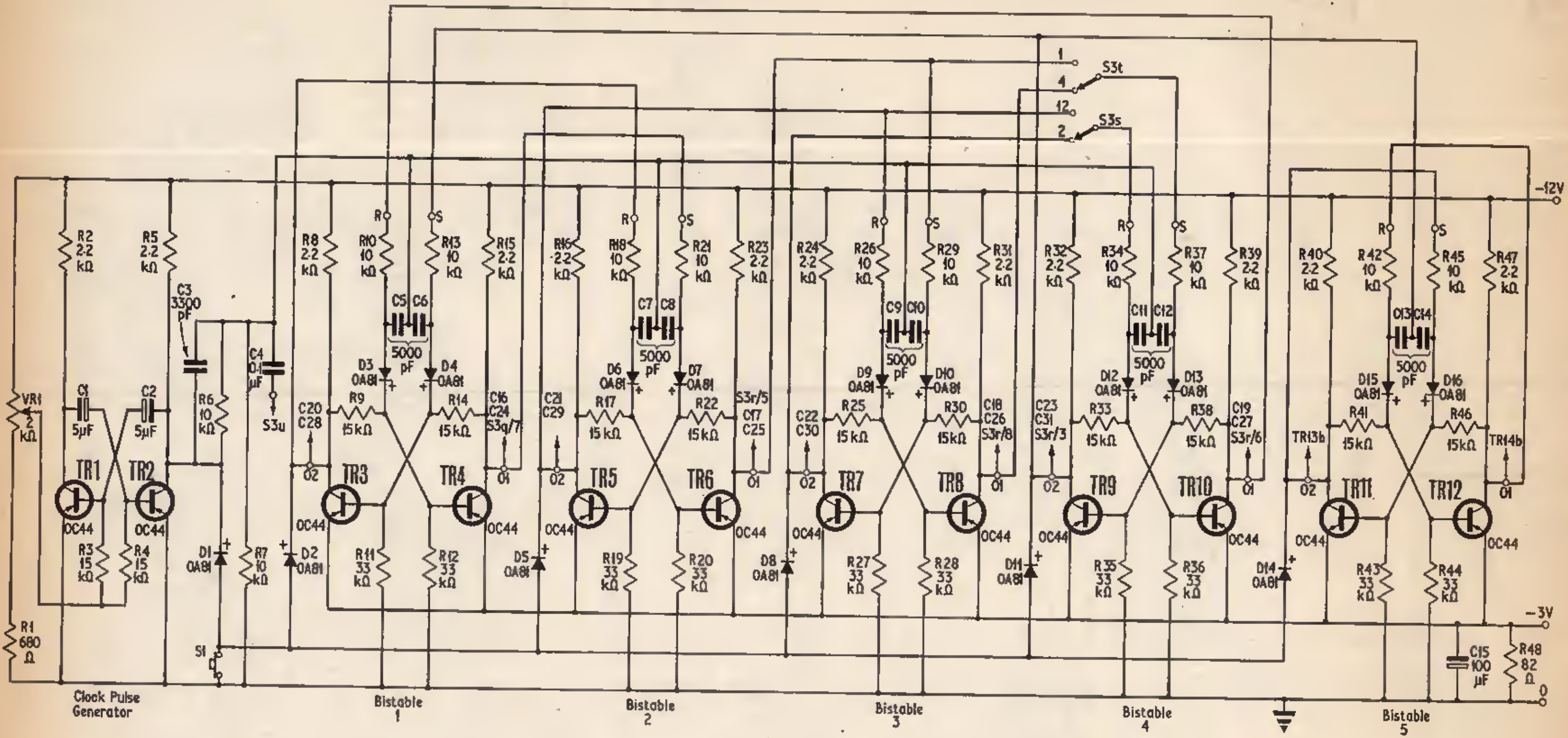


Fig. 2. *Circuit diagram of clock pulse generator, twisted ring counter and sequence gating bistable*

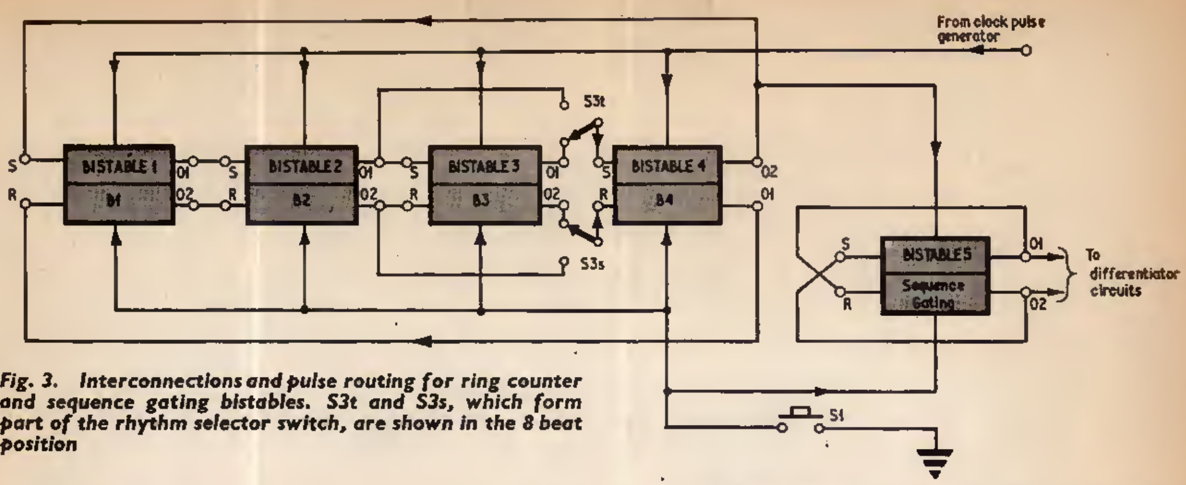


Fig. 3. Interconnections and pulse routing for ring counter and sequence gating bistables. S3t and S3s, which form part of the rhythm selector switch, are shown in the 8 beat position

simplify the design of the counter circuit the pulse amplitude was reduced by R6 and R7.

Coupling to the ring counter (bistables 1–4) is by way of capacitor C3 which ensures adequate rise time for the clock pulse generator's output when loaded by the cascaded bistables.

Since bistables 1 to 4 are identical in mode of operation the action of bistable 1 will only be considered before examining beat generation in the whole counter.

The circuit has two stable states TR3 on and TR4 off which is the reset state, and TR3 off and TR4 on which is the set state. Before operation of the start switch S1 the circuit is held in its reset condition by diode D2 which clamps the collector of TR3 to earth.

START SWITCH

Operation of the start switch allows clock pulses to pass to the base of TR3 or TR4, the routing being dependent on the voltage existing at the points R and S. These two points are connected in the complete circuit to the collector output O1 and O2 of bistable 4. Reference to Fig. 3 clarifies these bistable interconnections.

Since at any instant one transistor of each bistable will be on and the other off the potentials fed to S and R will be different and it may be seen from the circuit that the two possible potentials are −12V and −3V approximately (corresponding to off and on conditions respectively).

STEERING CIRCUITS

If we assume that the potential at S is −3V and that at R is −12V, the clock pulses arriving at C5 and C6 are differentiated by C6R13 and C5R10 but due to the potential difference between S and R only D4 allows pulses to pass. For D3 or D4 to conduct, the clock pulse amplitude must exceed the potential difference between S and TR3 base, or R and TR4 base, respectively. The first pulse steered via D4 to TR3 base turns TR3 off and TR4 on, that is the bistable is set. Subsequent pulses have no effect as long as the voltages at S and R are maintained. In normal operation the voltages at S and R will eventually change over due to a change of state of the bistable to which they are connected and the next clock pulse arriving at C5 and C6 will be steered via D3 and reset the bistable to its original state.

The pattern of operation for the first four bistable circuits obviously depends on the instants at which the voltages on S and R are changed over for each bistable element and this in turn depends on the way the elements are interconnected. To cater for a wide variety of rhythms it is necessary to have counter operation corresponding to both 3/4 and 4/4 time at least. Certain rhythms may need other counting sequences and this is considered later.

BASIC 8-BEAT COUNTER

The eight-beat counter can be used to generate a wide variety of rhythms involving 2, 4, 8 or 16 beats to the bar and the required form of interconnection is shown in Fig. 3. The sequence of operation for this arrangement, assuming that the start switch has just been opened, is as follows:

With all bistables initially reset.

Clock Pulse 1—Set B1
2—Set B2
3—Set B3
4—Set B4
5—Reset B1
6—Reset B2
7—Reset B3
8—Reset B4
9—Set 1, etc.

The O1 collector outputs of the first four bistables generate positive-going pulses for the first four beats in the sequence and the O2 outputs generate similar pulses for the last four beats of the sequence. The 16 beat cycle is produced by diverting these eight pulses alternately via two sets of pulse differentiators.

For rhythms involving 3/4 or 6/8 time only three bistable circuits are required in the counter and this is easily arranged by switching S and R of bistable 4 to O1 and O2 of bistable 2 instead of bistable 3. This

TABLE 1.

Pulse	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Set 1	D	—	Sb	—	Sb	—	Sb	—	D	—	Sb	—	Sb	—	Sb	—
Set 2	D	—	—	—	Hb	—	Hb	—	D	—	—	—	Hb	—	Hb	—
Alternate	D	—	Sb	—	Sb	—	Sb	—	D	—	—	—	Hb	—	Hb	—

D=Drum Sb=Short brush Hb=High bongo

BOARD B CIRCUIT

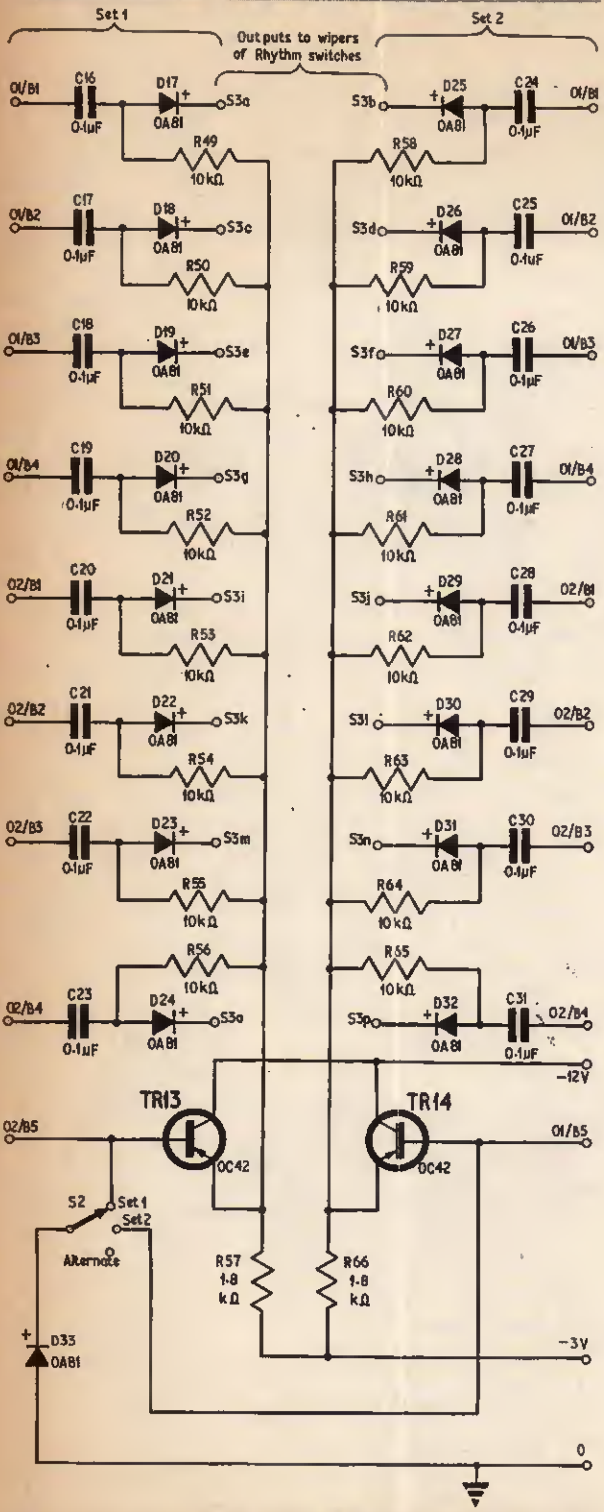


Fig. 4. The two sets of eight differentiators which shape and route the output pulses from the ring counter to the rhythm selector switch wafers S3a to S3p. Pulse sequences are governed by the switch position of S2

particular change of interconnections is accomplished by two wafers on the main rhythm selector switch. The resulting cycle now generates the first three beats at the O1 outputs of bistables 1, 2 and 4 and the last three beats at the O2 outputs of the same three bistables.

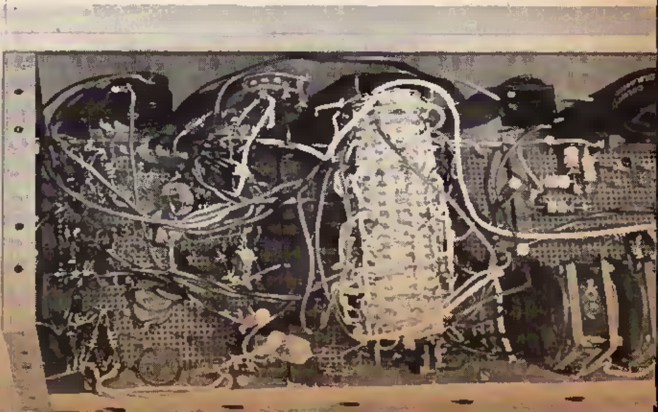
It should be noted that bistable 3 still operates simultaneously with bistable 4 due to its connection with bistable 2, but it does not affect the counting sequence and its outputs are not used when operating in this condition. The start switch is necessary to ensure that the counter does not run in an unwanted sequence involving the unused combinations of states of the four bistables and ensures that the first beat of each rhythm pattern appears at O1 on bistable 1. The counter output pulses are differentiated and only the positive-going spikes are used to operate the sound generating circuits.

DIFFERENTIATORS

The circuit for differentiating the output pulses is shown in Fig. 4. It will be seen that there are two sets of differentiator networks each receiving eight (or six) consecutive pulses from the main counter. However, only one set is operative at any one time depending on the state of bistable 5. This bistable is fed from the O2 output of bistable 4 and thus changes state for every complete cycle of 8 (or 6) pulses, and by controlling the emitter followers TR13 and TR14 the differentiated pulses are gated in groups (in a similar manner to the bistable steering) via the first or second set of diodes when the sequence switch is in the "alternate" position. The other two positions of the sequence switch override bistable 5 and allow pulses to pass via the first or second set of diodes. The diode outputs are connected to the wipers of S3a to S3p wafers on the rhythm switch which routes the pulses to the various sound generating circuits. Thus for each position of the rhythm switch it is possible to generate two different rhythm patterns of six or eight beats each, or one pattern of 12 or 16 beats using alternate sets of pulses. Fig. 5 gives the sequential routing of pulses for 16 beats at the rhythm switch assembly.

A simple example will make the operation of this section easier to follow. Let us assume that the differentiator circuit's output pulses are routed by way of the rhythm selector switches to the sound producing circuits in the following sequence. S3a and S3b to the bass drum circuit; S3e, S3i and S3m to the short brush; S3j and S3n to the high bongo. The counter is set for eight beat operation and for each position of the sequence switch S2 the following rhythms result (see Fig. 1). :

"Set 1" position of S2 produces a repeated rhythm involving drum, and three short brush sounds, whilst



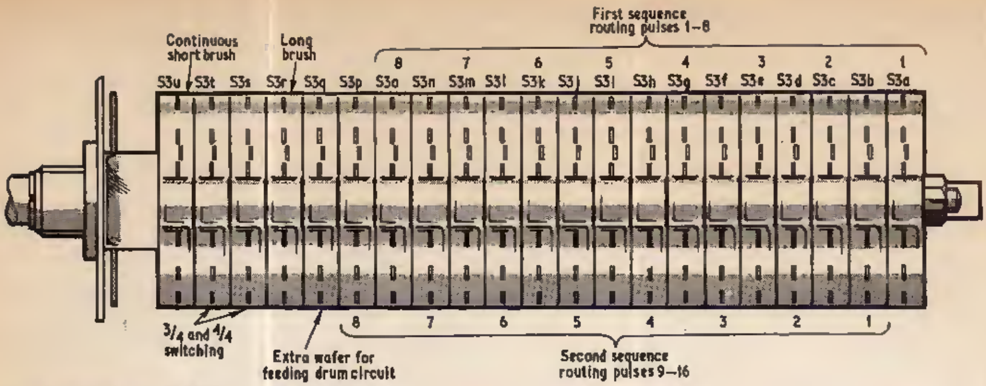


Fig. 5. 'Makaswitch' assembly, showing disposition of wafers and functions

COMPONENTS . . .

TWISTED RING COUNTER BOARD "A"

Resistors

R1	680Ω	R13	10kΩ	R25	15kΩ	R37	10kΩ
R2	2·2kΩ	R14	15kΩ	R26	10kΩ	R38	15kΩ
R3	15kΩ	R15	2·2kΩ	R27	33kΩ	R39	2·2kΩ
R4	15kΩ	R16	2·2kΩ	R28	33kΩ	R40	2·2kΩ
R5	2·2kΩ	R17	15kΩ	R29	10kΩ	R41	15kΩ
R6	10kΩ	R18	10kΩ	R30	15kΩ	R42	10kΩ
R7	10kΩ	R19	33kΩ	R31	2·2kΩ	R43	33kΩ
R8	2·2kΩ	R20	33kΩ	R32	2·2kΩ	R44	33kΩ
R9	15kΩ	R21	10kΩ	R33	15kΩ	R45	10kΩ
R10	10kΩ	R22	15kΩ	R34	10kΩ	R46	15kΩ
R11	33kΩ	R23	2·2kΩ	R35	33kΩ	R47	2·2kΩ
R12	33kΩ	R24	2·2kΩ	R36	33kΩ	R48	82Ω

All 10%; $\frac{1}{2}$ watt carbon

Potentiometer

VR1 2kΩ wire wound

Capacitors

C1 5μF 15V } elect.
C2 5μf 15V } elect.
C3 3,300pF polystyrene
C4 0·1μF ceramic
C5–C14 5,000pF mica (10 off)
C15 100μF 15V elect.

Diodes

D1–D16 OA81 (16 off)

Transistors

TR1–TR12 OC44 (12 off)

Switch

S1 Press to make/press to break (1A Castelco)
S2 Single-pole, 3-way

DIFFERENTIATORS BOARD "B"

Resistors

R49–R56 10kΩ
R57 1·8kΩ
R58–R65 10kΩ
R66 1·8kΩ

Capacitors

C16–C32 0·1μF

Diodes

D17–D33 OA81

Transistors

TR13–TR14 OC42

BONGOES, MONOSTABLE AND NOISE GENERATOR BOARD "C"

Resistors

R67–R68	22kΩ	R74	1·8kΩ	R80	1·8kΩ
R69	82kΩ	R75	390kΩ	R81*	See text
R70	10kΩ	R76	15kΩ	R82	3·9kΩ
R71	47kΩ	R77	33kΩ	R83	330Ω
R72	10kΩ	R78	39kΩ	R84	330Ω
R73	47kΩ	R79	3·3kΩ		

Capacitors

C33* } See text
C34* } See text
C35 0·01μF
C36 0·068μF
C37 1·0μF
C38 25μF elect. 25V
C39 250μF elect. 50V

Transistors

TR15 ME4103 TR16 OC71 TR17 OC44 TR18 OC71

Diodes

D34–D36 OA81

Inductors

L1–L2 700 turns of 36 s.w.g. enamelled wire wound on Mullard ferrite pot core (Henry's Radio)

LONG BRUSH, SHORT BRUSH, BASS DRUM AND PREAMP BOARD "D"

Resistors

R85	8·2kΩ	R91	39kΩ	R97	10kΩ	R103	120kΩ
R86	1·5MΩ	R92	10kΩ	R98	18kΩ	R104	47kΩ
R87	33kΩ	R93	10kΩ	R99	22kΩ	R105	4·7kΩ
R88	8·2kΩ	R94	10kΩ	R100	4·7kΩ	R106	4·7kΩ
R89	1·5MΩ	R95	120kΩ	R101	1·8kΩ	R107	330Ω
R90	10kΩ	R96	120kΩ	R102	120kΩ	R108	4·7kΩ

All 10%, $\frac{1}{2}$ watt carbon

Potentiometers

VR2 50kΩ VR3 10kΩ VR4 100Ω

Capacitors

C40	0·01μF	C46	1·0μF	C52	1,000pF
C41	0·002μF	C47	0·5μF	C53	0·068μF
C42	0·68μF	C48	0·05μF	C54	25μF 25V elect.
C43	0·5μF	C49	0·05μF	C55	2,200pF
C44	5·0μF 15V elect.	C50	25μF 25V elect.	C56	6,800pF
C45	0·1μF	C51	1,500pF	C57	6,800pF

Diodes

D37–D38 OA81

Transistors

TR19 OC42 TR20 OC42 TR21 OC42 TR22 OC71

Rhythm Switch Assembly

S3 Single-pole, 12-way "Break before make" wafers (Radiospares) (21 off)

Standard "Maka-Switch" shafting assembly with 6in spindle to suit switch wafers

Socket

SK1 coaxial socket

Inductor

L3 560 turns of 34 s.w.g. enamelled wire wound on Mullard LA1 ferrite pot core (Henry's Radio)

Chassis Assembly (Lektrokit)

S.r.b.p. chassis plate No. 4 (4 off)
Front panel No. 1 LK-401 (1 off)
Chassis rail LK-201 (2 off) Side plates LK-301 (2 off)
Covers LK-501 (3 off) Soldering pins LK-3011
6B.A. $\frac{1}{4}$in screws and nuts
(Parts for chassis assembly from Home Radio Ltd. Catalogue number shown should be included when ordering)

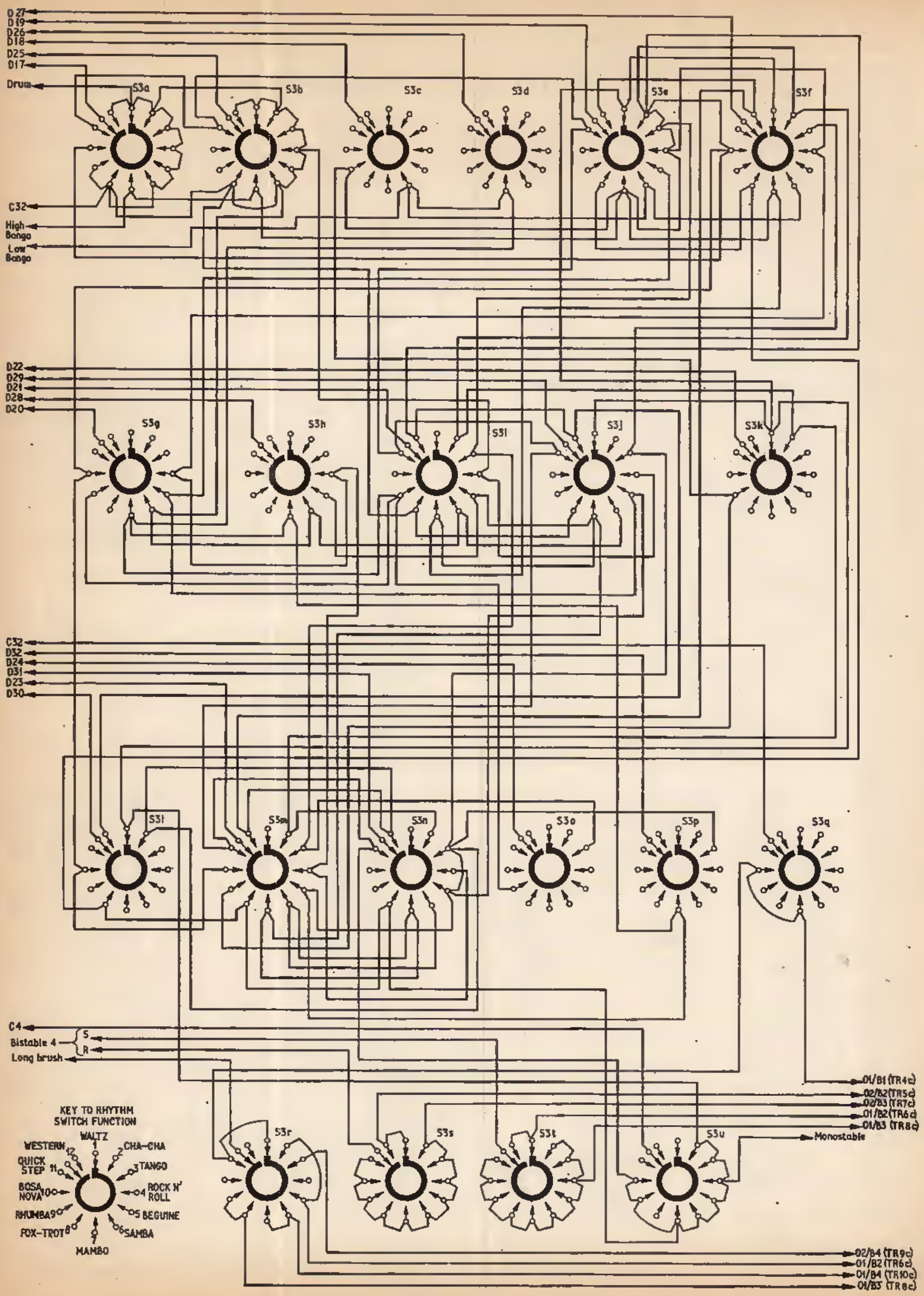


Fig. 6. Rhythm selector switch (S3) wiring diagram

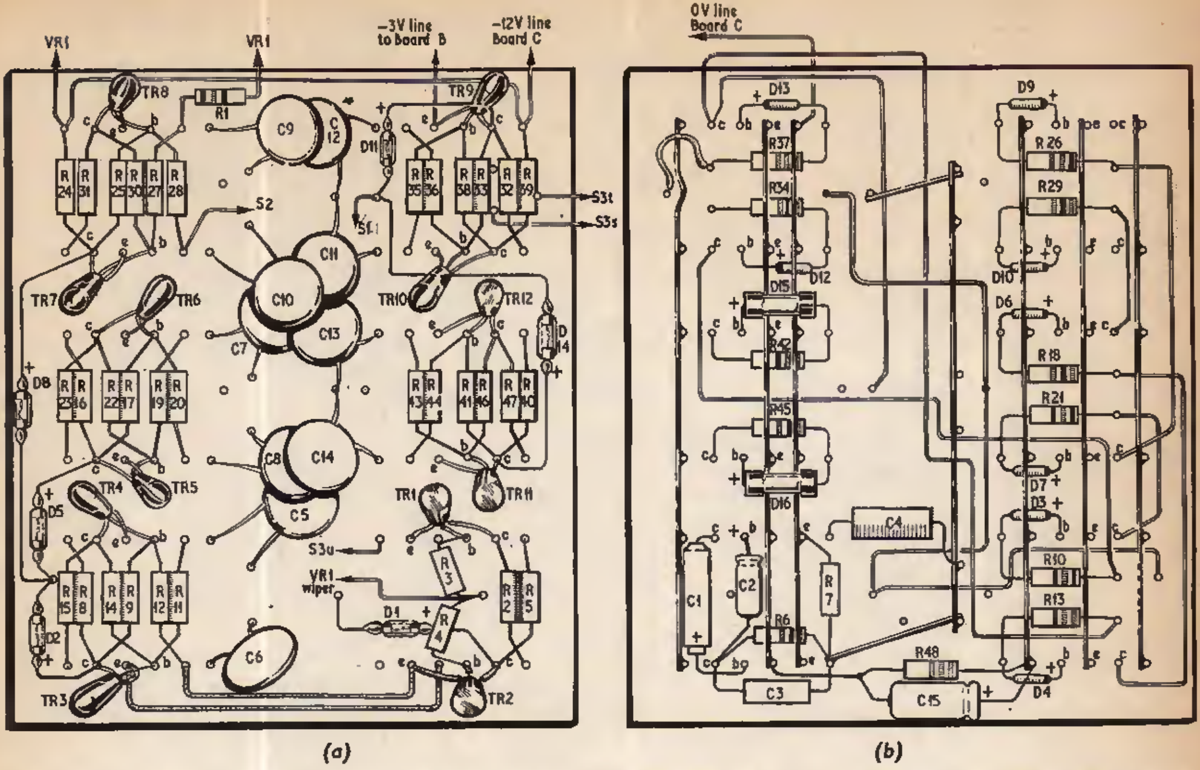


Fig. 7. Component layout and wiring for clock pulse generator and bistable board "A". (a) topside view; (b) underside view

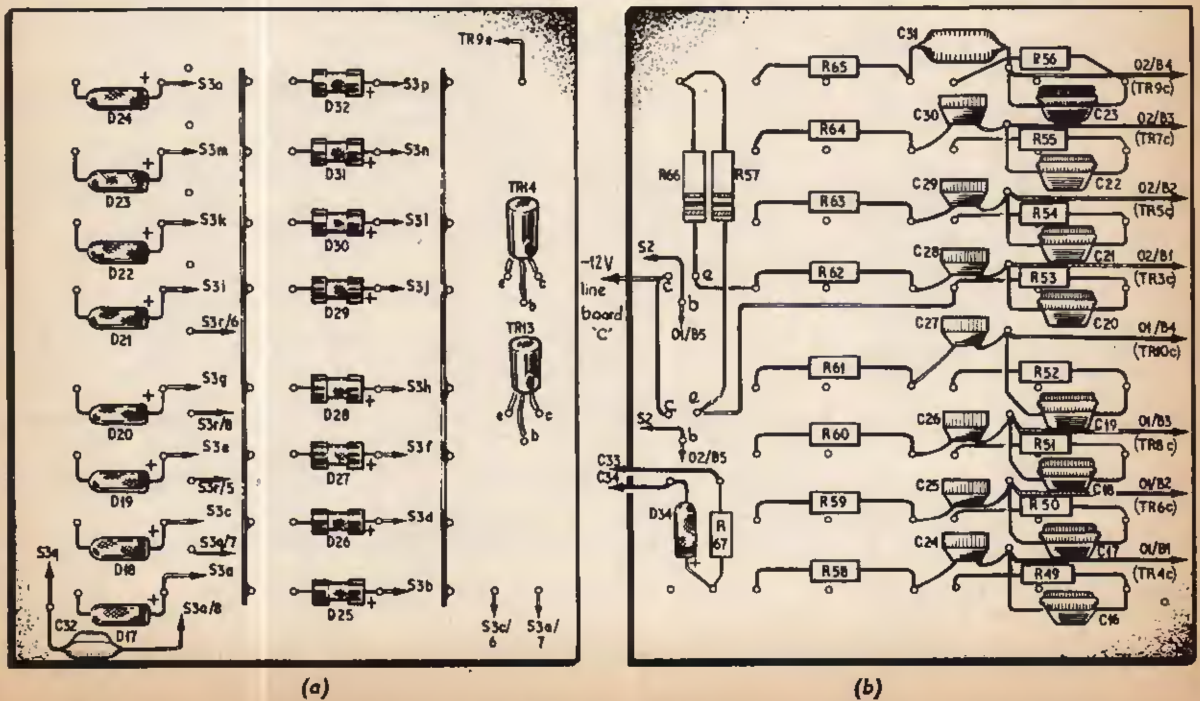


Fig. 8 Component layout and wiring for differentiator board "B". (a) topside view; (b) underside view

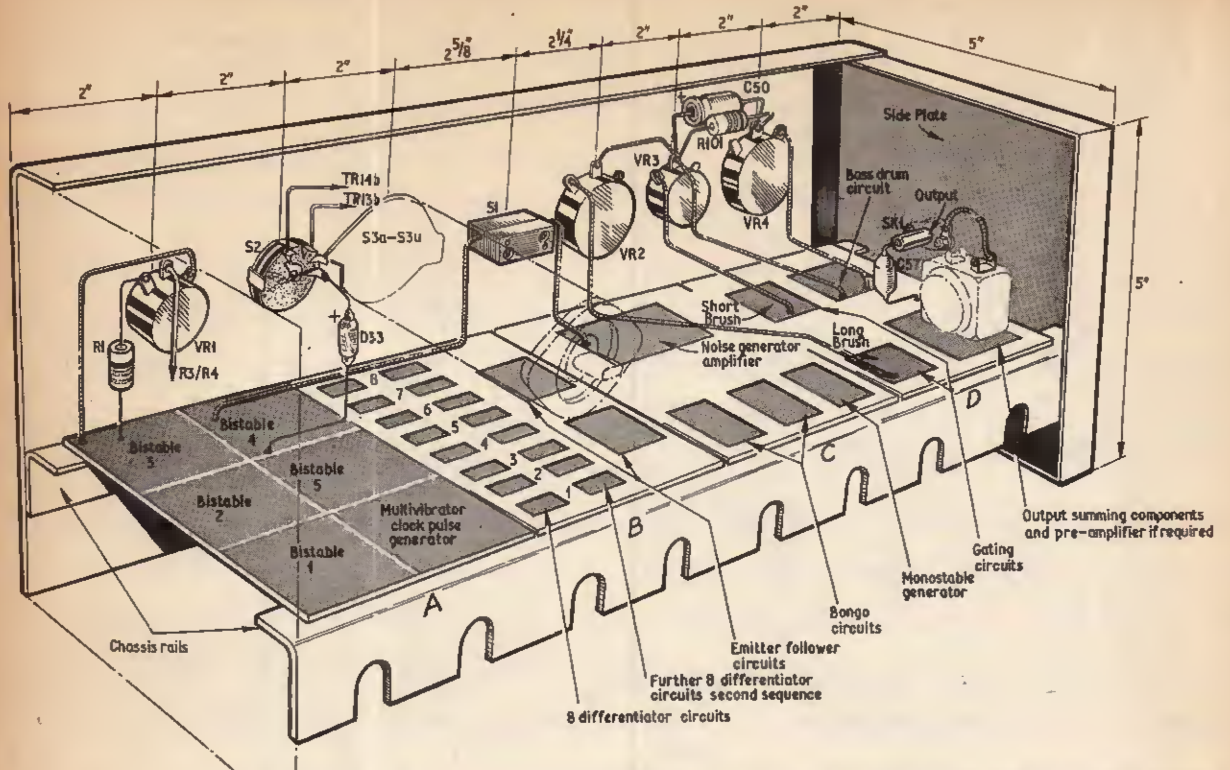


Fig. 9. Chassis assembly showing positioning of boards and panel controls

"Set 2" produces a repeated rhythm involving drum and two high bongo sounds. "Alternate" generates both the previous rhythms alternately.

RHYTHM SWITCH ASSEMBLY

The 12 position rotary switch used in the selection and routing of the various pulse patterns is made up from a "Maka switch" kit. This must be of the long type with 6in spindle.

Twenty-one single pole, 12-way wafers are individually threaded on to the spindle, each one being firmly butted against the other making sure that all the wiper tags are in common alignment.

Before inter wafer wiring is commenced reference should be made to Fig. 5 which shows the order of the switch wafers relative to the front panel. Using this in conjunction with the wiring diagram of Fig. 6 interconnection should be commenced.

Starting at switch wafer S3a, wiring to tags which are electrically common should first be made and then flying connections to other wafer tags as indicated. The inter wafer wiring should proceed systematically from switch wafer S3a through to S3u with no board flying lead connections being made at this stage. With wiring completed the switch bank should be placed to one side.

BOARD ASSEMBLY

Referring to Fig. 7a showing the topside of board A, solder pins should be located at the positions indicated. The tapered design of these makes for easy push fitting, and also allows the pins to be easily moved to other holes if some congestion is encountered if using larger size capacitors or resistors.

Components should now be mounted, each pin connection being a good mechanical bond by wrapping round a turn of component lead before soldering.

With topside assembly completed, the board should now be reversed and the underside wiring carried out as shown in Fig. 7b.

Board B assembly, Figs. 8a and 8b, should be completed and both boards laid temporarily aside.

CHASSIS ASSEMBLY

The prototype unit was built using a Lektrokit chassis system, see Fig. 9 Both the panel controls and the disposition of the circuits employed are shown on the annotated s.r.b.p. chassis plates. Since this first article is concerned with boards A and B component assembly on these alone will be dealt with.

It is convenient to commence the Lektrokit assembly shown in Fig. 9 by bolting the two chassis rails to one side plate using standard 6B.A. by ¼in cheesehead screws and nuts. The other side is then attached to the free end of the chassis rails in similar manner. Chassis boards A and B should then be mounted to the chassis rails by means of 6B.A. × ¼in screws and nuts.

Before attaching the front panel this should be drilled as indicated for the fixing of panel controls. Hole diameters have not been given, but the switch and control retaining nuts can function as templates for this.

Panel controls should then be attached and the front panel connected to the flanges of the side plates by 6B.A. × ¼in screws, the lower two of which pass also through the chassis rail.

Next month we will present the final part of this article which will deal with the sound forming circuits and final wiring of the unit.

NEWS BRIEFS

Big Deal!

ELECTRONIC data handling techniques are spreading through the London Stock Exchange. Several leading broking and jobbing firms are using facsimile systems installed by the Muirhead Group to speed communications between their small offices or "boxes" near the Stock Exchange and their main offices in other parts of the City.

One leading firm of stockbrokers find that, by sending facsimile copies of dealing slips via their Mufax communication system from their box to their office, they can provide an even flow of work for their contract department staff.

Colour Series for Trainee Engineers

A BBC TV COLOUR SERIES, intended to implement the Engineering Industry Training Board's integrated first year course for engineering craft trainees, started on BBC-2 Thursday, October 3, at 7.10 p.m.

While the series does not itself aim to provide a complete or continuous course, but a number of self-contained groups of programmes on selected topics, the groups are arranged, as far as possible, to fit the order of subjects as treated in most college time-tables, and also to provide a logical progression. All programmes reflect aspects of the trainees' work—theory, works practice and industrial application.

High Speed Gas

INSTRUMENTATION and mass-flow computers supplied by Honeywell's Industrial Products Group have a key automative role in the new East Midlands Gas Board supergrid system, now being changed from manual operation, directed centrally, to remote control from the Board's control room at Leicester.

Essential feature for control purposes is to know the quantity of gas passing into each grid offtake. Grid Control at East Midlands Gas Board requires this information in terms of standard cubic feet. Because of this and the fact that the gas density can vary at different points in the system, it was considered essential to compensate for these variations at the point of measurement and present all flow information to Central Control in standard form. This unifies the read-outs from all the various stations and enables the information to be processed into printed data.

This flow information, together with data such as backbone main and grid pressures, is displayed on digital indicators on an extensive control desk, with mimic diagram, at Central Control.

College Computers

A TOTAL of 22 analogue/hybrid computer systems from the Solartron range have been purchased this year by educational establishments both at home and overseas.

Latest two orders were signed on the stand during the recent IFIP Exhibition in Edinburgh, and both the systems will be installed in Scotland.

Robert Gordon's Institute of Technology, Aberdeen, followed-up their purchase of an HS7-1 earlier this year with an order for a double HS7-3A system valued at £30,000.

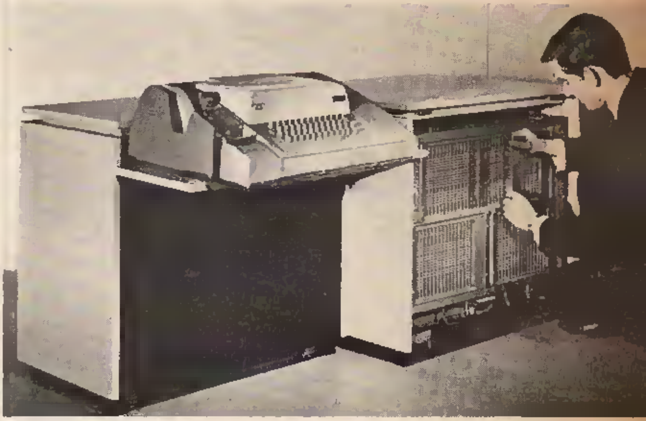
On the same day a £17,000 HS7-3A was also ordered by Paisley College of Technology.

Orders have also been placed recently by colleges in Ireland, Sweden and Italy.

The Unknown Mass

A £42,000 CONTRACT has been awarded to the English Electric Industrial Control and Automation Group at Kidsgrove by Imperial Chemical Industries, Pharmaceuticals Division, for an on-line M2140 computer system, see photograph.

The M2140 will be used to process data from a high resolution mass spectrometer. This mass spectrometer is used by the Pharmaceuticals Division's research department to determine the chemical structures of unknown chemical compounds.



Meetings . . .

SOCIETY OF ELECTRONIC AND RADIO TECHNICIANS

BIRMINGHAM
October 25, 7.30 p.m. *Colour Television—The Decoder*, by W. J. Anderson, at Room G.11, Bynck Kenrick Suite, University of Gosta Green, Birmingham 4.

GLASGOW
October 18, 7.30 p.m. *Airport Telecommunications*, by W. A. S. Aitken, at Y.M.C.A., 100 Bothwell Street, Glasgow, C.2.

MANCHESTER
October 31, 8.00 p.m. *Colour Television Servicing*, by T. M. Robinson, at John Dalton College, Manchester.

MIDDLESBROUGH
October 29, 7.30 p.m. *Microelectronics*, by T. M. Ball, at Cleveland Scientific Institute, Corporation Road, Middlesbrough, Yorkshire.

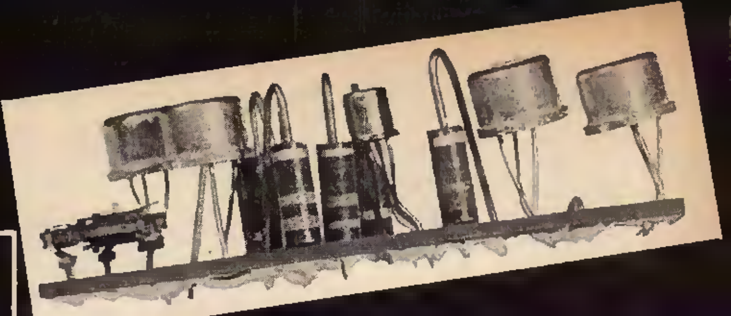
INSTITUTION OF ELECTRICAL ENGINEERS

LONDON
October 16, 5.30 p.m. *Thin Film Transistors*, by Prof. J. C. Anderson, at I.E.E., Savoy Place, London, W.C.2.

October 17, 10.00 a.m. Colloquium *System Structures of Modern Computers*, at Middlesex Hospital Medical School. Tickets for this meeting must be obtained from the Secretary, I.E.E., Savoy Place, London, W.C.2.

October 23, 5.30 p.m. *Electro-optics*, by Dr J. Bass and Dr K. F. Hulme, at I.E.E., Savoy Place, London, W.C.2.

FROST ALARM



By. D. F. MOODY

This unit, although primarily designed for the motorist as a road ice indicator, can also be used as an early warning device for the protection of domestic water pipes and greenhouse or outdoor plants when frost is imminent.

In preparing this design the requirements were for long term stability, ease of initial calibration, immunity from small supply variations and operation of the indicator from off to full on over a narrow temperature range.

The circuit employed is essentially a solid state bridge arrangement with a thermistor, or temperature sensing element, included in one of the bridge arms. Indication of bridge unbalance, caused when frost is imminent, can be either visual or audible.

Since ice formation on dimly lit roads at night is much less apparent than in the day, a lamp on the car dashboard which is illuminated with a cautionary red glow, when external temperature is at 0 degree Centigrade will prove an excellent indicator of prevailing road conditions.

For the householder, who is usually asleep when frost is abroad, the strident tones of an electric bell will provide the spur for some protective action.

In describing the unit, both systems will be presented.

HOW IT WORKS

In Fig. 1 it will be seen that TR1 and TR2 are complementary *pnp* and *npn* transistors forming two arms of a bridge circuit with the base bias resistors R1–R4, which span the supply, making up the other arms.

When balance is achieved by adjustment of VR1, the potential at the junction of the bias chain resistors R2 and R3 will be equal to the potential at the collector junction of TR1 and TR2 which is half the supply voltage. TR3 and TR4, which form part of the detector circuit, are non-conducting as the base/emitter potential drops of both transistors are negligible ensuring that both are cut off.

If the emitter resistance of TR2 increases the bridge circuit will become unbalanced. The resistance of thermistor X1, which exhibits a negative coefficient of resistance, will increase with a reduction of temperature with a subsequent increase of potential drop across the collector load of TR1 comprising TR2, VR1 and the thermistor.

Since this collector voltage rise is positive, both TR3 and TR4 will conduct so switching on TR5 which bottoms to illuminate the lamp LP1 or energise a relay, whichever load is employed.

CONSTRUCTION

Construction of the unit is fairly simple. Cut the copper strips according to Fig. 2. Then assemble the components, starting at one end of the board and working through to the other end.

When complete check the wiring and make sure the cases of the ASY26 and ASY28 transistors are not touching each other or any part of the circuit as the cases are connected to the base. If the lead lengths of the transistors are kept short this will prevent any subsequent movement and possible damage.

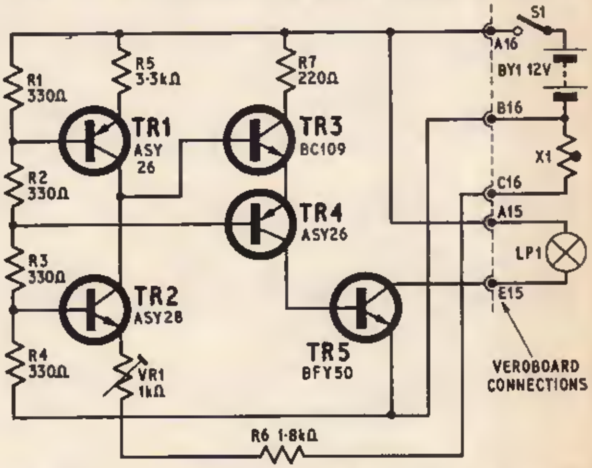


Fig. 1. Circuit diagram of frost alarm. Connections at A15/E15 can be either lamp or relay depending on application

CALIBRATION

The most convenient way to calibrate the unit is to connect the 12-volt supply, lamp, thermistor, and switch to the Veroboard as shown in Fig. 2, using long lengths of miniature p.v.c. 7/40 wire for the thermistor connection.

The module and supply should then be arranged on top of a refrigerator.

If a Centigrade thermometer is placed at a spot close to the ice-box, it is possible by adjustment of the thermostat controller to set the temperature at freezing point or 0 degree Centigrade. If the indicating unit is intended for domestic use, the refrigerator temperature adjustment should be for a couple of degrees above zero.

With these reference temperatures established the thermistor should be placed at the position occupied by the thermometer. The thin, flexible, 7/40 wires will permit closure of the refrigerator doors, whilst calibration is in progress. Since the thermistor is wire ended precautions should be taken to prevent any chance of accidental short circuit, by laying it on a piece of cloth.

The supply should now be switched on and VR1 gradually advanced till the lamp just switches on. Reducing the resistance value of this potentiometer slightly will just turn off the lamp. No more adjustment of the unit is necessary as calibration is now complete and the module is ready for installation.

If a bell indicator is required a lightweight relay with suitable contact rating for a volt bell should be substituted for the lamp. The calibration procedure for this should proceed on the lines as before.

HOUSING THE UNIT

The unit, including batteries, can be housed in a suitably sized wooden box if intended for domestic use.

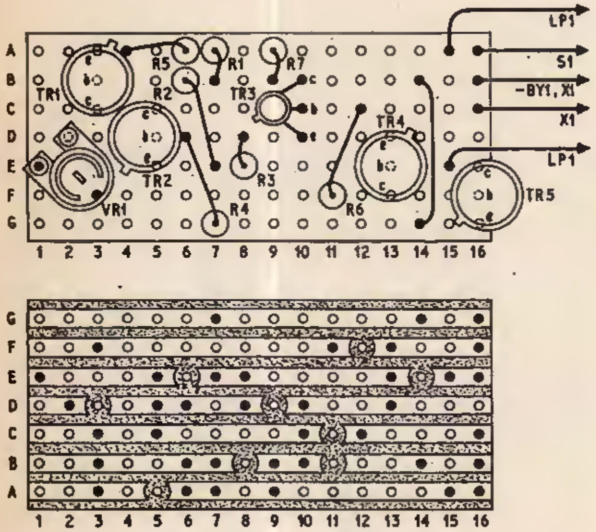


Fig. 2. Veroboard assembly showing top view arrangement of components and breaks in conductor strips

For motorists, since the supply is taken from the car battery, the box dimensions can be considerably reduced. In the author's prototype a small plastic case was used and then fitted to the dashboard. A convenient form of attachment is sticky tape.

Holes should be cut to the diameter of the lamp shank and the diameter of the calibration pre-set potentiometer VR1. This will make for easy screwdriver access even though calibration will only be rarely necessary, say once every two years.

If the unit is to be used in a car, S1 may be omitted. One of the two supply leads should be connected to some convenient anchorage point on the car chassis and the other connected to the ignition switch, so that power to the unit will be turned off when the ignition key is removed. Before embarking on these wiring instructions, it is important that the car chassis polarity should first be determined, that is whether positive or negative. When this is done, the relevant supply connections can be made without risk of damage.

COMPONENTS . . .

Resistors
R1 330Ω 5%
R2 330Ω 5%
R3 330Ω 5%
R4 330Ω 5%
R5 3·3kΩ 5%
R6 1·8kΩ 10%
R7 220Ω 10%
All ½W carbon

Potentiometer
VR1 1kΩ miniature carbon preset

Transistors
TR1 ASY26
TR2 ASY28
TR3 BC109
TR4 ASY26
TR5 BFY50
(Henry's Radio Ltd.)

Thermistor
X1 CZ9A

Switch
S1 Single pole on/off toggle

Battery
BY1 Two Ever Ready PP1, 6V batteries (see text)

Lamp
LP1 12V, 0·75W L.E.S. (Radiospares)
Relay (if required) 670Ω lightweight B and R type (Home Radio—Cat. No. Z70B)

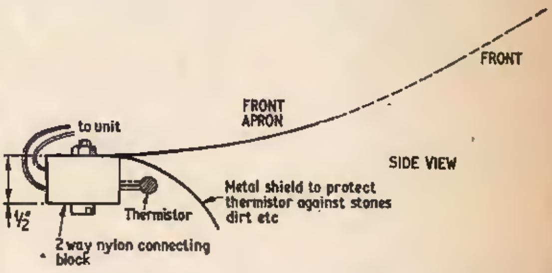


Fig. 3. Method of thermistor mounting to front apron of car

THERMISTOR MOUNTING

The thermistor was mounted on a section of nylon terminal block. In domestic applications the junction between thermistor and its unit connecting leads can be made mechanically with the terminal screws of the nylon block. For car use, these leads should be soldered and connected as before to preclude any chance of the retaining screws loosening and producing an open circuit.

Final fixing of the block should be by screw to either wall or shelf.

To detect road ice hazards, the block should be mounted at the front of the car, under the front bumper. To prevent damage to the thermistor by stones and dirt thrown up from the road, a small deflecting shield was formed by bending a length of sheet aluminium or tin to the width of the nylon block, see Fig. 3. If a ⅛in hole is drilled in the car's front apron, both shield and block can be affixed with a nut and bolt. ★

EXPERIMENTS WITH SOUND LIGHT & COLOUR

PART 4 By F.C. JUDD, A. Inst. E

THE cathode ray tube colour pattern display described in the second and third parts of this series lends itself most admirably for sound programming, i.e. for producing preconceived or random patterns and sequences of patterns in synchronisation with music. The system also offers exciting possibilities for filming, using all the various film techniques such as superimposing, zooming and panning. The writer has in fact produced a 15 minute colour film from the display, complete with electronic music sound tracks, but more of this later.

FORMATION OF PATTERNS

It may be realised that patterns can be preconceived by knowing precisely the frequencies and waveform of signals applied to the deflector coils and the frequencies of the grid pulses.

The photograph shown in Fig. 4.1 was taken from the c.r.t. display and although reproduced here in black and white it does show the basic formation of the pattern as circular. On the actual display the pattern appeared in multi-colour and moving, i.e. slowly spinning.

The pattern was formed from an amplitude modulated sine wave fed via the phase shift network to both deflector coils as described in Part 3. This produced the expanding rings effect shown in Fig. 4.2 and which is divided into four segments by grid blanking pulses. The one in the photograph (Fig. 4.1) is divided into five segments, but this division can be any number from two up to seven or eight or more.

Without the amplitude modulation and grid pulses the display would simply be a circle. With modulation at around 10Hz the circle will be displayed successively as in Fig. 4.4. With pulses applied to the c.r.t. grid parts of the expanding circle will be blanked out. The relationship between the fundamental frequency of the signal forming the circle and the grid pulses will decide exactly the number of blanked out segments.

The waveforms in Fig. 4.3 may serve to illustrate the pattern frequency to pulse frequency relationship more clearly, and (as Fig. 4.4 shows) would produce a pattern divided by two since each grid pulse occurs twice during one cycle of the pattern frequency. Therefore if the pattern frequency were 250Hz then the grid pulse frequency would be 500Hz.

The determination of given patterns is therefore a matter of relating the frequencies of deflector coil signals to those of the grid pulses. The frequency of the grid pulses can of course remain constant and the fundamental patterns or deflection signal frequencies varied accordingly.

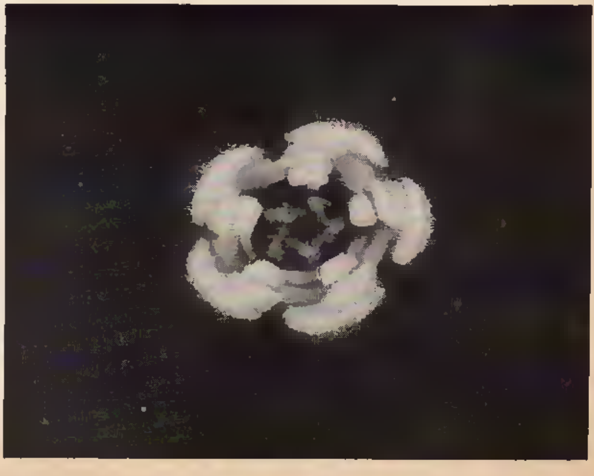


Fig. 4.1. A circular segmented pattern derived from the c.r.t. display

SIGNAL SOURCES

In order to produce complex patterns of this nature, at least two audio frequency sine square wave generators and a signal mixer are necessary—although interesting patterns can be produced from music only. The combinations of signal sources and ways in which these can be fed to the deflector coil amplifiers are as follows:

1. Audio generator to input 1 and audio generator to input 2.
2. Audio generator to input 1 and music signals to input 2 or vice versa.
3. Audio generator to both inputs with phase shift network in circuit.
4. Music to both inputs with phase shift network in circuit.
5. Audio generator and music signals mixed to both inputs via phase shift network.
6. Two or more audio generators with signals mixed to input 1 and music to input 2.

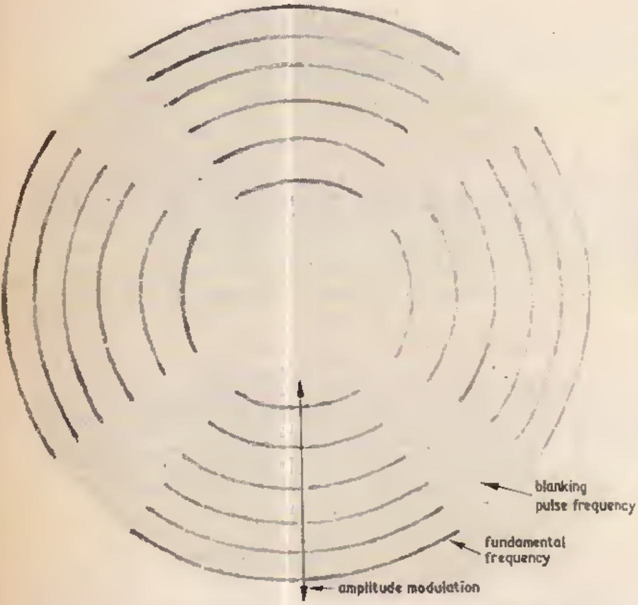


Fig. 4.2. How a circular "expanding rings" pattern similar to that shown in Fig. 4.1 is formed

CO-ORDINATING SOUND WITH PATTERNS

Since patterns can be partly or wholly formed from music signals, they can be made to appear to form and move in synchronisation, i.e. rhythmically with music. Moreover the signals for the patterns, whether derived from music or audio signal generators, can be recorded on magnetic tape with a conventional domestic tape recorder. A programme of patterns and music can therefore be tape recorded and replayed at any time.

ELECTRONIC MUSIC

The choice of music to which the patterns can be made to form and change and move must be left to aesthetic and musical tastes of the experimenter. Electronic music is of course a natural for a display of this kind and it was this type of music that originally prompted the writer to investigate the possibilities of sound, light and colour co-ordination as described in these articles.

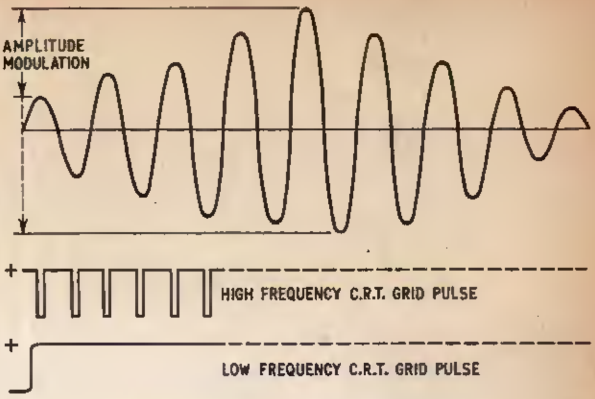


Fig. 4.3. Relationship of pattern signal frequency to grid pulse frequencies

There are a number of records of electronic music available and the fact that pure tone is frequently used in this kind of music makes it very suitable for producing patterns. Those who have the necessary audio signal generators and a tape recorder might well be able to produce both music sound tracks and patterns specifically composed one for the other.

CIRCULAR PATTERNS

Programming in its simplest form would be to feed music signals directly to both inputs of the display with the phase shift network in circuit. With this arrangement predominantly circular patterns would be formed and in exact time with the music.

As a variation a small 50Hz signal could be injected into one amplifier, just sufficient to produce a horizontal line to the maximum width of the screen. This forms a simple time base for music signals injected into the other deflector amplifier. The display will be rather like that of music on a conventional oscilloscope with a slow time base in a multiplicity of colours.

Fig. 4.4. How a pattern would be formed with the signals shown in Fig. 4.3

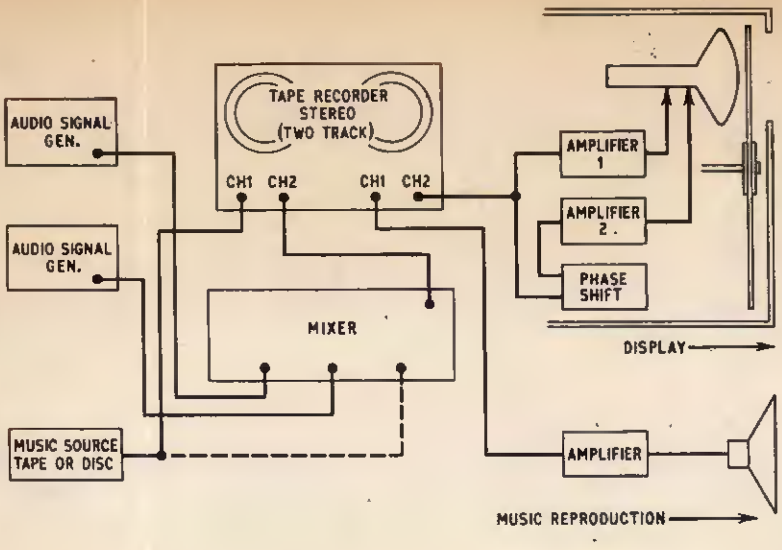


Fig. 4.5. System and equipment used by the author for programming pattern signals and music on magnetic tape

USING TWO DIFFERENT INPUTS

With the aid of one or more audio generators given patterns can be produced and made to come and go as well as move in time with music, but this requires very rapid manipulation of the generator controls.

A similar arrangement but one not so difficult to manipulate is to feed music to one amplifier and an audio generator to the other. The music signals will provide the rhythmic movement whilst formation or shape is produced with the generator controls, i.e. frequency variation, amplitude variation and switching from sine to square-waves.

TAPE RECORDER

Programming with a tape recorder and an audio generator, as well as music signals, provides the ultimate and most dynamic effects. With this equipment the signals for a programme can be recorded and the tape edited if necessary by the usual technique of cutting and splicing.

For example the pattern signals can be recorded first in chosen sequences by stopping and starting the tape. This allows ample time in which to carry out this part of the programming, i.e. the generator frequencies can be pre-set before actually recording. The ideal tape recorder for this is a half- or quarter-track stereo record/playback machine preferably with "off tape" outputs or at least through signal outputs. Such a recorder allows for feeding the pattern signals through to the display before and/or during actual recording.

The block diagram in Fig. 4.5 shows the arrangement employed by the writer for recording patterns and music tracks for the c.r.t. display described in the two previous articles.

LISSAJOUS PATTERNS AND MUSIC

Although comparatively simple in shape, the most striking patterns are 2 to 1 and 3 to 1 Lissajous patterns from sine or square waves. Over-complex patterns produced from music have no definite shape and after a while become uninteresting.

Superimposing music signals upon slowly moving Lissajous patterns is quite effective and gives the illusion of movement in time with the music. Low frequency signals produce the most contrasting colour effects, i.e. frequencies which are equal to, or multiples of the scanner speed and low frequency grid pulses (10, 15, 25 and 30Hz).

FILMING FROM THE DISPLAY

The brilliance intensity of the c.r.t. patterns is high enough for filming with ordinary 8mm artificial light colour film such as Kodachrome 25 ASA film, providing the patterns are reproduced within an area of approximately 2in × 2in. This means operating with a close-up lens, but most dynamic sequences can be filmed this way. The writer has made a 15 minute film with electronic music sound tracks. (Readers who are not equipped for filming might well find a local cinefilm enthusiast or cineclub interested in filming such unusual but nevertheless creative material from their own version of this c.r. colour display.)

The photograph, Fig. 4.6, shows the arrangement used by the writer with an 8mm reflex camera equipped for zooming and with a close-up lens so that patterns could be made to fill the cine screen. Here is a description of the way in which the film was produced.

First it was decided that a coloured background would enhance the overlays of colour patterns filmed directly from the display. The whole film was exposed at 12 frames per second with the aperture at f2.8 to a white surface illuminated in colour by means of a 60 watt lamp behind coloured cinemoid. Deep blues, green and dark red provided the best colour background.

SUPERIMPOSED PATTERNS

Then the film was run through no less than three more times in order to superimpose patterns one upon the other and employing all the filming techniques the camera would allow: zooming, panning, fading and de-focussing, etc. This, together with electronic

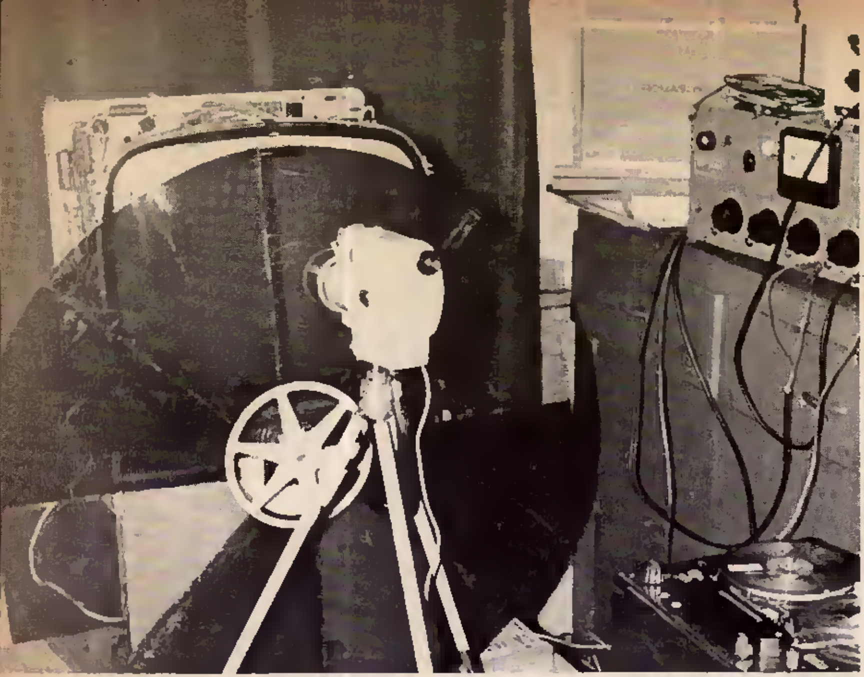


Fig. 4.6. Set-up for filming the c.r.t. colour pattern display. Note close-up lens on cine camera

control over the pattern signals, produced some excellent shots which were then edited for showing with sound tracks of electronic music.

A short sequence of film is shown in Fig. 4.7. Unfortunately this is not reproduced here in colour but in the original the background is deep red with the patterns appearing in yellow and mauve. The film speed was 12 to 16 frames per second at F2.8.

PROGRAMMING THE SIMPLE COLOUR LIGHT DISPLAY

The method of feeding music signals directly to the input of the simple colour light block display was dealt with in Part 1, which also gave constructional details of the display itself.

Audio sine tones from a signal generator and a tape recorder could also be employed to obtain repeating sequences of colour change and movement with this light display. The method of programming is similar to that described in the previous paragraphs, i.e. music is recorded on one track and control signals on the other. By using audio sine wave signals much more defined changes can be obtained since tones can be selected with frequencies midway between those covered by the filter circuits.

In conclusion the writer would like to mention that one Practical Electronics reader suggested the use of thyristor control for larger lamps in a display similar to the one described in our opening article. The method proposed could of course be used. In fact there is virtually no limit to the possible arrangements for controlling light from filtered music, or by means of impulse or tones recorded on magnetic tape themselves in synchronisation with music. The writer has attempted only to outline the subject and provide sufficient basic circuit information and other details to encourage others to experiment with two possible methods. A great field is open for those prepared to explore. ★

Fig. 4.7. An 8mm film strip showing patterns from the c.r.t. display. The original film was in brilliant colour (see text)

RADIO TRADE SHOWS

Jottings from jaunts around the London trade shows

A VISIT to the Earls Court Radio Show used to be an outing for all the family. Dad went to nod knowledgeably over specifications, Mum to see her idols on the BBC stand—and make the final buying decisions—and the kiddies to collect colourful leaflets.

Declining commercial support finally closed the "public" show in 1964, and the handful of separate trade shows held during the run of the show, particularly by foreign manufacturers excluded from the main event, has grown ever since.

TWENTY-TWO DIFFERENT SHOWS

This year, a record 57 manufacturers and distributors, more than half of whom were traceable to continental origins, displayed their wares in 22 centres in London over a period of five days. The majority occupied hotel bedrooms, the more illustrious took over complete ballrooms, and some used their own premises.

All the exhibitors we spoke to were in favour of this fragmented showing and had no regrets over the exclusion of Mum, Dad and offspring—there were fewer distractions and those who came to view came also to buy. A retailer said he found the staff on the stands better informed than the professional demonstrators of Earls Court days, and the environment more suitable for viewing and listening. But he was concerned for the less well-known exhibitors, whose success depended on how energetically they advertised before the show. It takes a dealer with stout walking boots and a heart of gold to traverse five miles of London's West End to see the efforts of a newcomer!

This short report will concentrate mainly on new audio equipment—development in other fields will be covered by the companion journals *Practical Television* and *Practical Wireless.*

UNITS v. RADIOGRAMS

Although there is undoubtedly a trend to integrated amplifier/tuners with separate record playing decks and loudspeakers, this is not quite so definite as a tour around this caravan of shows might initially suggest.

Most of the unit audio was due to continental exhibitors who, as has been stated, were present in force. A large British manufacturer said that radiograms were still very popular in this country and would never be outstripped by strings of "bits and pieces"—even though he was well aware which approach gave better performance per pound. Another, who earned a comfortable living from "bits and pieces" said the opposite.

Sinclair System 2000 f.m. tuner

Perpetuum-Ebner PE2020 automatic/manual turntable with base and transparent cover

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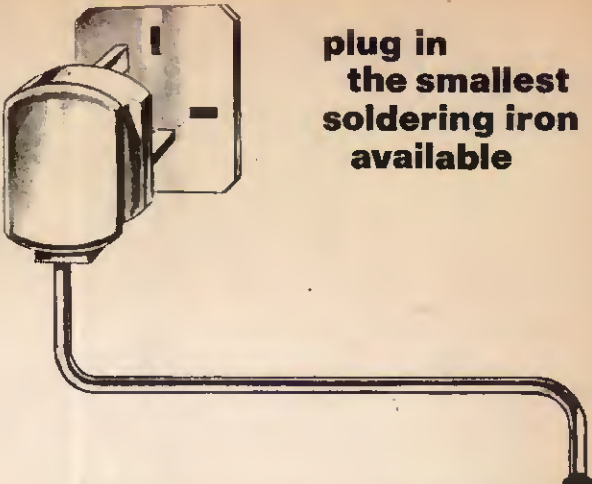

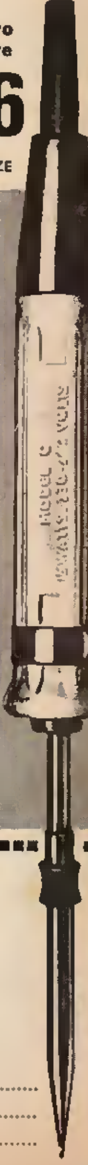

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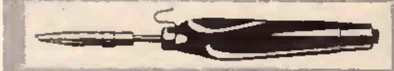

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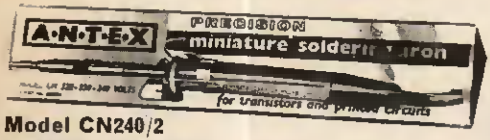

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Arena stereo tuner amplifier type T1500F with two HT21 speaker units

IMPRESSIVE ADVANCES

Approaching from central London, our first port of call was the Arena display in the Piccadilly Hotel, where we were greeted by news of "the most advanced tuner-amplifier on the market". It uses silicon diodes for tuning both v.h.f. and medium wavebands, uses an improved version of the company's plug-in modular construction, has a sensitivity of 0·5 microvolts on f.m. and has an audio output of 90W r.m.s. per channel. The exhibits also provided a second opportunity to hear the smaller-scale T1500F tuner-amplifier which was briefly reviewed in the May issue of PRACTICAL ELECTRONICS.

Second audio exhibit to highlight the advance in electronics was the now well-known Sinclair 10W integrated circuit amplifier, a pair of which had been made up as a stereo amplifier specially for the show and demonstrated through the new Q14 mini speaker. Another exhibit was the System 2000 pulse counting f.m. tuner, which uses varactors to permit continuous tuning by remote control. A new tuner, to complement the Neoteric amplifier, is to appear shortly.

PERCUSSION GENERATOR

The Eagle products stand provided a welcome opportunity for creative knob-twiddling in the shape of the Rhythm Master percussion generator, which gives seven percussion sounds and nine rhythms. (Do-it-yourselfers will be interested in the rhythm generator design that appears elsewhere in this issue.) The display included some of the variety of plugs, sockets, microphones, and effects generators handled by the company.

RECORD PLAYING EQUIPMENT

On the Perpetuum-Ebner stand we saw Germany's attempt to overcome the audiophile's inbred mistrust of automatic record changing. The PE2020 has a 7lb turntable, adjustable vertical tracking angle, stylus pressure and antiskating force, a rotating centre spindle and an ingenious stepped turntable for detecting record-size.

Record playing equipment for different needs, but equally ingenious, was shown by Discatron. The RHR9001 was a combined portable radio and 45 r.p.m. record player, similar in styling to a conventional radio. Other combinations included a record and tape player, and a radio, record and tape player.

RADIO FOR CASSETTE RECORDER

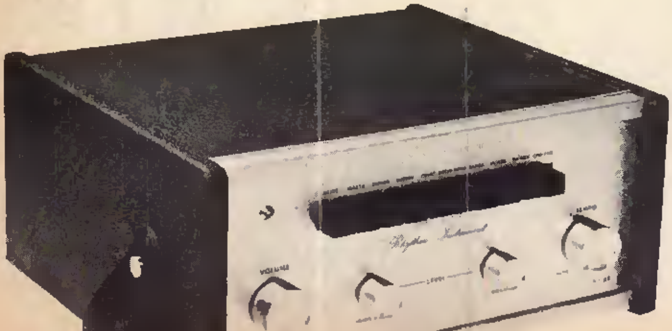
An interesting accessory on the Aiwa stand was a small radio tuner which slips into their 736 Compact cassette recorder. The TPR101, a combined recorder and multi-band radio, gained its first public showing.

A last minute addition to the Alba range was a deluxe radiogram, Model 4007.

With a 30W amplifier and two tuner units, Crown made their first attack on the British hi-fi market.

WELL CONTENTED TRADE VISITORS

As a percentage of the whole, there was little innovation in this collection of displays. Colour TV, f.e.t.s., integrated circuits, micro-speakers have ceased to amaze—but no trade visitor was likely to feel bored. He could enter a competition for £1,000, a holiday in Hamburg or a night on the town. He could relax and watch cabaret, or politely refuse 57 complimentary Martinis on the trot. ★



Eagle Products
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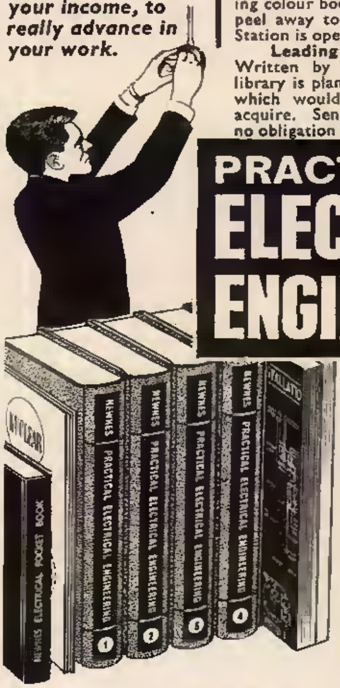

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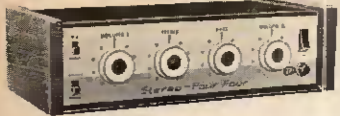

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A major breakthrough in electronics rivalling in importance that brought about by the transistor has been achieved by recent research on semiconductors. A whole new family of semiconductor devices is being developed, which will in time do for microwave electronics what the transistor has already done for the present-day application of electronics in the domestic and industrial fields. This important development depends on the ability of a semiconducting material, gallium arsenide, to emit microwaves when a voltage is applied to a slice of the material. This concluding article deals with negative resistance and the L.S.A. device used to overcome the problem of high frequency limitations.

Last month we considered the properties of semiconductor materials and the theory behind the transistor. The high frequency limitation of the latter device was pointed out.

This month we introduce some comparatively new semiconductor devices which overcome these high frequency limitations and thus offer promise of further great advances in semiconductor technology.

A NEGATIVE RESISTANCE DEVICE

The next semiconductor active device of major importance that came on the scene utilised the property of negative resistance.

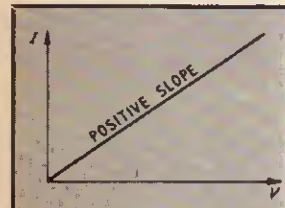

Fig. 21a

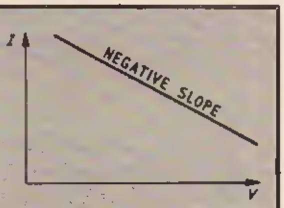

Fig. 21b

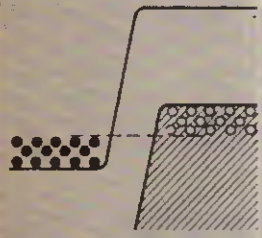

Fig. 22a

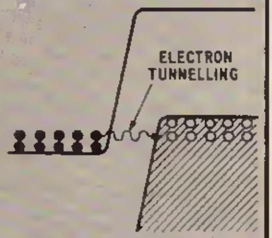

Fig. 22b

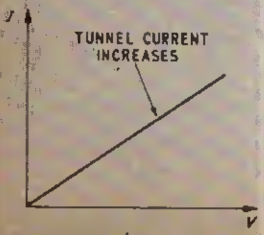

Fig. 23

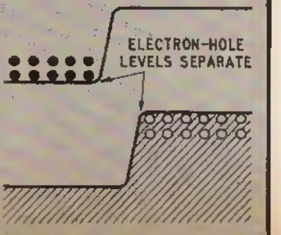

Fig. 24

Ordinary positive resistance is given by the voltage/current ratio for the current flow due to the voltage applied across a resistance. This would be given by the slope of a current-voltage graph as shown in Fig. 21a.

The characteristic of negative resistance on the graph shows a negative (downward) slope as in Fig. 21b, i.e. an increase in voltage resulting in a decrease in current.

Current is determined by the rate of flow of electric charge, so it depends both on the numbers and the velocities of the charge carriers as well as their charge. In normal positive resistance, the number n of charge carriers flowing in a circuit usually stays constant while their velocity increases regularly with increasing applied voltage, so that I increases with V.

If we could somehow decrease n with increasing V sharply enough, there will be a decrease in I and thus negative resistance will occur.

THE TUNNEL DIODE

The tunnel diode, a negative resistance device working in this way, was invented in 1958 by a Japanese physicist, L. Esaki. It consists of a single pn junction in which the p- and n-type regions are very heavily doped. Thus the difference in levels on both sides is so great that the bottom of the conduction band in the n-type region is below the top of the valence band in the p-type region. This is illustrated in Fig. 22a.

Practically no electrons and holes can flow across the junction and the current is virtually zero. If the junction is biased forward very slightly, reducing the potential difference, the electrons still cannot run uphill into the p-type region as the potential difference is still very great. However, they are now brought into levels corresponding with those of the holes opposite them in the p-type region. These holes are nothing but absences of electrons.

By the laws of quantum physics, an electron in the n-type region is able to "tunnel" through the junction barrier into an empty electron level at the same height in the p-type region, i.e. a hole. This surprising effect is allowed a certain small probability by quantum physical laws.

As the number of electrons is so large, some of them do tunnel through and are able to constitute a current across the junction (see Fig. 22b). As the bias is increased, more electron and hole levels are brought opposite one another and the tunnel current increases, see Fig. 23.

As the bias is increased further, the electron and hole levels separate again, and the number of electrons able to tunnel across decreases (Fig. 24). The tunnel current thus decreases with increasing voltage.

The current-voltage graph thus has a negative slope and the junction exhibits negative resistance (Fig. 25). On increasing the bias still further, the junction begins to conduct an appreciable normal forward bias current.

Thus a tunnel diode with an appropriate bias applied to it will behave as a negative resistance. It can be used in an LC circuit to generate electrical oscillations (Fig. 26).

SHORT TRANSIT TIME

The theoretical high frequency response of the tunnel diode should only be limited by the time taken for the electrons to tunnel through the junction. As the tunnelling is an extremely fast phenomenon, this transit time limitation is much less restrictive than that on the transistor, and thus it can work at much higher frequencies. Tunnel diodes can be operated in the lower frequency section of the microwave spectrum. However, the tunnel diode also has its own high frequency limitations.

Like all diodes, it has exposed net charges on either side of the junction. These charges are slightly affected by an external bias, and so the junction has a very small capacitance C_j, which must be added to the C in the LC circuit. The frequency of oscillation is now

$$1/[2\pi\sqrt{L(C + C_j)}]$$

Thus no matter how small we make L or C, the junction capacitance will always impose an upper limit on the frequency of oscillation of the resonant circuit.

However, the tunnel diode is a significant advance on the transistor as a high frequency active device. It has two layers and one junction compared with three layers and two junctions of the transistor, which is a reduction in complexity. Gallium arsenide (GaAs) devices do not depend at all on junction effects for their functioning. Their negative resistance is purely a property of their bulk material, and depends only on the behaviour of the charge carriers in the bulk material.

THE NEGATIVE RESISTANCE PROPERTY OF GaAs

The negative resistance of gallium arsenide depends not on a decrease in n with an increase of voltage, but a decrease in velocity, with n remaining constant. When an n-type GaAs slice is biased to a certain voltage, a further increase in voltage will result in a decrease in the velocity of the electrons. Since it is the electric field (voltage per unit length) across the slice that matters rather than the voltage, a graph of the velocity of the electrons against the applied electric field must be plotted and is shown in Fig. 27.

When the field across the GaAs slice is above about 3,000 volts per centimetre, it starts to exhibit negative resistance, as the current across the slice will decrease due to the decreasing velocity with increasing electric field, i.e. voltage across the slice. A decrease in the velocity of the electrons means that less charge will flow across the slice in a given time, i.e. less current will flow.

THE FIRST GaAs OSCILLATOR

The first GaAs active device functioning as a negative resistance oscillator was discovered by J. B. Gunn in 1964 while he was doing research on the high field properties of semiconductors. A rod of GaAs when biased above 3kV/cm began oscillating electrically and also emitted microwaves, the oscillations being at microwave frequencies.

H. Kroemer then put forward the explanation that the GaAs rod was acting as an oscillator because of its negative resistance property. Kroemer drew attention to the fact that three British physicists, B. K. Ridley, T. B. Watkins and C. Hilsum, had hitherto predicted that GaAs would show the property of negative resistance under these conditions.

FUNDAMENTAL THEORY

To understand why GaAs exhibits negative resistance, it is necessary to refer to fundamental semiconductor physics. Our previous energy level diagrams (see Part 1) only show the energy values of the electrons in a semiconductor, the horizontal axis simply standing for the physical dimensions of the semiconductor bulk.

An energy level diagram can be drawn to show both the energy and momentum of the electrons in the conduction band (Fig. 28a). In this diagram, the horizontal axis stands for the momentum of the electrons. An electron in the conduction band must lie on the curved line, i.e. it can only have the simultaneous values of energy and momentum that the points on the line have. This is because the energy and momentum of a moving object are closely related. This relation involves the mass of the object.

Now, as the electron moves in the semiconductor, its movement is affected by the positive charges of the atomic nuclei in the semiconductor. Thus it does not move in quite the same way as a free electron in space. The effect of these nuclei on the electron can be taken into account by considering the electron as having an effective mass quite different from its actual mass. The

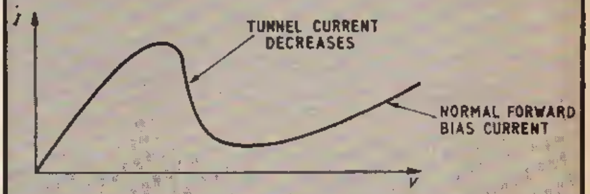

Fig. 25

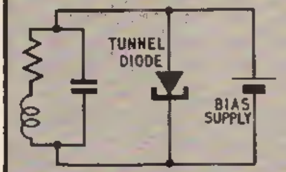

Fig. 26

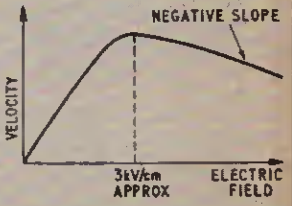

Fig. 27

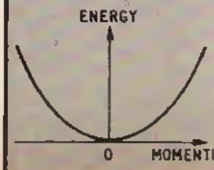

Fig. 28a

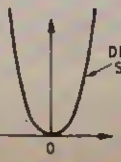

Fig. 28b

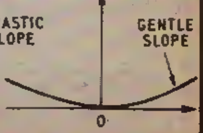

Fig. 28c

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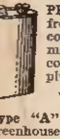

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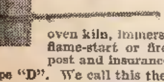

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BARGAIN OF THE YEAR

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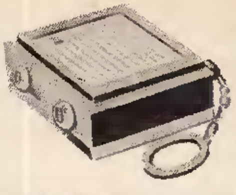

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2. Magneto bell, which will work with above generator or from the mains through a step down transformer.
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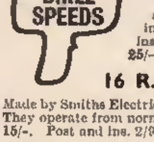

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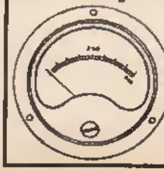

Meters are always being needed and they are jolly costly when you have to buy them in a hurry. So it's sensible to take advantage of this offer: 2½in. (3in. o.d.) flush mounting moving coil meters only 8/6 each. These are scaled 0–300mA but once the internal shunt is removed the f.s.d. is usually about 10mA so you can make it into almost anything by adding shunts or series resistors. These are Ex. W.D. of course but are all new and unused. Price only 8/6 each plus 2/6 post. 12 or more post free.

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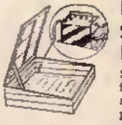

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25V	1·6	6·4	12·5	25	50	80
40V	1	4	8	16	32	50
64V	0·64	2·5	5	10	20	32
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16V	250	400	640	1,000
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40V	100	160	250	400
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400V: 1,000, 1,500, 2,200, 3,300, 4,700pF, **6d.** 6,800pF, 0·01, 0·015, 0·022μF, **7d.** 0·033μF, **8d.** 0·047μF, **9d.** 0·068, 0·1μF, **11d.** 0·15μF, **1/2.** 0·22μF, **1/6.** 0·33μF, **2/3.** 0·47μF, **2/8.**
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difference between the effective mass and the actual mass varies with different semiconductors and also with the energy levels of the electron.

Considering the movement of an electron in a semiconductor, using its effective mass instead of its actual mass, the effect of the atomic nuclei on the electron can be taken into account automatically. The effective mass of an electron at any point on the energy-momentum diagram is related to the slope of the curve at that point.

Thus in a semiconductor, whose energy-momentum diagram looks like that in Fig. 28b, the effective masses of the electrons at the bottom of the conduction band is less than those at the bottom of the conduction band of a semiconductor with an energy-momentum diagram of gentler slope like that in Fig. 28c.

ENERGY-MOMENTUM CURVE

Gallium arsenide has an energy-momentum curve with a drastic slope (Fig. 28b). The electrons at the bottom of the conduction band have a small effective mass.

Now, GaAs also has secondary curves of gentler slope higher up in its energy-momentum diagram (Fig. 29a). If we apply a voltage to a GaAs slice, the electrons having a small effective mass are easily moved and the current across the slice increases. As they are accelerated by the voltage, they gain energy and they rise up the curve on the diagram. We show the rise only on one side of the momentum axis as they are accelerated and gain momentum only in one direction—that due to the applied voltage.

As they approach the levels of the secondary curve, they begin to get transferred to the energy levels there. This is because the energy levels there are much more numerous than the energy levels on the main curve at the same height (Fig. 29b).

Once they are on the bottom of the secondary curve, their effective masses are much larger as the slope of the secondary curve is much gentler. As a result, their velocity decreases, since an object with a large mass is harder to move than an object with a small mass. As we further increase the voltage, more and more electrons get transferred to the secondary curve and the overall velocity of the electrons decreases. The velocity-electric field curve thus has a negative slope (Fig. 30).

The electron current will thus decrease with increasing applied voltage, and the GaAs slice exhibits negative resistance.

THE GUNN EFFECT

A slice of gallium arsenide when biased into the negative resistance region should be able to generate electrical oscillations when put into an LC circuit.

When Gunn observed the oscillations in the GaAs rod, what was actually happening was that the rod itself and its mounting made up its own LC circuit and thus oscillated at a frequency determined by its own physical dimensions. As the oscillations were at microwave frequencies, the rod radiated the oscillating electrical energy in the form of electromagnetic waves. This is because a circuit element carrying an oscillation will radiate more and more electromagnetic energy as the wavelength of the oscillation decreases and becomes comparable to the physical dimensions of the element. This is a fundamental of aerial theory.

This microwave emission phenomenon from GaAs was called the Gunn Effect after its discoverer.

ELECTRON BUNCHING

In the Gunn Effect, it was later found that when the GaAs rod is biased into the negative resistance region, and begins to emit microwaves, a bunch of electrons collects at one end of the rod near the contact and travels to the other end. As soon as it reaches the other end, another bunch forms at the first end and the process repeats itself. This occurred in step with the oscillations; in fact, it seemed to determine the frequency of the oscillations.

The electrons in the rod when it is in the negative resistance region do not behave like normal electrons in a normal positive resistance material. In a positive resistance material a bunch of electrons will be dispersed in a short time. In a negative resistance material, as the electrons travel along in the material due to the voltage applied to the material, any slight bunching up leads to a greater accumulation of electrons. This is because the bunching up creates a higher field in the area of the bunch due to the electrons' own charges.

This higher field affects the electrons in and near the bunch, which then slow down because of the negative velocity-field slope. Thus instead of dispersing, a further accumulation of electrons takes place and what is known as a domain forms and travels across the rod.

DOMAIN FORMATION

The actual nature of the domain is an accumulation of electrons preceded by a layer depleted of electrons. The overall number of electrons in the rod remains the same (Fig. 31).

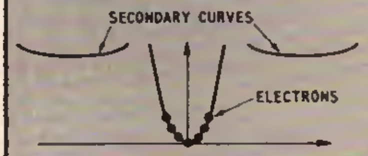

Fig. 29a

Fig. 29b

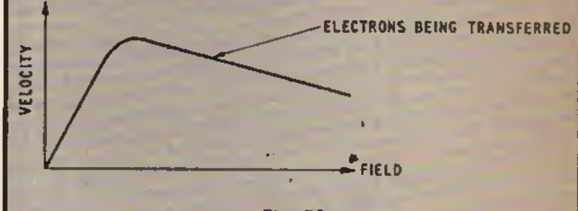

Fig. 30

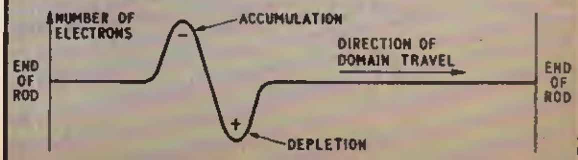

Fig. 31

The result of this domain formation and travel is to limit the high frequency response of the device. The frequency of the oscillations is tied to the transit-time of the domain across the rod. The domains will always form since natural inhomogenities in the GaAs will always result in uneveness in the electron distribution in the rod. This uneveness is most pronounced at the end of the rod where the electrical contacts are made, so that the domains form at the ends. Only one domain is sustained at a time; as the domain consists of electrons, it travels under the influence of the applied field to the other end of the rod. Another domain then forms at the first end and repeats the process.

EFFECTIVE CAPACITANCE

We may look at the high frequency limitation of the Gunn Effect device from another angle. The domain consists of a layer of accumulated electrons having a negative charge relative to the rest of the rod, and a depleted layer having a net positive charge. This is like a charged capacitor because the accumulated charge depends on the external applied field.

Thus like the tunnel diode, the Gunn Effect device is frequency-limited by this effective capacitance. However, it is able to oscillate in the microwave region of the electromagnetic spectrum.

THIN SLICES BY EPITAXIAL GROWTH

Clearly then, the high frequency microwave response is limited by the formation of the domains. In practice, the frequency limit is pushed up by making the domain transit-time as short as possible. This is done by making the distance between the contacts as short as possible, and thin slices of gallium arsenide and not rods are used as microwave oscillators.

These slices are formed by a process known as epitaxial growth, which also gives layers of the very high purity required for this purpose. Thin films of GaAs are deposited onto a heavily doped GaAs substrate which serves as one contact. A further thin film of heavily doped GaAs is deposited on the working layer to serve as the other contact (Fig. 32).

Microwaves of up to about 30GHz have been emitted from such devices. However, the restriction on the thickness of the slice limits the power capability of the device. As higher frequencies are reached by using thinner layers, the power output drops sharply.

THE LSA MODE

Since the frequency limitation is imposed by the moving domains, could we not get rid of them? If we could, such a GaAs slice would be able to function as a pure negative resistance device in an oscillator circuit.

J. E. Carroll, in early 1966, found that by putting a Gunn Effect device in a suitable circuit, the domain could be extinguished before it reached the other end. In the middle of 1966, M. W. Kennedy discovered that he could make a Gunn Effect device oscillate at a frequency far in excess of its usual one determined by the domain transit-time. J. A. Copeland then demonstrated theoretically and experimentally that in this case, the domains were being prevented from forming at all.

Here at last was the major breakthrough. The GaAs was now being used as a pure negative resistance oscillator, Fig. 33a, and the frequency of oscillations was determined by the external LC circuit (actually a cavity at microwave frequencies).

How were the domains prevented from forming? They form only when the GaAs is in the negative resistance region of the velocity-field curve. The GaAs slice was put in a resonating circuit and biased into the negative resistance region. A load impedance in the circuit was of such a value that the oscillating voltage across the load was large enough to bring the voltage bias across the GaAs slice at one end of each oscillatory swing into the positive resistance section of the velocity-field diagram (Fig. 33b).

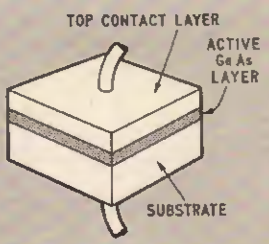

Fig. 32

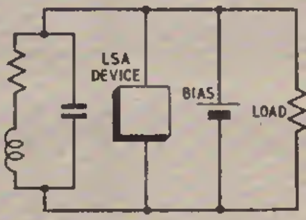

Fig. 33a

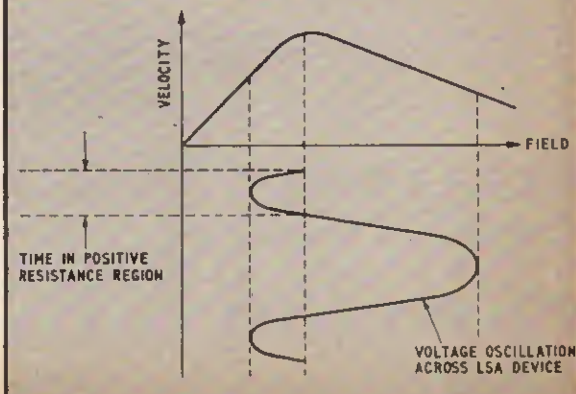

Fig. 33b

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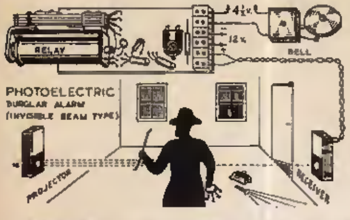

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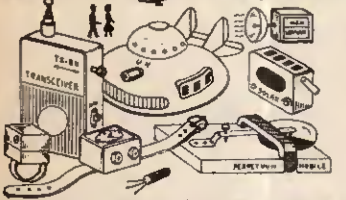

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While the GaAs is in this section it has a normal positive resistance; thus the electrons do not accumulate to form a domain but will disperse in the normal way. The formation and existence of the domain can only take place between each swing into the positive resistance region, when the GaAs is back in the negative resistance region.

PURE NEGATIVE RESISTANCE

In the quenched domain mode observed by Carroll, the time between swings was long enough to permit domain formation, but short enough to quench the domain before it reached the other end of the slice. Now, if this time, which is determined by the frequency of the oscillation, were even shorter, the domains which take a finite time to form will not even have any chance to do so. Thus the GaAs slice can operate as a pure negative resistance device. This was achieved by Kennedy and Copeland.

The frequency of oscillation which is now determined by the resonant LC network must be high enough to prevent domain formation. This is a good thing, since it is the higher frequencies that we are interested in anyway.

HIGHER POWER POSSIBLE

Because there is no transit-time limitation on the devices, they do not have to be made very thin. They can be fairly long so that they can handle much greater powers than Gunn Effect devices at higher frequencies. Copeland has recommended that they be made long in the direction parallel to the current flow and thin in a perpendicular direction to the flow, so that heat can be easily removed from the sides of the devices (Fig. 34).

This mode of operation of gallium arsenide as a negative resistance material is known as the Limited Space-charge Accumulation (LSA) mode, since the electrons are prevented (limited) from accumulating to form space-charge (bunched charges).

LSA devices are the first true negative resistance devices which depend only on the properties of a bulk material and not on layers or junctions. It is interesting to note this further step in the decrease of the number of layers necessary in a semiconductor active device, compared to the three layers of the transistor and the two layers of the tunnel diode. Furthermore, each progressive step has pushed the frequency limit of oscillation higher.

THE FUTURE OF LSA DEVICES

LSA devices hold exciting promise for the future wider applications of microwave electronics. In the not too distant future one can envisage the commercial production of small portable radar sets.

Using Gunn Effect devices, prototype portable radar sets have been constructed and demonstrated by the Royal Radar Establishment.

The availability of tiny, simple and efficient microwave generators and oscillators at millimetre wavelengths brings nearer the day when the personal portable sound and colour television transceiver for communication with anybody else in the world is a working reality.

At the time of writing, Copeland has obtained 20mW output of c.w. microwaves at 88GHz with GaAs slices operating in the LSA mode. The GaAs slices were thin and originally intended for operation in the Gunn Effect mode. When proper LSA devices to Copeland's design have been constructed, they will undoubtedly be able to generate much higher powers.

Even then, the powers already obtained are much higher than those ever generated by previous semiconductor active devices at such high frequencies.

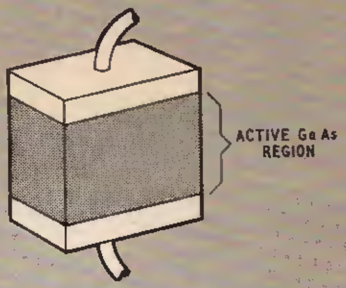

Fig. 34

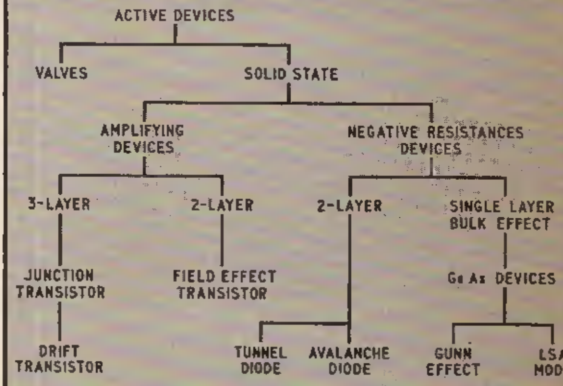

Fig. 35

INTENSE RESEARCH

Research on LSA devices is now proceeding intensely in many laboratories and gaining momentum with each week. The writer is certain that by the time this article appears, significant progress will have been made in the practical construction, operation and application of these devices.

As a matter of interest, a chart (Fig. 35) showing the progress of the development, and the relationships of active devices is included. ★

MUSICAL PHASE

In the article *Musical Phase* (September) the name of the co-author M. G. Lewis B.Sc., was inadvertently omitted. Mr. Lewis was in fact responsible for the invention of the Pradge phase generating equipment described in this article.

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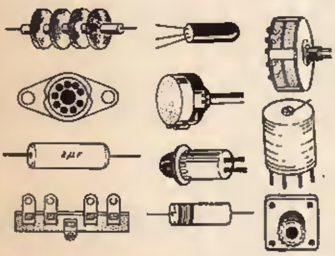

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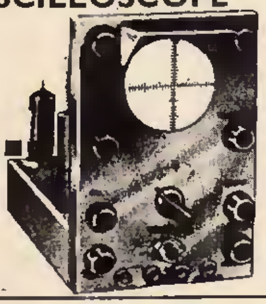

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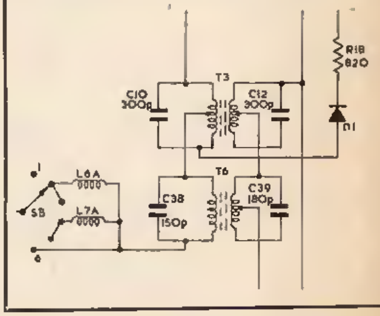

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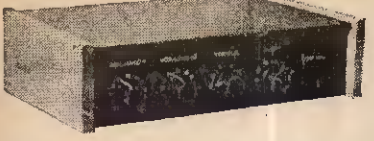

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A top-quality record player amplifier employing heavy duty double wound mains transformer, ECC83, EL84, EZ80 valves. Separate Bass, Treble and Volume controls. Complete with output transformer matched for 3 ohm speaker. Size 7in. w. × 3 d. × 6 h. Ready built and tested. PRICE 75/-. P. & P. 6/-.

ALSO AVAILABLE mounted on board with output transformer and speaker ready to fit into cabinet below. PRICE 97/6. P. & P. 7/6.

DE LUXE QUALITY PORTABLE R/P CABINET
Uncut motor board size 14½ × 12in., clearance 2in. below, 5¼in. above. Will take above amplifier and any B.S.R. or GARRARD autochanger or Single Player Unit (except AT60 and SP25). Size 18×15×8in. PRICE £3.9.6. P. & P. 9/6.

HARVERSON'S SUPER MONO AMPLIFIER

A super quality gram amplifier using a double wound mains transformer, EZ80 rectifier and ECL82 triode pentode valve as audio amplifier and power output stage. Impedance 3 ohms. Output approx. 3·5 watts. Volume and tone controls. Chassis size only 7in. wide × 3in. deep × 6in. high overall. AC mains 200/240V. Supplied absolutely Brand New completely wired and tested with valves and good quality output transformer. LIMITED NUMBER ONLY.

OUR ROCK BOTTOM BARGAIN PRICE **49/6** P. & P. 6/-

8 WATT AMPLIFIER. Push Pull using ECC83, EZ80 and two EL84 valves. Suitable for use with tuner or gram. Separate bass, treble and volume controls. Absolutely complete with attractive facia panel. Size 12 × 3¼ × 5in. high. Brand new and tested **£7.17.6.** P. & P. 8/6.

BRAND NEW 3 OHM LOUDSPEAKERS
5in. 14/-; 6½in. 18/6; 8in. 27/-; 7 × 4in. 18/6; 10 × 6in. 27/6. E.M.I. 8 × 5in. with high flux magnet 21/-. E.M.I. 13½ × 8in. with high flux ceramic magnet 42/- (15 ohm 45/-). E.M.I. 13 × 8in. with two inbuilt tweeters and crossover network. 3 or 15 ohms 4 gns. P. & P. 5in. 2/-, 6½ & 8in. 2/6, 10 & 12in. 3/6 per speaker.
BRAND NEW. 12in. 15W H/D Speakers, 3 or 15 ohms. By well-known British maker. Now with Hi Flux ceramic ferrobar magnet assembly. £5.10.0. P. & P. 5/-. Guitar Models: 25w. £6; 35w. £8.
E.M.I. 3½in. HEAVY DUTY TWEETERS. Powerful ceramic magnet. Available in 3 or 8 ohms 15/- each; 15 ohms 18/6 each. P. & P. 2/6.
12in. "RA" TWIN CONE LOUDSPEAKER. 10 watts peak handling. 3 or 15 ohm, 35/-. P. & P. 3/6.
35 OHM SPEAKERS
3½in. 12/6; 7 × 4in. 21/-. P. & P. 2/- per speaker.

VYNAIR AND REXINE SPEAKERS AND CABINET FABRICS app. 54in. wide. Usually 35/- yd., our price 13/6 yd. length. P. & P. 2/6 (min. 1 yd.). S.A.E. for samples.

LATEST COLLARO MAGNAVOX 363 STEREO TAPE DECK. Three speeds 4 track, takes up to 7in. spools. Send S.A.E. for latest prices.
B.S.R. TD2, 4-TRACK STEREO TAPE DECK. Send S.A.E. for latest price.
QUALITY PORTABLE TAPE RECORDER CASE. Brand new. Beautifully made. Only 49/6. P. & P. 3/6.
Dual Purpose Bulk Tape Eraser and Tape Head Demagnetiser 35/-. P. & P. 3/-.
ACOS CRYSTAL MIKES. High imp. for desk or hand use. High sensitivity, 18/6. P. & P. 1/6.
ACOS HIGH IMPEDANCE CRYSTAL STICK MIKES. Listed at 42/-. OUR PRICE 21/-. P. & P. 1/6.
SPECIAL OFFER! MOVING COIL STICK MIKE. Fitted on/off switch for remote control. High quality. High or low impedance. (State imp. required). **BARGAIN PRICE** 30/-. P. & P. 2/6.

NEW S.T.C. TYPE 25 MINIATURE RELAYS— 12 volt. 4 s/p, c/o contacts. 1 amp rating. Coil resistance 185 ohms. Size approx. ¾ × 1⅛ × 1⅜in. high. 10/- each. P. & P. 1/6.

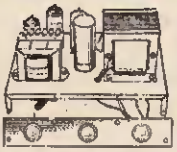
Also some similar to above but coil resistance 5,800 ohms 48 volt operation. 8/- each. P. & P. 1/6.

SPECIAL OFFER! PLESSEY TYPE 29 TWIN TUNING GANG. 400pF + 146pF. Fitted with trimmers and 5:1 integral slow motion. Suitable for nominal 470 kc/s I.F. Size approx. 2 × 1 × 1½in. Only 8/6. P. & P. 2/6.
MAINS TRANSFORMER. For transistor power supplies. Pri. 200/240V. Sec. 9–0–9 at 500mA. 11/-. P. & P. 2/6. Pri. 200/240V. Sec. 12–0–12 at 1 amp. 14/6. P. & P. 2/6. Pri. 200/240V. Sec. 10–0–10 at 2 amp. 27/6. P. & P. 3/6.
MATCHED PAIR OF 2½ WATT TRANSISTOR DRIVER AND OUTPUT TRANSFORMERS. Stack size 1½ × 1½ × ⅞in. Output trans. tapped for 3 ohm and 15 ohm output. 10/- pair plus 2/- P. & P.
PARMEKO 7–10 watt OUTPUT TRANSFORMERS to match pair of ECL82's in push-pull. Sec. tapped 3·75, 7·5 and 15 ohm. Stack size 2¼ × 1 × 2in. approx. ONLY 12/-. P. & P. 3/-.
7–10 watt OUTPUT TRANSFORMERS to match pair of ECL86's in push-pull to 3 ohm output. ONLY 11/-. P. & P. 2/6.
BRAND NEW MAINS TRANSFORMERS for Bridge Rectifier. Pri. 240V AC. Sec. 240V at 50mA and 6·3V at 1·5 amp. Stack size 2⅞ × ¾ × 2½in. 10/6. P. & P. 3/6. (Special quotations for quantities).

NEON A.C. MAINS INDICATOR. For panel mounting, cut out size 1⅛ × ¾ × ⅞in. deep inc. terminal. White case with lens giving brighter light. For mains 200/250V. 2/6 each. P. & P. 6d. (6 or more post free).

HIGH GRADE COPPER LAMINATE BOARDS
8 × 6 × $\frac{1}{16}$in. FIVE for 10/-. P. & P. 2/-.

BRAND NEW TRANSISTOR BARGAINS. GET 15 (Matched Pair) 15/-; V15/10p, 10/-; OC71 5/-; OC76 6/-; AF117 7/6.
Set of Mullard 6 transistors OC44, 2—OC45, AC128D, matched pair AC128 25/-; Mullard LFH3 Audio Transistor Pack AC128D and matched pair AC128 12/6; ORP12 Cadmium Sulphide Cell 10/6. All post free.



3-VALVE AUDIO AMPLIFIER MODEL HA34
Designed for Hi-Fi reproduction of records. A.C. Mains operation. Ready built on plated heavy gauge metal chassis, size 7½in w. × 4in. d. × 4¾in. h. Incorporates ECC83, EL84, EZ80 valves. Heavy duty, double wound mains transformer and output transformer matched for 3 ohm speaker, separate Bass, Treble and volume controls. Negative feedback line. Output 4½ watts. Front panel can be detached and leads extended for remote mounting of controls. Complete with knobs, valves, etc., wired and tested for only **£4.5.0.** P. & P. 6/-.
HSL "FOUR" AMPLIFIER KIT. Similar in appearance to HA34 above but employs entirely different and advanced circuitry. Complete set of parts, etc. 79/6. P. & P. 6/-.

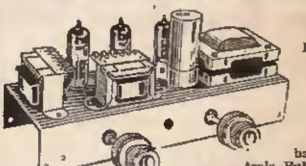
SPECIAL OFFER!

A great opportunity to purchase a first class **GENERAL PURPOSE, HIGH GAIN, HIGH SENSITIVITY, PORTABLE AMPLIFIER.** Completely self contained and can be used for a variety of purposes, i.e. Intercom, Baby Alarm, Booster unit for transistor radios etc., also ideal for classroom unit etc. Works perfectly with our special offer High Impedance Dynamic Microphone (30/-). Output 1000mW. Uses standard 9 volt battery. Smart two tone carrying case size 12 × 4 × 9in. fitted standard input jack socket, volume controls, 7 × 4in. speaker. Completely built and tested, brand new with full maker's guarantee.

Only 79/6 P. & P. 5/6

STEREO AMPLIFIER

Incorporating 2 ECL86's and 1 EZ80, heavy duty, double wound mains transformer. Output 4 watts per channel. Full tone and volume controls. Absolutely complete.

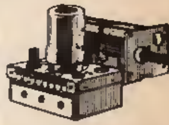


ONLY £5.9.6
P. & P. 8/-. Super Deluxe version with ECL86 valves, sep. bass, treble and balance controls. Full feedback. 8 gns. P. & P. 8/-.

HIGH GAIN 4 TRANSISTOR PRINTED CIRCUIT AMPLIFIER KIT
Type TA1

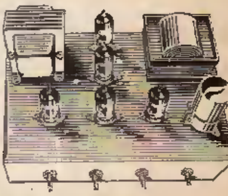
- Peak output in excess of 1½ watts.
- All standard British components.
- Built on printed circuit panel size 6 × 3in.
- Generous size Driver and Output Transformers.
- Output transformer tapped for 3 ohm and 15 ohm speakers.
- Transistors (GET114 or 81 Mullard OC81D and matched pair of OC81 o/p).
- 9 volt operation.
- Everything supplied, wire, battery clips, solder, etc.
- Comprehensive easy to follow instructions and circuit diagram 2/6 (Free with Kit). All parts sold separately. **SPECIAL PRICE 45/-.** P. & P. 3/-. Also ready built and tested, 52/6. P. & P. 3/-.

FM/AM TUNER HEAD



Beautifully designed and precision engineered by Dormer & Wadsworth Ltd. Supplied ready fitted with twin ·0005 tuning condenser for AM connection. Prealigned FM section covers 86–102Mc/s. I.F. output 10·7Mc/s. Complete with ECC85 (6L12) valve and full circuit diagram of tuner head. Another special bulk purchase enables us to offer these at 27/6 each. P. & P. 3/-. **GORLER F.M. TUNER HEAD.** 88–100 Mc/s. 10·7 Mc/s. I.F. 15/- plus 2/6 P. & P. (ECC85 valves, 8/6 extra).

10/14 WATT HI-FI AMPLIFIER KIT



A stylishly finished monaural amplifier with an output of 14 watts from 2 EL84s in push-pull. Super reproduction of both music and speech, with negligible hum. Separate inputs for mike and gram allow records and announcements to follow each other. Fully shrouded section wound output transformer to match 3–15Ω speaker and 2 independent volume controls, and separate bass and treble controls are provided giving good lift and cut. Valve line-up 2 EL84s, ECC83, EF86 and EZ80 rectifier. Simple instruction booklet 2/6 (Free with parts). **All parts sold separately.** ONLY £7.9.6. P. & P. 8/6. Also available ready built and tested complete with std. input sockets. £9.5.0. P. & P. 8/6.

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(Please write clearly)

PLEASE NOTE: P. & P. CHARGES QUOTED APPLY TO U.K. ONLY. P. & P. ON OVERSEAS ORDERS CHARGED EXTRA.

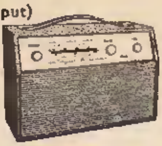
THE DORSET (600mW Output)

7-transistor fully tunable M.W.–L.W. superhet portable—with baby alarm facility. Set of parts. The latest modulised and pre-alignment techniques makes this simple to build. Sizes: 12" × 8" × 3".

MAINS POWER PACK KIT: 9/6 extra.

Price £5.5.0 plus 7/6 p. & p. Circuit 2/6 FREE WITH PARTS.

THE ELEGANT SEVEN MK. III (350mW output)



7-transistor fully tunable M.W.–L.W. portable. Set of parts. Complete with all components, including ready etched and drilled printed circuit board—back printed for foolproof construction.
MAINS POWER PACK KIT: 9/6 extra.

Price £4.9.6 plus 7/6 p. & p.

Circuit 2/6 FREE WITH PARTS.

50 WATT AMPLIFIER A.C. MAINS 200–250V

An extremely reliable general purpose valve amplifier—with six electronically mixed inputs. Suitable for use with: mics, guitars, gram, tuner, organs, etc. Separate bass and treble controls.

Price 27 gns. plus 20/– p. & p.

X101 10W SOLID-STATE HI-FI AMP WITH INTEGRAL PRE-AMP

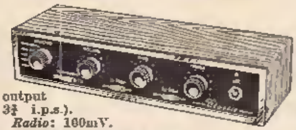
Specifications: *R.M.S Power Output* (into 3 ohms speaker): 10 watts continuous (sine wave), 13 watts music power. *Sensitivity* (for rated output): 1mV into 3K ohms (0·33 micro-amp) *Total Distortion* (@ 1Khz): at 5 watts 0·35%, at rated output 1·5%. *Frequency Response*: Minus 3dB points 20Hz and 40Khz. *Speaker*: 3–4 ohms (3–15 ohms may be used). *Supply voltage*: 24V d.c. @ 800mA (6–24V may be used).

Control assembly: including resistors and capacitors.
1. Volume: PRICE 5/–.
2. Treble: PRICE 5/–.
3. Comprehensive bass and treble: PRICE 10/–.
The above 3 items can be purchased for use with the X101.

Price 49/6 plus 2/6 p. & p.

Power Supplies for the X101:
P101 M (for mono) 35/– plus 4/6 p. & p. P101 S (for stereo) 42/6 plus 4/6 p. & p.

THE CLASSIC



Controls: Selector switch. Tape speed equalisation switch (3¾ and 7½ i.p.s.). Volume. Treble. Bass. 2 position scratch filter and 2 position rumble filter.

Specification: Sensitivities for 10 watt output at 1KHz. *Tape head*: 3mV (at 3¾ i.p.s.). *Mag. P.U.*: 2mV. *Cer. P.U.*: 80mV. *Radio*: 160mV. *Aux.*: 100mV. *Tape/Rec. output*: 100mV. Equalisation for each input is correct to within ± 2dB (R.I.A.A.) from 20Hz to 20KHz. *Tone control range:* Bass ± 13dB at 60Hz. Treble ± 14dB at 15KHz. *Total distortion*: (for 10 watt output) <1·5%. *Signal noise*: <—60dB. A.C. mains 200–250v.

Size 12½" long, 4¼" deep, 2¾" high. Teak finished case. **Price 8 gns.** p. & p. free.

The RELIANT 10W SOLID-STATE HIGH QUALITY AMPLIFIER

Specifications: *Output*: 10 watts R.M.S. Sine-wave; 13 watts R.M.S. Music-power. *Output impedance*: 3 to 4 ohms. *Inputs*: 1. Xtal mic 10mV; 2. Gram/radio 250mV. *Tone controls*: Treble control range ± 12dB at 10KHz; Bass control range ± 13dB at 100Hz. *Frequency response* (with tone controls central): Minus 3dB points are 20Hz and 40KHz. *Signal to noise ratio*: better than —60dB. *Transistors*: 4 silicon Planar type and 3 Germanium type. *Mains input*: 220–250V a.c. *Size of chassis*: 10" × 3¾" × 2". A.C. Mains, 200–250V. For use with Std. or L.P. records, musical instruments, all makes of pick-ups and mikes. Separate base and treble lift control Two inputs with control for gram. and mike. Built and tested. 8" × 5" speaker to suit: Price 14/6 plus 1/6 p. & p. Crystal mike to suit: 12/6 plus 1/6 p. & p.
PRICE £5.5.0 plus 5/– p. & p.

RECORD PLAYER SNIP

The "Princess" 4 speed automatic record changer and player engineered with the utmost precision for beauty, long life and trouble free service. Will take up to ten records which may be mixed 7in to 10in or 12in. Patent stylus brush cleans stylus after each playing and at shut off, the pick-up locks itself into its recess, a most useful feature with portable equipment—other features include pick-up height adjustment and stylus pressure adjustment. This truly is a fine instrument which you can purchase this month at only £5.19.6 complete with cartridge and ready to play. Post and insurance 7/6 extra. A.C. Mains 240v.

Price £5.19.6

CYLDON U.H.F. TUNER

Complete with PC88 and PC86 Valves. Full variable tuning. New and unused. Size 4¾" × 5½" × 1¾". Complete with circuit diagram.
35/– plus 3/6 p. & p.

THREE-IN-ONE HI-FI 10 WATT SPEAKER

A complete Loud Speaker system on one frame, combining three matched ceramic magnet speakers with a low loss cross-over network. Peak handling power 10 watts. Impedance 15 ohms. Flux density 11,000 gauss. Resonance 40–60c/s. Frequency range 50c/s to 20kc/s. Size 13½" × 8⅛" × 4½". By famous manufacturer. List price £7. Our price 69/6 plus 5/– p. & p. Similar speaker to the above without tweeters in 3 and 15 ohms 39/6 plus 5/– p. & p.

Goods not despatched outside U.K. Terms C.W.O. All enquiries S.A.E.

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ORGAN BUILDERS! SILICON N.P.N. TRANSISTORS, ALL INDIVIDUALLY TESTED IN PUBLISHED DIVIDER CIRCUIT! GOLD-PLATED LEADS FOR EASY SOLDERING! Unbeatable value at 1/6 each or £5/-/- per 100.

TRANSISTORISED FLUORESCENT LIGHT. 8 WATT 12in TUBE. Current drain only 700mA! Complete and tested £2/19/6 only!
Or in kit form:

Case		7/6
Transistor		10/-
Lamp holders—	pair	4/-
Condensers, etc.		3/-
Transformer (on printed circuit)		13/6
Tube		8/-

TRANSISTORS
OC200, OC203, OC204, all at 2/- each.
ASY22, 2N753, BSY28, BSY65, 2G344A, 2G345A, 2G345B, 2G371A, 2G378A, all at 1/6 each.
Transistors similar to OC44, OC71 and OC72, all 1/- each.
Unmarked, untested transistors, 7/6 for 50.

LIGHT SENSITIVE TRANSISTORS (similar OCP 71). 2/- each.
30 watt transistors (ASZ17), 10/- each.

DIODES. Very low leakage. Make excellent detectors, also suitable for keying electronic organs, 1/- each, 20 for 10/-.

RECTIFIERS
BY100, 800 p.i.v., 2/6 each, 24/- per doz., £7/10/- per 100, £50 per 1,000.
BYZ13, 6-amp, 400 p.i.v., available on same terms.

MULLARD POLYESTER CAPACITORS FAR BELOW COST PRICE!

0·001μF	400 volts	3d	0·02μF	200 volts	3d
0·0015μF	400 volts	3d	0·15μF	160 volts	6d
0·0018μF	400 volts	3d	0·22μF	160 volts	6d
0·0022μF	400 volts	3d	0·27μF	160 volts	6d
0·01μF	400 volts	3d	1μF	125 volts	1/-

VERY SPECIAL VALUE! Small Silver-mica, Ceramic, Polystyrene Condensers. Well assorted. Mixed types and values. 10/- per 100.
PAPER CONDENSERS, MIXED BAGS, 0·0001 to 0·5μF. 12/6 per 100.

RESISTORS! Give-away offer! Mixed types and values, ¼ to ½ watt. 6/6 per 100, 55/- per 1,000. Individual resistors 3d each. Also ½ to 3 watt close tolerance. Mixed values. 7/6 100, 55/- 1,000.
WIRE-WOUND RESISTORS. 1 watt to 10 watts. Mixed bags only. 16 for 10/-.

RECORD PLAYER CARTRIDGES
ACOS

GP	67/2	Mono.	15/- complete with needles.
GP	91/3	Stereo Compatible	£1/-/- ,,
GP	93/1	Stereo Ceramic	£1/5/- ,,
GP	94/1	Stereo Ceramic	£1/5/- ,,

Small pick-up arms complete with cartridge and needle, 10/- only.

TRANSISTORISED SIGNAL INJECTOR KIT R.F./I.F./A.F. 10/- only

TRANSISTORISED SIGNAL TRACER KIT 10/- only

VEROBOARD

2½in × 1in	0·15in matrix	1/1	17in × 2½in	0·15in matrix	11/-
3¾in × 2½in	0·15in matrix	3/3	17in × 3¾in	0·15in matrix	14/8
3¾in × 3¾in	0·15in matrix	3/11	3¾in × 2½in	0·1in matrix	3/9
5in × 2½in	0·15in matrix	3/11	3¾in × 3¾in	0·1in matrix	3/11
5in × 3¾in	0·15in matrix	5/6	5in × 2½in	0·1in matrix	3/11
			5in × 3¾in	0·1in matrix	5/6

Spot Face Cutter 7/6. Pin Insert Tool 9/6. Terminal Pins 3/6—36.

MULTIMETERS. 20,000 ohms per volt.
Ranges: a.c. 1,000V, 500V, 100V, 50V, 10V.
d.c. 250mA, 2·5mA, 50μA
d.c. 2,500V, 500V, 250V, 50V, 25V, 5V.
Resistance: 0/60kΩ and 0/6MΩ.
Special price £4/-/- only.

ELECTROLYTIC CONDENSERS

0·25μF	3 volt	4μF	4 volt	25μF	12 volt	100μF	16 volt
1μF	6 volt	4μF	12 volt	25μF	25 volt	125μF	25 volt
1μF	20 volt	4μF	25 volt	30μF	6 volt	320μF	4 volt
1·25μF	16 volt	6μF	6 volt	30μF	10 volt	320μF	10 volt
2μF	3 volt	8μF	3 volt	50μF	6 volt	400μF	6·4 volt
2μF	350 volt	8μF	12 volt	64μF	2·5 volt		
2·5μF	16 volt	10μF	6 volt	64μF	·9 volt		
3μF	25 volt	10μF	25 volt	100μF	9 volt		
3·2μF	64 volt	25μF	6 volt	100μF	16 volt		

All at 1/- each.

20 assorted (our selection) 10/-.

Orders by post to:
G. F. MILWARD, DRAYTON BASSETT, NEAR TAMWORTH, STAFFS.

Please include suitable amount to cover post and packing. Minimum 2/-. Stamped addressed envelope must accompany any enquiries.

For customers in Birmingham area goods may be obtained from Rock Exchanges, 231 Alum Rock Road, Birmingham 8.

BI-PRE-PAK
LIMITED

TRANSISTORS PRICE

AC107	3/–	OC170	3/–
AC126	2/4	OC171	4/–
AC127	2/4	OC200	3/6
AC128	2/4	OC201	7/–
ACY17	3/–	2G301	2/6
AF114	4/–	2G303	2/6
AF115	3/6	2N711	10/–
AF116	3/6	2N1302-3	4/–
AF117	4/6	2N1304-5	5/–
AF118	3/6	2N1306-7	6/–
AF119	3/6	2N1308-9	8/–
AF186	10/–	2S303	5/–
AF139	10/–	**Power**	
BFY50	4/–	**Transistors**	
BSY25	7/6	OC20	10/–
BSY26	3/–	OC23	10/–
BSY27	3/–	OC25	8/–
BSY28	3/–	OC26	5/–
BSY29	3/–	OC28	10/–
BSY95A	3/–	OC35	5/–
OC41	2/6	OC36	7/6
OC44	1/11	AD149	10/–
OC45	1/9	2N2287	20/–
OC71	2/6	**Diodes**	
OC72	2/6	AAY42	2/–
OC73	3/6	OA10	2/–
OC81	2/6	OA70	1/9
OC81D	2/6	OA79	1/9
AF102	12/6	OA81	1/9
OC139	2/6	OA182	2/–
OC140	3/6	IN914	1/6

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EXCITING NEW PAKS

FOR AMATEURS, PROFESSIONALS, FACTORIES, ORGAN BUILDERS, AND THOSE PEOPLE THAT JUST USE LARGE QUANTITIES OF TRANSISTORS.

XA PAK

Germanium PNP type transistors, equivalents to a large part of the OC range, i.e. 44, 45, 71, 72, 81, etc.

PRICE £5 PER 1000

XB PAK

Silicon TO-18 CAN type transistors NPN/PNP mixed lots, with equivalents to OC200-1, 2N706a, BSY27/29, BSY95A.

PRICE £5.5.0 PER 500
PRICE £10 PER 1000

XC PAK

Silicon diodes miniature glass types, finished black with polarity marked, equivalents to OA200, OA202, BAY31-39 and DK10, etc.

PRICE £5 PER 1000

ALL THE ABOVE UNTESTED PACKS HAVE AN AVERAGE OF 75% OR MORE GOOD SEMICONDUCTORS. FREE PACKS SUSPENDED WITH THESE ORDERS. ORDERS MUST NOT BE LESS THAN THE MINIMUM AMOUNTS QUOTED PER PACK.

P/P 2/6 PER PACK (U.K.)

PRE-PAKS

Selection from our lists

No.			Price
B1	50 Unmarked Trans. Untested		- 10/-
B2	4 Solar Cells Inc. Book of Instructions		- 10/-
B6	17 Red Spot AF Transistors		- 10/-
B6A	17 White Spot RF Transistors		- 10/-
B9	1 ORP 12 Light Sensitive Cell		- 9/-
B53	25 Sil. Trans. 400 Mc/s	Brand New	- 10/-
B54	40 ,, ,, NPN To5	Trans Voltage	- 10/-
B55	40 ,, ,, NPN To18	& Gain Fallouts	10/-
B56	40 ,, ,, NPN/PNP	All Tested	- 10/-
B68	10 Top Hat Recs. 750 M/A 100-800 PIV		- 10/-
B69	20 Diodes. Gld-Bnd. Germ Sil. Planer		- 10/-
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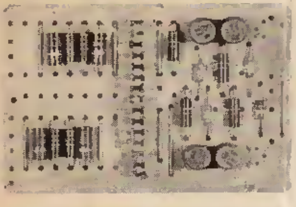

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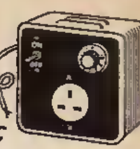

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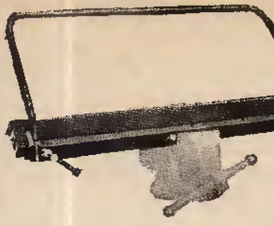

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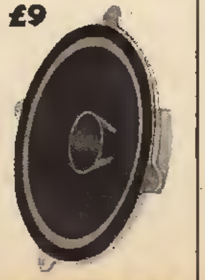

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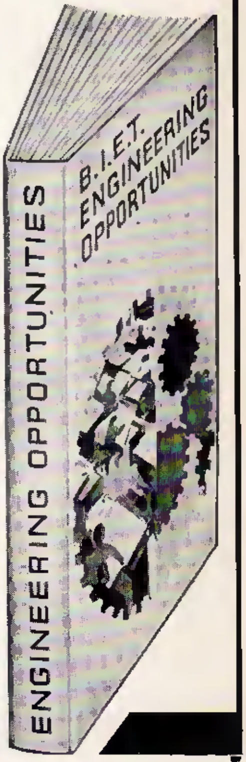

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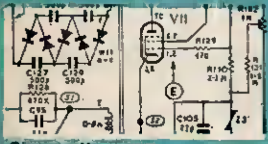
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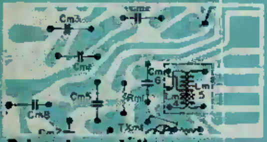
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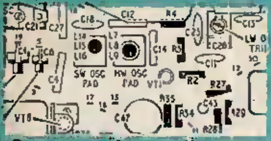
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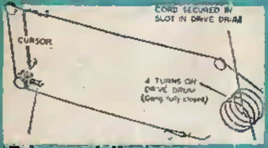

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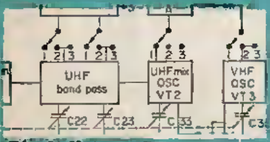

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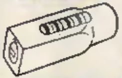

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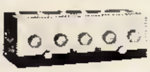

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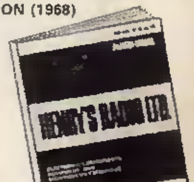

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