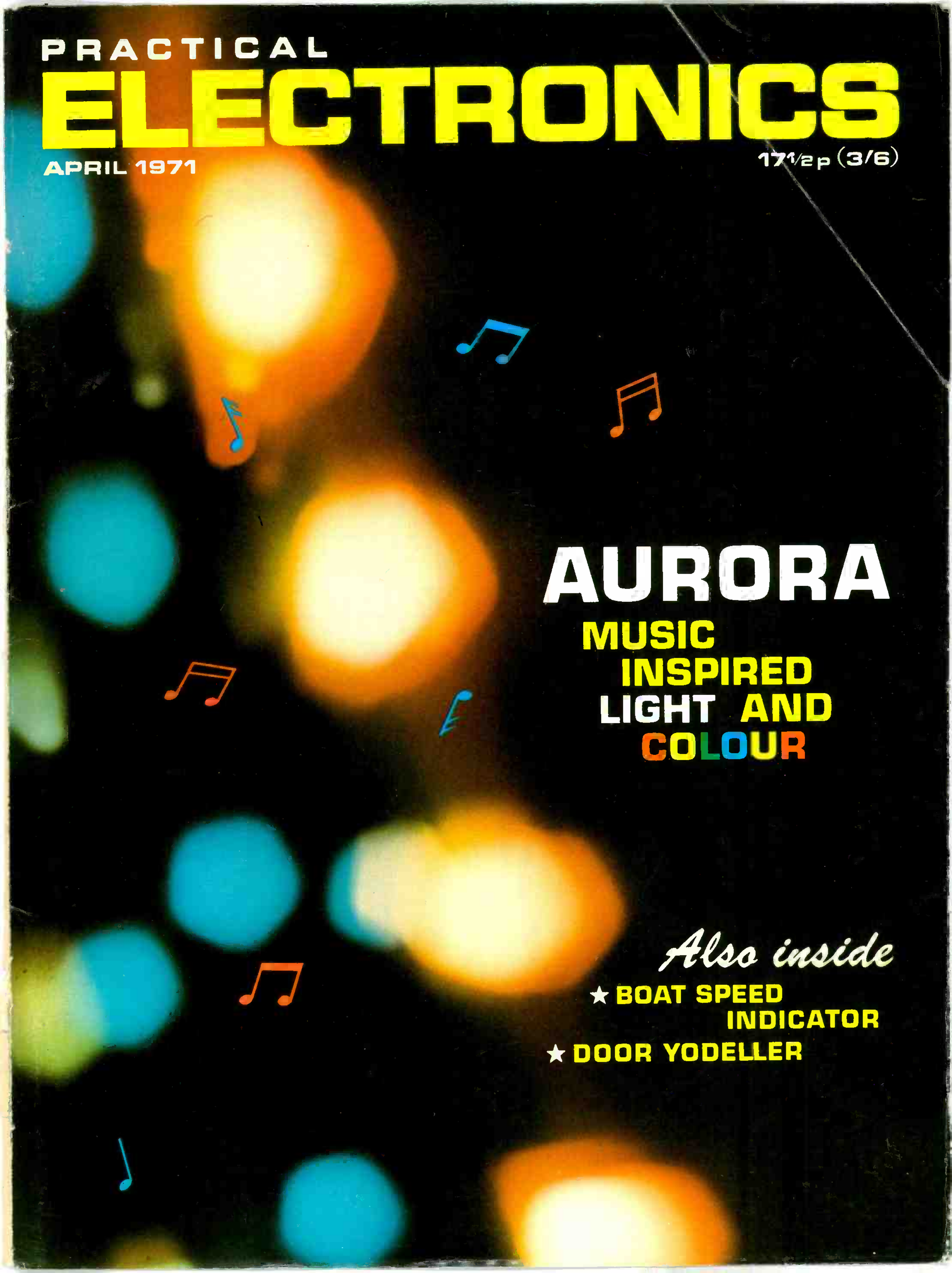
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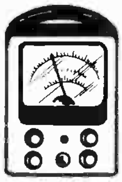
KG-620 4½" VTVM KIT ★ NEW!



SPECIFICATIONS

Ranges: *0-1·5-5-15-50-150-500-1,500V full scale; with optional High-Voltage Probe, to 25,000V.*

Accuracy: *±3% Of full scale reading.*

Input Resistance: *11 megohms (1 meg in probe) up to 1,500V.*

Ranges (rms): *0-1·5-5-15-50-150-500-1,500V full scale (p-p); 0-4·2-14-42-140-420-1,400-4,200V full scale.*

Decibels: *−10 to +65 in 7 ranges.*

Response: *±1dB, 30Hz to 3MHz; ±3dB, 30Hz to 5MHz; with optional H.F. Probe, to 250MHz.*

Accuracy: *±5% of full scale reading.*

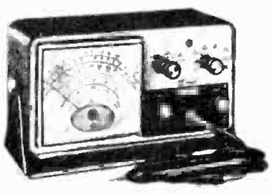
Ranges: *0-1,000-10,000-100,000 ohms: 0-1-10-100-1,000 megohms.*

Centre Scales: *10, 100, 1,000, 10,000, 100,000 ohms; 1 and 10 megohms.*

Battery *1½V size U2.*

Recommended List Price £18·27½: **£9·95** Assembled Price **£14** (RR Price £30)

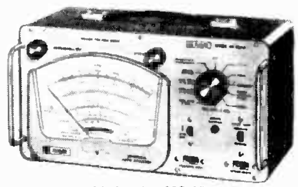
KG-625 Deluxe 6in Vacuum Tube Voltmeter Kit



Huge 6in Meter Scale ● Ranges: *d.c. 0–0·5–1·5–5–15–50–150–500–1,500V full scale.* **● Accuracy:** *±3% of full scale reading* **● Input Resistance:** *11MΩ to 1,500V* **● Ranges:** *a.c. 0–1·5–5–15–50–150–500–1,500V full scale. 0–4·2–11–42–140–420–1,400–4,200V full scale* **● Accuracy:** *±5%* **● Frequency Response:** *±1dB, 30Hz to 3MHz; ±3dB, 30Hz to 5MHz* **● Ohmmeter Ranges:** *0–1,000–10,000 ohms; 0–1–10–100–1,000MΩ* **● Battery:** *1½V U2.*

Recommended List Price £24·97½ **£12·60**

KG-375A Deluxe Solid-State Auto Analyzer Kit



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Recommended List Price £23·87½:

£16·80

Assembled Price **£22·05**

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KG-371 Deluxe Solid-State Timing Light

Performance surpasses assembled units costing much more

Helps Set Ignition Timing ● Checks Synchronisation of Double Breaker Arms ● Checks for Sticking Automatic Spark-Advance Mechanism ● Checks Distributor Cam Wear ● Built-in d.c. Power Supply ● Reliable Solid-State Circuit ● Your car gives More miles per gallon; Improved performance; Greater reliability.

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Package Price: 1 × PZ5, 1 × Stereo 60 & 2 × Z30—**£18·90**

MICROMATIC KIT—**£2·30**

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E.M.I. LOUDSPEAKERS (Post 30p per order)

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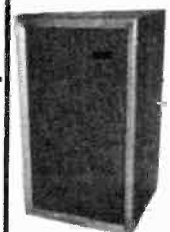
Jason

Introducing The New "Delta" 10 watt Enclosure



Incorporating the famous EMI 150 set consisting of a 13 × 8in. bass unit with a high flux ceramic magnet and a concentric tweeter impedance 8Ω 20 watt peak handling power (10 watts RMS) or 20 watts peak.

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5in 600ft	45p	5in 900ft	52½p	5in 1,200ft	75p	5¾in 2,400ft	£1·70
5¾in 900ft	52p	5¾in 1,200ft	65p	5¾in 1,800ft	95p	7in 3,600ft	£2·40
7in 1,200ft	62½p	7in 1,800ft	92½p	7in 2,400ft	£1·35	**QUADRUPLE**	
						3in 600ft	42½p

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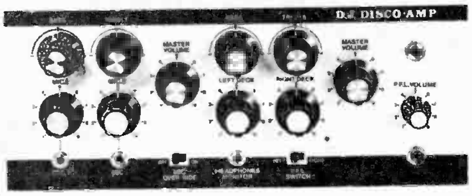

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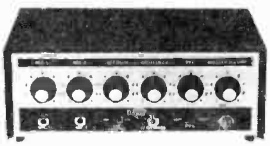
50 ohm or 600 ohm mic inputs may be ordered at extra cost. Size: Front Panel 16¾in × 7in. Cut out 15¼in × 6in. Fuses A.C. 1·5 amp (B.S.) mounted on back panel.

PRICE £85 inc. P. & P.



D.J. 102 DISCOTHEQUE MIXER PRE-AMPLIFIER

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REF.	ALLOY	SWG	
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Size 5 (illustra-ted)	Savbit	18	15p *
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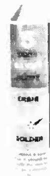
*Recommended Price



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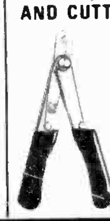

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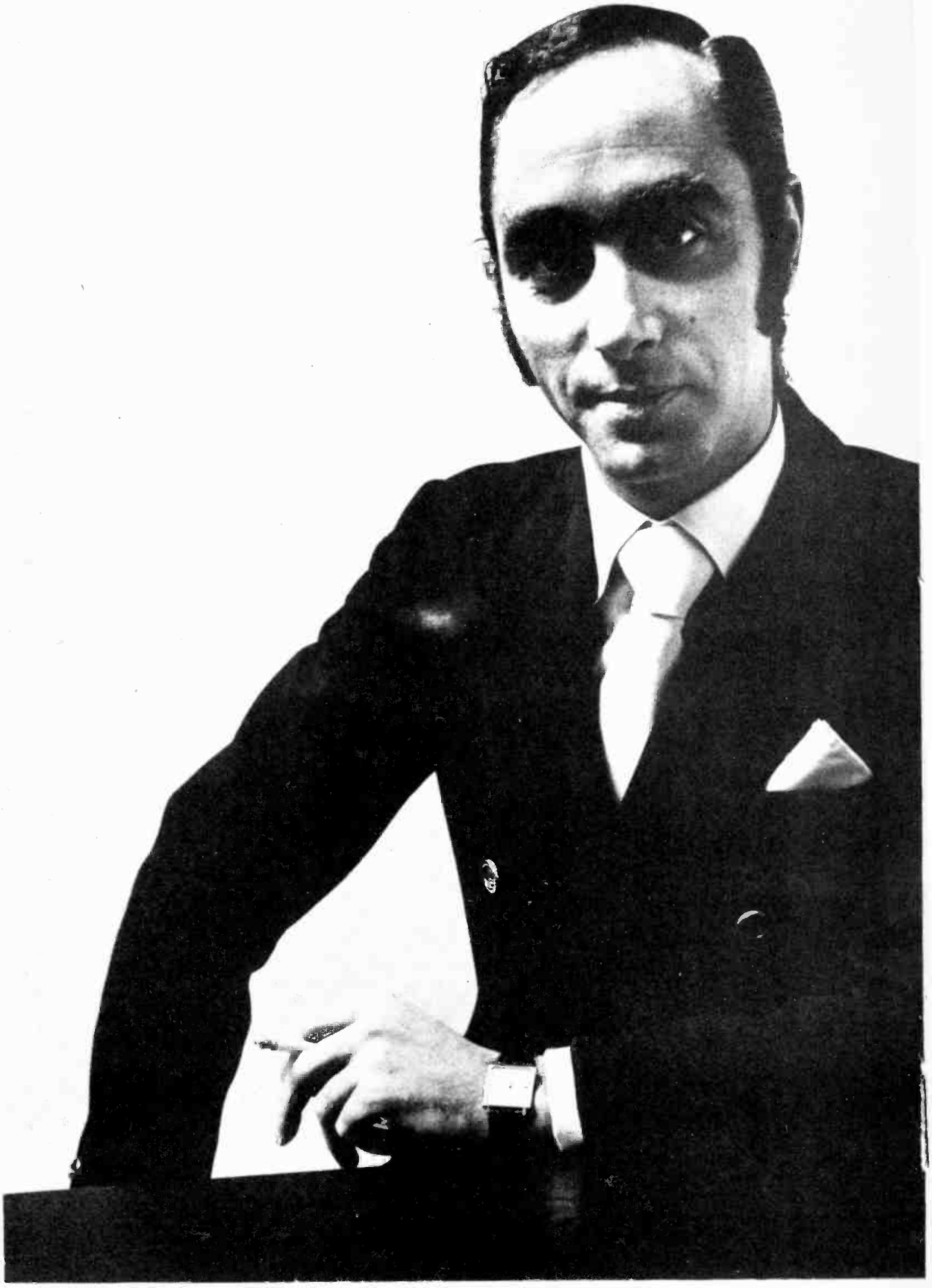

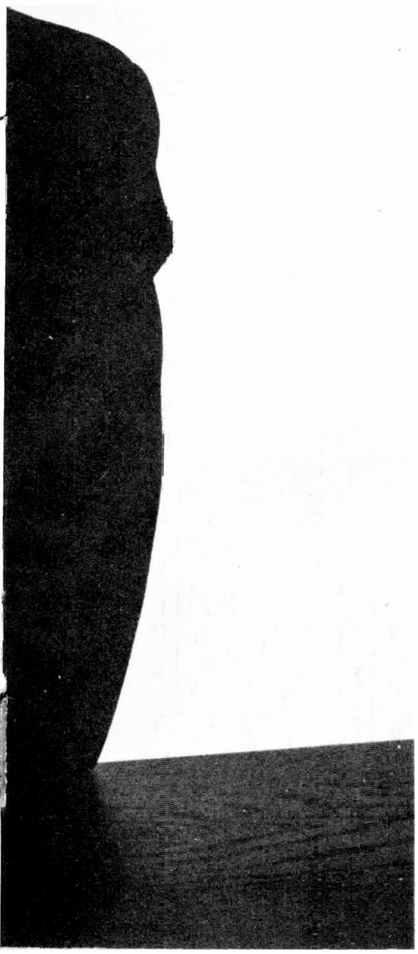

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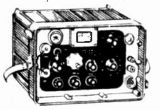

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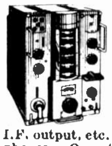

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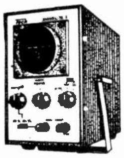
TO-2 PORTABLE OSCILLOSCOPE



A general purpose low cost economy oscilloscope for everyday use. Y amp. Bandwidth 2 CPS–1 MHZ. Input imp. 2 megΩ 25 P.F. Illuminated scale. 2in. tube. 115 × 180 × 230mm. Weight 8lb. 220/240 V a.c. Supplied brand new with handbook. **£22·50**. Carr. 50p.

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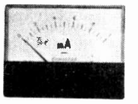


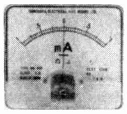
50μA	£3·47½	500μA	£3·12½
50-0-50μA	£3·37½	1mA	£2·97½
100μA	£3·37½	20V d.c.	£2·97½
100-0-100μA	£3·25	50V d.c.	£2·97½
		300V d.c.	£2·97½
		1A d.c.	£2·97½
		5A d.c.	£2·97½
		300V a.c.	£2·97½
		VU Meter	£3·75

BAKELITE PANEL METERS — TYPE S-80, 80 mm square fronts

50μA	£3·12½	1A d.c.	£2·47½
50-0-50μA	£2·97½	5A d.c.	£2·47½
100μA	£2·97½	300V a.c.	£2·62½
100-0-100μA	£2·87½	VU Meter	£3·37½
500μA	£2·62½		
1mA	£2·47½		
20V d.c.	£2·47½		
50V d.c.	£2·47½		
300V d.c.	£2·47½		

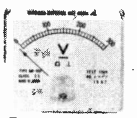
"SEW" CLEAR PLASTIC METERS

Type MR.85P. 4¼in × 4¼in fronts.



50μA	£3·60	50mA	£2·60
50-0-50μA	£3·10	100mA	£2·60
100μA	£3·10	500mA	£2·60
100-0-100μA	£3·10	1A	£2·60
200μA	£2·87½	5A	£2·60
500μA	£2·75	15A	£2·60
500-0-500μA	£2·60	30A	£2·60
1mA	£2·60	20V d.c.	£2·60
1-0-1mA	£2·60	50V d.c.	£2·60
5mA	£2·60	150V d.c.	£2·60
10mA	£2·60	300V d.c.	£2·60
		15V a.c.	£2·60
		300V a.c.	£2·60
		S Meter 1mA	£2·87½
		VU Meter	£3·60
		1A a.c.*	£2·60
		5A a.c.*	£2·60
		10A a.c.*	£2·60
		20A a.c.*	£2·60
		30A a.c.*	£2·60

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



50μA	£2·00	150mA	£1·37½
50-0-50μA	£1·87½	200mA	£1·37½
100μA	£1·87½	300mA	£1·37½
100-0-100μA	£1·75	500mA	£1·37½
200μA	£1·75	750mA	£1·37½
500μA	£1·50	1A	£1·37½
500-0-500μA	£1·37½	2A	£1·37½
1mA	£1·37½	5A	£1·37½
1-0-1mA	£1·37½	10A	£1·37½
2mA	£1·37½	3V d.c.	£1·37½
5mA	£1·37½	10V d.c.	£1·37½
10mA	£1·37½	15V d.c.	£1·37½
20mA	£1·37½	20V d.c.	£1·37½
50mA	£1·37½	100V d.c.	£1·37½
100mA	£1·37½	150V d.c.	£1·37½
		300V d.c.	£1·37½
		500V d.c.	£1·37½
		750V d.c.	£1·37½
		15V a.c.	£1·37½
		50V a.c.	£1·37½
		150V a.c.	£1·37½
		300V a.c.	£1·37½
		500V a.c.	£1·37½
		S Meter 1mA	£1·60
		VU meter	£2·10

Type MR.52P. 2½in square fronts.

50μA	£3·10	20V d.c.	£2·00
50-0-50μA	£2·60	50V d.c.	£2·00
100μA	£2·60	300V d.c.	£2·00
100-0-100μA	£2·37½	15V a.c.	£2·00
500μA	£2·25	300V a.c.	£2·00
1mA	£2·00	S Meter 1mA	£2·10
5mA	£2·00	VU Meter	£3·10
10mA	£2·00	1A a.c.*	£2·00
50mA	£2·00	5A a.c.*	£2·00
100mA	£2·00	10A a.c.*	£2·00
500mA	£2·00	20A a.c.*	£2·00
1A	£2·00	30A a.c.*	£2·00
5A	£2·00		
10V d.c.	£2·00		

Type MR.45P. 2in square fronts.

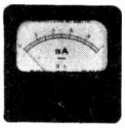
50μA	£2·25	10V d.c.	£1·50
50-0-50μA	£2·10	20V d.c.	£1·50
100μA	£2·10	50V d.c.	£1·50
100-0-100μA	£1·87½	300V d.c.	£1·50
200μA	£1·87½	15V a.c.	£1·50
500μA	£1·60	300V a.c.	£1·50
500-0-500μA	£1·50	S Meter 1mA	£1·87½
1mA	£1·50	VU Meter	£2·25
5mA	£1·50	1A a.c.*	£1·50
10mA	£1·50	5A a.c.*	£1·50
50mA	£1·50	10A a.c.*	£1·50
100mA	£1·50	20A a.c.*	£1·50
500mA	£1·50	30A a.c.*	£1·50
1A	£1·50		
5A	£1·50		

Type MR.65P. 3½in × 3¼in fronts.

50μA	£3·37½	20V d.c.	£2·10
50-0-50μA	£2·75	50V d.c.	£2·10
100μA	£2·75	150V d.c.	£2·10
100-0-100μA	£2·60	300V d.c.	£2·10
200μA	£2·60	15V a.c.	£2·10
500μA	£2·37½	50V a.c.	£2·10
500-0-500μA	£2·10	150V a.c.	£2·10
1mA	£2·10	300V a.c.	£2·10
5mA	£2·10	500V a.c.	£2·10
10mA	£2·10	S Meter 1mA	£2·37½
50mA	£2·10	VU meter	£3·37½
100mA	£2·10	50mA a.c.*	£2·10
500mA	£2·10	100mA a.c.*	£2·10
1A	£2·10	200mA a.c.*	£2·10
5A	£2·10	500mA a.c.*	£2·10
10A	£2·10	1A a.c.*	£2·10
15A	£2·10	5A a.c.*	£2·10
20A	£2·10	10A a.c.*	£2·10
30A	£2·10	20A a.c.*	£2·10
50A	£2·37½	30A a.c.*	£2·10
5V d.c.	£2·10		
10V d.c.	£2·10		

"SEW" BAKELITE PANEL METERS

Type MR.65 3½in square fronts.



25μA	£3·50	500mA	£1·75
50μA	£2·37½	1A	£1·75
50-0-50μA	£2·25	5A	£1·75
100μA	£2·25	15A	£1·75
100-0-100μA	£2·25	30A	£1·75
500μA	£2·10	50A	£1·75
1mA	£1·75	5V d.c.	£1·75
1-0-1mA	£1·75	10V d.c.	£1·75
5mA	£1·75	20V d.c.	£1·75
10mA	£1·75	50V d.c.	£1·75
50mA	£1·75	150V d.c.	£1·75
100mA	£1·75	300V d.c.	£1·75
		30V a.c.*	£1·75
		50V a.c.*	£1·75
		150V a.c.*	£1·75
		300V a.c.*	£1·75
		500mA a.c.*	£1·75
		1A a.c.*	£1·75
		5A a.c.*	£1·75
		10A a.c.*	£1·75
		20A a.c.*	£1·75
		30A a.c.*	£1·75
		50A a.c.*	£1·75
		VU meter	£3·10

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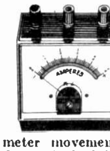
"SEW" EDUCATIONAL METERS



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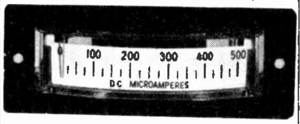
50μA	£4·50	20V d.c.	£3·97
100μA	£4·25	50V d.c.	£3·97
1mA	£3·97	300V d.c.	£3·97
50-0-50μA	£4·25	Dual range 500mA/5A d.c.	£4·25
1-0-1mA	£3·97	5V/50V d.c.	£4·25
1A d.c.	£3·97	Triple range 1mA/10mA/100mA	£4·62
5A d.c.	£3·97		
10V d.c.	£3·97		

EDGWISE METERS



PE.70 3 17/32in × 1 15/32in × 2¼in deep.

50μA	£3·00	500μA	£2·60
50-0-50μA	£2·87½	1mA	£2·37½
100μA	£12·87½	300V a.c.	£2·37½
100-0-100μA	£2·75	VU meter	£3·25
200μA	£2·75		

MARCONI TF142E DISTORTION FACTOR METERS. Excellent condition. Fully tested. **£20.** Carr. 75p.

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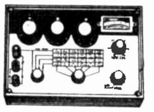

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2pF-2,000 mfd 2 ohms–200 megohms. Also checks impedance, turns ratio, insulation, 200/250V a.c.
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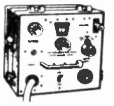

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2N914	22p	AF180	52p	NKT278	25p
2N916	22p	AF181	42p	NKT281	27p
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2N1304	25p	BAY31	7p	OA47	10p
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2N1306	25p	BC108	12p	OA79	10p
2N1307	25p	BC109	12p	OA81	10p
2N1308	30p	BC113	25p	OA85	12p
2N1309	25p	BC116	40p	OA90	10p
2N1613	22p	BC125	55p	OA91	7p
2N1711	25p	BC126	55p	OA95	7p
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2N2218	30p	BC182L	10p	OC23	60p
2N2219	32p	BC184L	12p	OC24	60p
2N2368	17p	BC186	25p	OC25	37p
2N2369	20p	BC212L	12p	OC26	25p
2N2369A	20p	BCY30	25p	OC28	62p
2N2484	35p	BCY31	30p	OC29	62p
2N2613	35p	BCY32	50p	OC35	50p
2N2646	50p	BCY33	25p	OC36	62p
2N2904	30p	BCY34	30p	OC41	25p
2N2923	17p	BCY38	40p	OC42	30p
2N2924	17p	BCY42	15p	OC44	17p
2N2925	17p	BCY43	20p	OC45	15p
2N2926G	12p	BCY71	30p	OC46	27p
2N2926Y	12p	BCY72	15p	OC70	12p
2N2926O	12p	BCZ11	40p	OC71	15p
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2N3705	15p	BF182	32p	OC83	25p
2N3706	22p	BF184	25p	OC84	25p
2N3707	15p	BF185	25p	OC139	25p
2N3708	17p	BF194	17p	OC140	37p
2N3709	12p	BF195	15p	OC169	20p
2N3710	12p	BF200	37p	OC170	25p
2N3711	12p	BF224	30p	OC171	30p
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2N3905	30p	BFX13	25p	OC203	40p
2N3906	30p	BFX29	30p	OC204	40p
2N4058	17p	BFX30	32p	OC205	62p
2N4059	25p	BFX44	37p	OC207	75p
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2N4287	17p	BFX88	25p	P346A	25p
2N4288	15p	BFY18	25p	PL4001	14p
2N4289	17p	BFY20	62p	PL4002	15p
2N4290	15p	BFY50	22p	PL4003	16p
2N4291	15p	BFY51	20p	PL4004	17p
2N4292	15p	BFY52	22p	PL4005	19p
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2N5355	27p	BSX19	17p	PL4007	24p
2S102	25p	BSX20	17p	T1843	40p
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2S104	37p	BSX76	15p	T1845	17p
40250	50p	BSY26	17p	T1846	17p
40361	55p	BSY27	20p		
40362	60p	BSY28	17p		
AC107	37p	BSY38	20p		
AC126	25p	BSY39	22p		
AC127	25p				
AC128	25p	BSY51	32p		
AC154	15p	BSY56	90p		
AC176	25p	BSY95A	15p		

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6CW4	63p	DY87	35p	PFL200	70p
6F1	62p	E88CC	65p	PL36	55p
6F6G	30p	E180F	95p	PL81	50p
6F13	38p	EABC80	35p	PL82	45p
6F14	65p	EAF42	35p	PL83	45p
6F15	65p	EB91	20p	PL84	40p
6F18	45p	EBC41	55p	PL500	75p
6F23	80p	EBC81	30p	PL504	80p
6H6	20p	EBF80	40p	PY32	55p
6J4	50p	EBF83	40p	PY33	63p
6J5	20p	EBF89	32p	PY80	35p
6J5GT	30p	EBL21	60p	PY81	30p
6J6	20p	EC86	60p	PY82	30p
6J7	45p	EC88	60p	PY83	38p
6K8G	35p	ECC40	60p	PY88	40p
6L6GT	45p	ECC84	30p	PY800	50p
6LD20	40p	ECC85	60p	PY801	50p
6Q7	40p	ECC88	40p	U25	75p
6SA7	40p	ECF80	35p	U26	75p
6SG7	35p	ECF82	35p	U50	32p
6SJ7	40p	ECF86	65p	U52	33p
6SK7	35p	ECH21	57p	U191	75p
6SL7	35p	ECH35	60p	U281	40p
6SN7	35p	ECH42	70p	U282	40p
6SQ7	40p	ECH81	30p	U301	40p
6U4	80p	ECH83	40p	U801	£1
6V6G	25p	ECL80	40p	UABC80	35p
6V6GT	32p	ECL82	35p	UAF42	55p
6X4	30p	ECL83	65p	UBC41	50p
6X5G	30p	ECL86	40p	UBC81	40p
6X5GT	27p	EF37A	60p	UBF80	40p
10C2	50p	EF39	40p	UBF89	35p
10F1	90p	EF40	50p	UCC84	49p
10P13	55p	EF41	65p	UCC85	40p
10P14	£1·10	EF42	70p	UCF80	55p
12AT6	30p	EF80	25p	UCH21	60p
12AT7	30p	EF85	35p	UCH42	70p
12AU7	30p	EF86	30p	UCH81	35p
12AV6	33p	EF89	28p	UCL82	35p
12AX7	30p	EF91	33p	UCL83	60p
12BA6	35p	EF92	40p	UF41	60p
12BE6	35p	EF183	30p	UF80	35p
12BH7	40p	EF184	35p	UF85	40p
19AQ5	35p	EH90	40p	UF89	35p
20D1	45p	EL33	£1·25	UL41	65p
20F2	75p	EL34	50p	UL84	30p
20L1	£1·10	EL41	55p	UY41	45p
20P1	50p	EL42	58p	UY85	30p
20P3	60p	EL81	55p	VR105/30	38p
20P4	£1·10	EL84	25p	VR150/30	35p
20P5	£1·20	EL85	43p		
25L6	45p	EL91	32p		

ZENER DIODES

400W (3·3 to 33V) .. 15p
1·5W (2·4 to 200V) .. 20p
10W (3·9 to 100V) .. 25p

SEND SAE FOR FULL LISTS!

INTEGRATED CIRCUITS

L900 40p; L914 40p; L923 60p; IC-10 £2·50; SL403 £2·25; MC1303 £2·62; MC1304 £2·75; PA246 £2·45; CA3005 £1·17; CA3011 74p; CA3052 £1·65; FCH131 50p; FCH161 50p; FJH141 25p; FJH171 25p; FJH181 25p; FJH221 25p; FJH231 25p; FJH241 25p; FJH251 25p; FJJ121 60p; FJJ131 60p; FJJ211 £1·25; FJY101 25p.

DISCOUNTS
10% on 12+ any one type.
15% on 25+ any one type.
Large quantity discounts on application
Postage—Semi Conductors 8p; Valves 15p.

HI-FI EQUIPMENT

SAVE UP TO 33⅓% OR MORE

SEND S.A.E. FOR DISCOUNT PRICE LISTS AND PACKAGE OFFERS!

GARRARD

FULL CURRENT RANGE OFFERED, BRAND NEW AT FANTASTIC SAVINGS

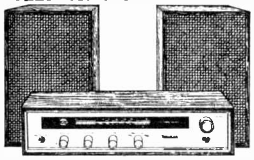
2025T/C stereo	£9·87	SL72B	£26·97
40 MKII stereo	£8·40	AP76	£20·97
3000 stereo	£10·50	SL75B	£30·75
SP25 MKIII	£11·75	SL95B	£40·97
SL65B	£14·97	401	£29·37

Carriage 37½p extra each item.

TEAK PLINTHS AND PERSPEX COVERS
1. For SP25, SL65, SL55, 3000, 2025T/C, 2025, 1000. £3·97½
2. For AP75, SL75, SL95. £5·97½
3. For SP25 etc. to operate with lid in place £5·97½
Carriage 37½p extra each type.

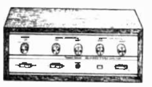
Full range of Garrard accessories available.

TELETON SPECIAL OFFER!



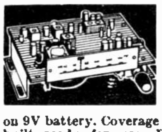
CR10T AM/FM STEREO TUNER AMPLIFIER WITH MATCHING PAIR SA1003 SPEAKER SYSTEMS
Output 4 watts per channel. Excellent reception AFC, built-in MPX. Cer/XTAL Input. Total List £50·25. OUR PRICE £29·95. Carr. 62½p.
Also available with Garrard 2025T/C Record Changer, Plinth, cover and stereo cartridge. Ready wired. £45. Carr. £1.

TELETON SAQ-206 STEREO AMPLIFIER



Latest exciting release. Beautifully styled with walnut case. 6 + 6 watts r.m.s. Switched inputs for Mag, Xtal, aux, tape. Incorporates volume, bass, treble, sliding balance, scratch filter and loudness controls. Rec. List £29. Our price £19·97. Carr. 37p.

★ TRANSISTORISED FM TUNER ★



6 TRANSISTOR HIGH QUALITY TUNER, SIZE ONLY 6 × 4 × 2½in. 3 I.F. stages. Double tuned discriminator. Ample output to feed most amplifiers. Operates on 9V battery. Coverage 88-108 MHz. Ready built ready for use. Fantastic value for money. £6·37½, P. & P. 12½p.
Stereo multiplex adaptors £4·97½.

HOSIDEN DH-08S DE LUXE STEREO HEADPHONES

Features unique mechanical 2-way units and fitted adjustable level controls. 8 ohm impedance. 20–20,000 cps. Complete with spring lead & stereo jack plug. £7·97½. P. & P. 12½p.

AMERICAN TAPE

First grade quality American tapes. Brand new Discount on quantities.

3in. 225ft. L.P. acetate	17½p
3¼in. 600ft. T.P. mylar	50p
5in. 600ft. std. plastic	42½p
5in. 900ft. L.P. acetate	50p
5in. 1,200ft. D.P. mylar	75p
5¾in. 1,200ft. L.P. acetate	62½
5¾in. 1,200ft. L.P mylar	80p
5¾in. 1,800ft. D.P. mylar	£1·12½
5¾in. 2,400ft. L.P. mylar	£1·97½
7in. 1,200ft. std. acetate	62½p
7in. 1,800ft. L.P. acetate	75p
7in. 1,800ft. L.P. mylar	£1·00
7in. 2,400ft. D.P. mylar	£1·25
7in. 3,600ft. T.P. mylar	£2·25

Postage 10p. Over £3 post paid.

SPECIAL OFFERS!

Garrard SP25/III fitted Goldring G800 cartridge and wooden plinth and plastic cover. Ready wired. Total list price £35.
OUR PRICE £22·50. Carr. 50p.
GOLDRING GL69/2 fitted Goldring G800 cartridge complete with de luxe base and cover. Total list price £50·80.
OUR PRICE £39. Carr. 50p.

B.S.R. McDONALD

MP60 .. £11·95 610...... £15·95
510...... £12·95 310...... £10·95
Carr. 37½p extra each item
Teak Base and Perspex Cover
For above BSR range £3·97½. Carr. 37½p.
TPD1 Series with plinth and cover and ready wired.
MP60.... £19·50 610...... £22·97
510...... £20·97
Carr. 50p extra each item

GOODMANS SPECIAL OFFERS!

Maxamp 30 Stereo Amplifier 15 + 15 watt r.m.s. with matching Stereomax AM/FM Tuner. Total list price £136·52.
OUR PRICE **£89** THE PAIR Carriage £1

GOODMANS SPEAKERS!

Maxim. OUR PRICE £32·60 pr. Carr. 50p.
Mezzo III. OUR PRICE £25·50. Carr. 50p.
Magnum K2. OUR PRICE £33. Carr. 50p.
Mambo. OUR PRICE £32·50 pr. Carr. 50p.
Marimba. OUR PRICE £35 pr. Carr. 50p.
Magister. OUR PRICE £41·50 each. Carr. £1.
Minister. OUR PRICE £39·97. Carr. 50p.

TAPE CASSETTES

Top quality in plastic library boxes.
C60 60 min 42½p 3 for £1·22½
C90 90 min 62½p 3 for £1·80
C120 120 min 75p 3 for £2·17½
Cassette Head Cleaner 56p. All Post extra.

TE-1035 STEREO HEADPHONES

Low cost high performance stereo headphones. Foam rubber ear cups. Adjustable headband. 8 ohm impedance. 25–16,000Hz. With lead and stereo jack plug.
ONLY £1·97½. P. & P. 12½p.

SINCLAIR EQUIPMENT

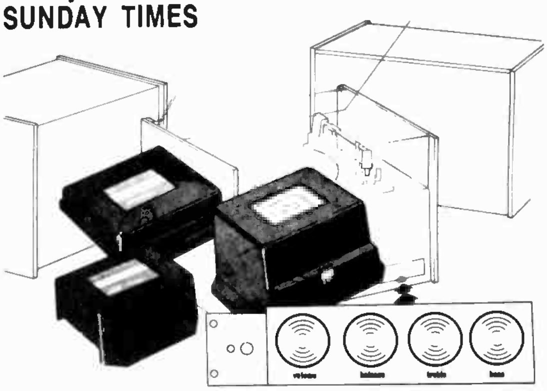
Project 60. Package offers. 2 × Z30 amplifier, stereo 60 pre-amp, PZ5 power supply, £19. Carr. 37½p. Or with PZ6 power supply, £21. Carr. 37½p. 2 × Z50 amplifier, stereo 60 pre-amp, PZ8 power supply, £21·50. Carr. 37½p. Transformer for PZ8, £2·97½ extra. Add to any of the above £4·87½ for active filter unit and £16 for a pair of Q16 speakers. Project 60 FM Tuner £20·97½. Carr. 37½p. All other Sinclair products in stock. 2,000 amplifier, £23. Carr. 37½p. 3000 Amplifier £36. Carr. 37½p. Neoteric amplifier £46, Carr. 37½p.

← See previous page ● **G. W. SMITH & CO. (RADIO) LTD.** ● See opposite page →

Laskys

MULLARD UNILEX *AUDIO MODULES*

Do-it-yourself stereo as featured in the SUNDAY TIMES



With nothing more than simple tools and the parts described below, you can build your own stereo system with excellent results guaranteed. The heart of the system comprises our Mullard Unilex modules and a control unit. All the modules and the control unit are supplied to you fully built and only require connecting together. Screw terminals and each module is housed in a tough plastic case, giving you complete freedom to use any of the recommended cabinets or your own design to suit your home.

Control Unit. Fitted with Bass, Treble, Volume and Balance controls. A metal fascia panel is supplied and all wires are ready fitted for connecting to the pre-amp. Size 9in. x 10in. x 1in. Plus 2in. long control shafts. **£3.25**

Pre-amplifier Module Type EP-9001. Input impedance: P/U 2.2M Tuner 1M Input Sens.: P/U 320mV. Tuner 140mV. Treble control range–14dB to 14dB at 16KHz. Bass control range—14dB to 14dB at 60Hz. Size: 4in. x 5in. x 1in. **£3.10**

Amplifier Module Type EP-9000. Output 4 watts per channel to 12 ohms to 15 ohms or 8 ohms with series resistor. Frequency resp. (to 3dB at 50mW): 50Hz to 16KHz. Harmonic distortion less than 2% at typical listening level. Size: 30in. x 4in. x 10in. **£5.80** per pair

Power Supply Module Type EP-9002. For use with control unit, EP-9001 and 2 x EP-9000. For 220/250 volt AC mains. Size 50in. x 30in. x 3in. **£4.60**

PACKAGE DEAL

Two EP-9000 Modules **£5.80** ● EP9002 Module **£4.60** ● EP-9001 Module **£3.10** ● Control Units **£3.25** ● Instruction Book **25p.** TOTAL LIST PRICE **£17.00**
PACKAGE PRICE £14.95 post 20p.

FANTAVOX 105

MODEL VHF 105

An 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 535-1600 KHz 88-108 MHz respectively — with no electrical conversion or connection required. The model VHF-105, self powered by one 9V (PP3 type) battery, is merely placed close to the receiving set and then tuned over 110 to 135 MHz 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 vol. controls of each accordingly. The Model VHF-105 has a smartly designed black plastic cabinet with brushed metal front panel and 18in. chrome telescopic antenna, size only 4 x $2^7/_8$ x $2^3/_8$ in. (inc knobs). Complete with battery and full instructions.

LASKY'S PRICE **£3.60** Post 10p

MIDLAND 10-406 AM/AIRCRAFT RADIO

The first pocket size receiver of its type allowing you to tune-in to the entire air communications band covered by 108-137 MHz in addition to full AM medium wave. Intermediate frequencies: AM 455 KHz: VHF 10.7 mc/s. Output power: 200mV $2^1/_2$in. P.D. 8 ohm speaker. A built in ferrite rod aerial is provided for AM reception. The 10-406 is finished in blue with chrome trim, chrome telescopic antenna. Size: $6^5/_8$ x $3^5/_8$ x $1^7/_8$in. Complete with batteries, magnetic earphone, instructions and circuit date.

LASKY'S PRICE **£8.35** Post 13p

ADC 40 PRECISION PICK-UP ARM

The ADC 40 Mk II is a complete low inertia arm with side thrust compensator and anti-drag lead out arrangement. Single-thrust ball bearings used at four points. Accurately machined walnut non-resonant arm. Adjustable counter-weight. Plug-in head shell accommodates nearly all cartridges. Easy installations. Built-in arm rest. Arm length $10^5/_8$ in. overall. Pivot to stylus tip 9 in. Rear overhang $1^3/_4$ in.

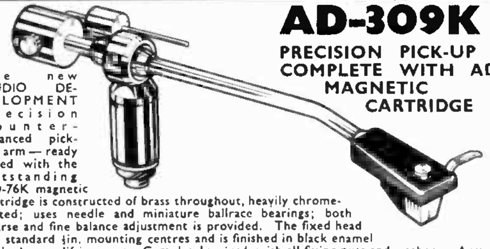
List Price £19.41

OUR PRICE £6.95 Post 18p

AUDIO DEVELOPMENT

AD-309K

PRECISION PICK-UP ARM COMPLETE WITH AD-76K MAGNETIC CARTRIDGE



The new AUDIO DEVELOPMENT precision counter-balanced pick-up arm — ready fitted with the outstanding AD-76K magnetic cartridge is constructed of brass throughout, heavily chrome-plated; uses needle and miniature ballrace bearings; both coarse and fine balance adjustment is provided. The fixed head has standard ½in. mounting centres and is finished in black enamel with chrome lifting spur. Completely wired, with all fixing nuts and washers. Arm rest also supplied. Tech. details: Overall length 285mm; needle to pivot length 223mm; offset angle 24°; overhang 10mm. Requires single 7/16in. dia. mounting hole.

LASKY'S PRICE **£8.50** Post Free

AUDIO DEVELOPMENT AD-76K

Stereo Magnetic Cartridge. Frequency response 20–20,000Hz. Output: 5mV. Stylus: Diamond LP.
Tracking force: 2 gms ±0.5 gm.
Replacement stylus type JS.P1 £2.05 post free.

£4.50 Post Free

AUDIO DEVELOPMENT AD-96K

Stereo Magnetic Cartridge. Frequency response 20–20,000Hz. Output: 5mV. Stylus: Diamond LP.
Tracking force: 2 gms.
Replacement stylus type Y.960S **£2 57 post free**

£5.93 Post Free

Lasky's COMPACT CASSETTES

C60 ● C90 ● C120

Exclusively made for us in USA Great Savings.

	Each	Post	Five for	Post	Ten for	Post
C60—	37p	5p	£1.65	20p	£5.95	25p
C90—	57p	5p	£2.75	20p	£9.90	25p
C120—	87p	5p	£3.75	20p	£12.10	25p

U.S.A. Cassette head cleaner. 53p Post 5p

INTERNATIONAL

MAGNETIC RECORDING TAPE FROM THE U.S.A. AT LASKY'S RECORD LOW PRICES

3in.	Message tape, 150ft.	13p	5¾in.	Long play, 1200ft. Mylar	75p
3in.	Message tape, 225ft.	19p	5¾in.	Triple play, 2400ft.	£1 75
3in.	Message tape, 300ft.	38p	7in.	Standard play, 1200ft. Acetate	63p
3¼in.	Triple play, 600ft Mylar	50p	7in.	Standard play, 1200ft. Mylar	63p
5in.	Double play, 1200ft.	75p	7in.	Long play, 1800ft. Mylar	98p
5in.	Long play, 900ft. Acetate	50p	7in.	Double play, 2400ft. Mylar	£1.25
5in.	Standard play 600ft.	40p	7in.	Long play 1800ft. Acetate	75p
5¾in.	Double play, 1800ft. Mylar	£1.13	7in.	Triple play 3600ft. Mylar	£2 50
5¾in.	Long play 1200ft. Acetate	75p			
5¾in.	Standard play 900ft. PVC	63p			

P. & P. 5p extra per reel, 4 reels and over Post Free. Special quotes for quantities.

SONY TFM-8030L

BARGAIN SCOOP

HIGH PERFORMANCE 11 TRANSISTOR THREE WAVEBAND *PORTABLE BATTERY MAINS RADIO*

This is a really top performance, top quality solid state receiver packed with SONY know-how and backed by the outstanding reliability for which SONY are renowned. Now this outstanding set is available from Laskys at over 27% below the manufacturers list price making it without a doubt the NUMBER ONE SCOOP of 1971! Just look at these outstanding features. Covers MW, LW and FM (VHF). 11 transistor circuit for high sensitivity and stability Powerful output to 5" P.M. Dynamic speaker with rich clear tone quality. AFC for drift free VHF reception. Push button wavechange selectors and tone control.

Choice of three power sources—9V battery, household mains or car battery with suitable adaptors. Dial light for use in the dark. External jacks for earphone, tape recording, external power input and car aerial. Ultra modern styling and superb finish with padded featherette covered cabinet for superior sound damping with chrome trim, strong carrying handle.

The SONY TFM 8030L will enliven your leisure hours anywhere, anytime with exciting sound, news, sport, music, etc. Technical specification: Freq. range, FM 87-108MHz, LW150-Z85kHz, MW530-1, 605kHz. Circuit: 11 transistors, 7 diodes and 2 thermistors. Aerial System: Directional telescopic for FM, internal ferrite bar for LW/MW. Power Output: 1.85W max. Speaker PM Dynamic—4Ωimp. Power Source: 9v power pack battery (Ever-Ready PP9 or equiv.), AC mains with adaptor, Car battery with adaptor. Size: 9$\frac{3}{4}$(W) x 8$\frac{9}{16}$(H) x 3$\frac{3}{8}$(D). Complete with earphone and battery and full instruction manual.

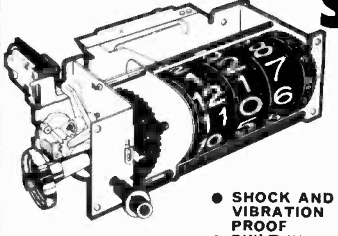
MANUFACTURERS LIST PRICE £29.75

LASKY'S SPECIAL OFFER PRICE £21.50

Optional Extras. SONY AC-90e AC adaptor £4.00 DCC-126 stabilised car battery cord £6.00. Both post FREE if purchased with radio.

Post 35p

EXCLUSIVE DIGITAL CLOCK SCOOP!



- MADE ESPECIALLY FOR LASKY'S BY FAMOUS MAKER
- MAINS OPERATION
- 12 HOUR ALARM
- AUTO "SLEEP" SWITCH
- HOURS, MINUTES AND SECONDS READ-OFF
- FORWARD AND BACKWARD TIME ADJUSTMENT
- SILENT OPERATION SYNCHRONOUS MOTOR
- SHOCK AND VIBRATION PROOF
- BUILT IN ALARM BUZZER

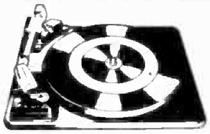
SPECIAL QUOTATIONS FOR QUANTITIES

This unique DIGITAL CLOCK is now available **EXCLUSIVELY FROM LASKY'S** in chassis form for you to mount in any housing that you choose. All settings are achieved by two dual-concentric controls at the front including: ON-OFF-AUTO and AUTO ALARM, "sleep" switch, 10 minute division "click" set alarm (up to 12 hour delay), time adjustment. Ultra simple mechanism and high quality manufacture guarantee reliable operation and long life.
The sleep switch will automatically turn off any appliance—radio, TV, light, etc., at any pre-set time up to 60 min. and in conjunction with the AUTO setting will switch on the appliance again next morning.
The clock measures 4$\frac{3}{4}$W × 1$\frac{3}{4}$H × 3$\frac{3}{4}$D (overall from front of drum to back of switch). SPEC: 210/240V AC, 50Hz operation; switch rating 250V, 3A. Complete with instructions. **HUNDREDS OF APPLICATIONS.**

COMPLETE WITH KNOBS.

LASKY'S PRICE **£6·95** Post 18p

GARRARD SP25 Mk III



The SP 25 series record deck has proved to be one of the most popular of its type in the world. Styled in black and silver, this moderately priced three-speed unit complies with the Din 45-500 Hi-Fi performance standard. The tubular low resonance aluminium pick-up arm is counter-balanced by a resiliently mounted weight. Stylus force is adjusted by an optical-type knurled knob, finely calibrated from 0.5 grm. in steps of 1 grm. Bias compensation is set with a finger-tip adjustment, the scale being calibrated to correspond with the stylus force. The viscous damped cue control facilities raising and lowering the pick-up arm onto the track required without damage to either the record or stylus. The 10$\frac{1}{2}$in. aluminium turntable is driven by the well-proven Garrard 4-pole high and low voltage induction motor. Actual size including max. rear and side overhang of pick-up arm 15$\frac{1}{16}$ in. wide x 12$\frac{1}{2}$in. front to rear x 2$\frac{7}{8}$in. above and 2$\frac{1}{2}$in. below edge of unit plate.

LASKY'S PRICE **£12.50** WITH 9TA CARTRIDGE Post 35p

McDONALD

PROFESSIONAL SERIES FOUR-SPEED SINGLE PLAY UNIT

MP60

High-precision low-mass fully counterbalanced pick-up arm, heavy balanced turntable, simple to operate controls, viscous cueing device, slide-in cartridge carrier, four pole motor.

LASKY'S PRICE **£12.50** Post 35p

complete with plinth and cover **£15.75** Post 40p

610 AUTOMATIC TURNTABLE

Same specifications as the MP60 but with synchronous four pole motor and full automatic change facilities.

LASKY'S PRICE **£15.45** Post 35p

WITH PLINTH AND COVER £18.75 Post 40p

510 AUTOMATIC TURNTABLE

Counterbalanced pick-up arm, pressed steel turntable, bias compensator, viscous curing and synchronous four pole motor

LASKY'S PRICE **£13.45** Post 35p

WITH PLINTH AND COVER £16.95 Post 40p

310 AUTOMATIC TURNTABLE

Low-mass square sectron pick-up arm, cue and pause lever, visual stylus pressure indicator, slide-in cartridge carrier, four pole motor.

LASKY'S PRICE **£9.95** Post 35p

WITH PLINTH AND COVER £13.45 Post 40p

NOW AVAILABLE LASKY'S EXCLUSIVE

LASKY-McDONALD plinth and cover available separately at £4.75 Post 25p

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LASKY'S RADIO Est. OVER 38 YEARS ESTABLISHED

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VOL. 7 No. 4
April 1971

PRACTICAL ELECTRONICS

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Art Editor J. D. POUNTNEY **Technical Illustrators** J. A. HADLEY P. A. LOATES
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ONE GOOD REASON

THERE are all sorts of reasons why people build electronic equipment for themselves. A very good one is, simply, that unless they do, they go without!

No wild exaggeration, this. While the semiconductor industry can turn out vast quantities of thought-provoking circuit devices—orginally developed for professional applications, it is true—is it not strange that equipment manufacturers have not seized upon these to embody in a host of imaginative functional products for the domestic consumer?

Oh yes, for sure the radio, television, and audio equipment business is well saturated, as the shop windows and showrooms in every high street testify. But the very proliferation of traditional entertainment products from both home and overseas factories induces a lop-sided view of electronics and what it can do for everyman and his wife. For instance, light and heat sensitive semiconductors, and power switching thyristors and triacs, are all crying out for more general use; to say nothing of logic systems based on miniature integrated circuits which offer possibilities for programming routine switching operations within the home.

There has been plenty of pie-in-the-sky talk of the electronics-run home of the future. When will the big breakthrough occur?

While prodding the commercial world to venture into these unusual and as yet scarcely explored domestic regions, we do see that this is not so simple nor (perhaps) as profitable as satisfying mass market needs for standardised conventional products like radio and audio equipment. Many installed automatic systems, such as intruder detectors, and environment sensing and controlling equipments, have to be tailored to suit specific needs and situations. And coping with a number of possible combinations from a wide range of units in order to build up an ideal installation for one customer would give the retailer some headaches, no doubt.

This is, of course, where we came in: if you do require something rather special in this particular line of electronics, the chances are you will have to build it yourself. This is just one further demonstration of the paradoxical situation we now have, and which arises directly from the highly productive semiconductor industry: the general availability of mass produced, efficient and versatile devices is helping in the preservation of individual craftsmanship.

F.E.B.

PRICE INCREASE

As from next month, the price of PRACTICAL ELECTRONICS will be 20p (4s). We regret the necessity for this increase, which is due to rising production costs.

THIS MONTH

CONSTRUCTIONAL PROJECTS

SPECIAL SERIES

GENERAL FEATURES

NEWS AND COMMENT

Our May issue will be published on Friday, April 16

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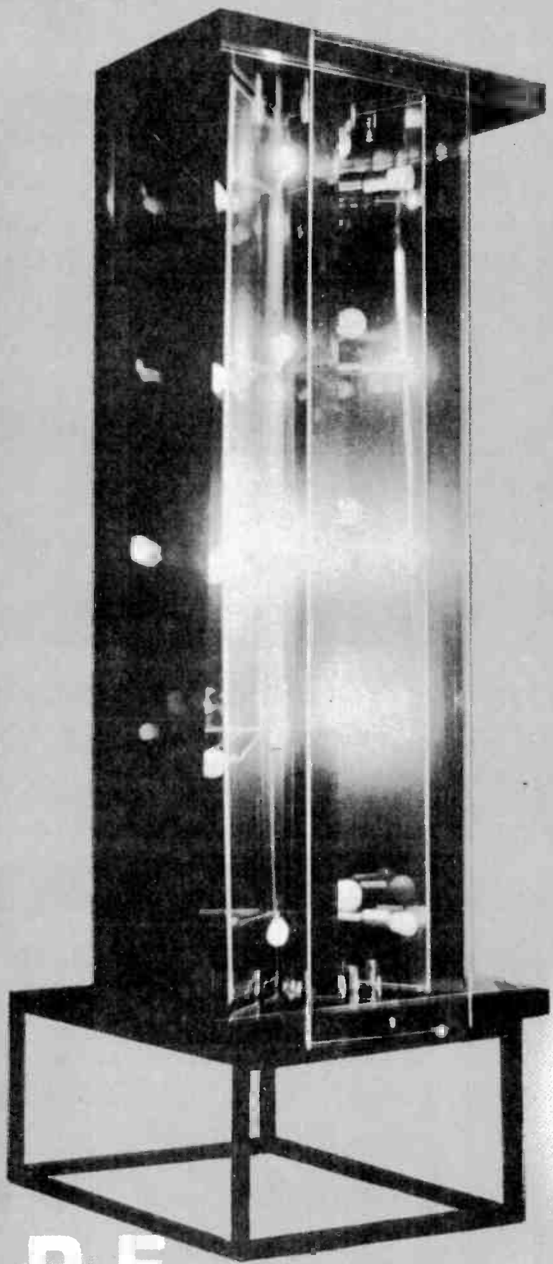
Create living colour that "moves" with the mood of your music.

P.E. AURORA is a controlled lighting system that can be as simple or as complex as you like to make it.

The selected audio frequency ranges can be "coloured" and the lighting arranged in whatever domestic decor you choose.



SOUND controlled colour light displays can be arranged to provide several kinds of visual effects some of which have been exploited for television and discotheques. The growing interest in this idea among amateurs and professionals was obvious at the recent Audio and Music Fair, when PRACTICAL ELECTRONICS presented to the public a versatile system called "P.E. Aurora".

This is a do-it-yourself design capable of exploitation to provide domestic mood lighting appropriate to any kind of music (serious, classical, jazz, or pop), and can be controlled from any audio amplifier or pre-recorded sequencer programme.

Any such system calls for three basic pieces of equipment:

1. A source of instructions to provide the light control information;
2. A piece of equipment which will convert these instructions into controlled power which is then applied to the lights;
3. The light system itself.

This series of articles describes an overall system which is driven by the signal from an audio amplifier; describes other methods of providing the initial instructions to drive a single general purpose power controller, and a novel technique for displaying the final effect.

At the end of the constructional series several alternative application systems will be described—some which have been successfully used by the designer and others, which are food for thought for further experimentation.

MUSIC INSPIRED LIGHT AND COLOUR

P.E. AURORA

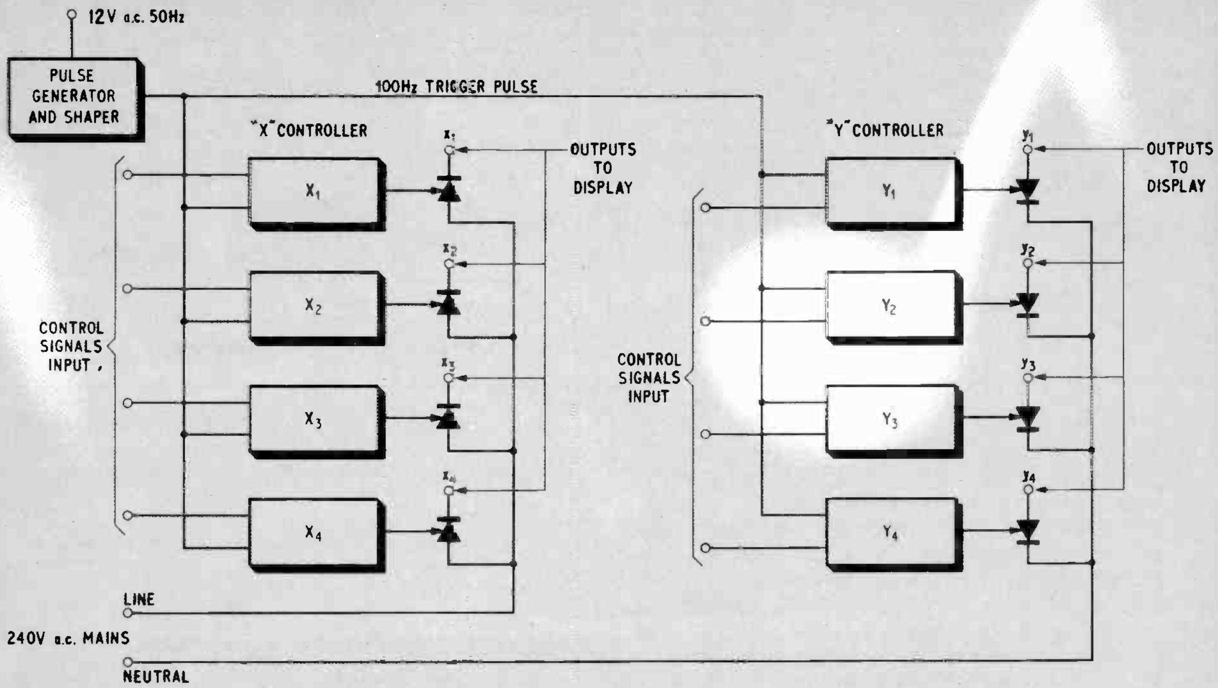
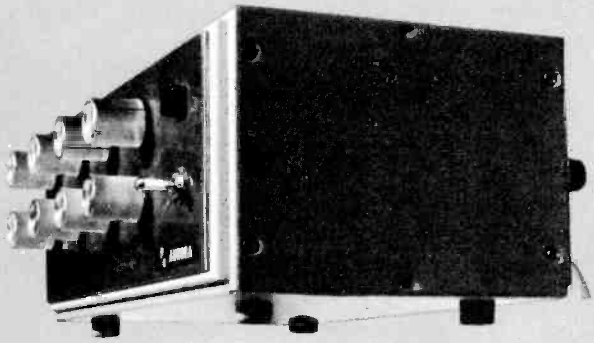


Fig. 1. Basic eight channel thyristor switching system used to operate a 16-lamp matrix of P.E. Aurora



PART 1
By M. J. HUGHES M.A.

*The **P.E. Aurora** system was specially commissioned by Practical Electronics and is the result of close collaboration with M. J. Hughes, M.A., who designed the electronics, and M. Leonard, A.R.I.B.A., who was responsible for the artistic presentation of this light display shown at the "Audio & Music Fair" and the "Electric Theatre" exhibition.*

THYRISTOR OR TRIAC CONTROL

The heart of the system to be described is a d.c. voltage controlled phase shifter, coupled to a trigger circuit, which in turn fires either triacs or thyristors early or late within the mains a.c. waveform. The controller's input is of high impedance and has a linear control over input voltages ranging from 0·5V to 1·0V d.c.

The input is 100 per cent isolated from the output, thus the control voltages can be derived with safety from many forms of semiconductor circuitry. Two such circuits will be described in detail: a narrow band filter unit—for sound to light control, and a self programming digital unit which provides constantly changing light patterns.

Other input circuits, which will be discussed later, include tape control (using a conventional ¼in or cassette tape recorder) and several types of optical feedback control.

The system to be described will be based on eight individual control channels supplying a matrix of 16 lamp nodes, but individuals can tailor their systems to suit the application or their pockets. The basic system is shown in block form in Fig. 1.

DESIGN SPECIFICATIONS

As the original intention was to make the "P.E. Aurora" a versatile piece of equipment the following design parameters were self-imposed:

1. Ultimate a.c. power control should be by readily available thyristors or triacs and the

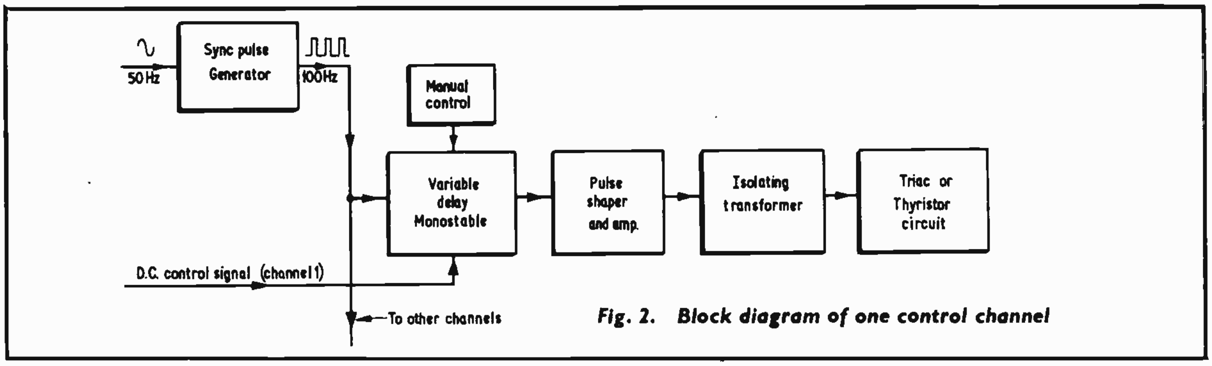


Fig. 2. Block diagram of one control channel

equipment should interface with as wide a range of trigger requirements as possible, in conjunction with the a.c. mains frequency.

2. Either triacs or thyristors could be used without any change in circuitry, provided they are capable of operation from the voltage and current source of the switching circuit.
3. The power side of the controller should be isolated from the input for safety reasons—this isolation should not be by optical means (which is quite often specified) because it presents difficulties in producing a simple mechanical construction.
4. Phase angle control should be over a range of as near 180 degrees as possible to obtain full lamp brightness and as near full extinction as possible.
5. Input signal requirements should be as wide as possible and be such that the equipment can be used with semiconductor circuitry.
6. Simple unstabilised power supplies should be used. All circuitry should be simple, should use low price components, and should need no specialised test equipment for setting up, apart from a multimeter and possibly an audio signal generator.
7. Perhaps the most difficult of the specifications to achieve; that the lamp brightness should appear linearly related to the input control signal.

All the above parameters have been met in the equipment to be described.

FREQUENCY LOCKED SWITCHING

Fig. 2 shows a block diagram of a single control channel. All thyristor or triac phase control systems should be accurately locked to the mains freqüency so that linear control may be effected by firing the device early or late within a single mains frequency cycle or half-cycle.

The triacs require a trigger pulse every positive and negative half-cycle of the mains while a thyristor—a unidirectional switching device—requires trigger pulses during positive half-cycles only. The sync pulse generator produces a single positive going pulse at the start of every positive and negative going half-cycle of the mains frequency. This pulse is applied to all channels in parallel (the present generator will satisfactorily drive up to 10 control channels).

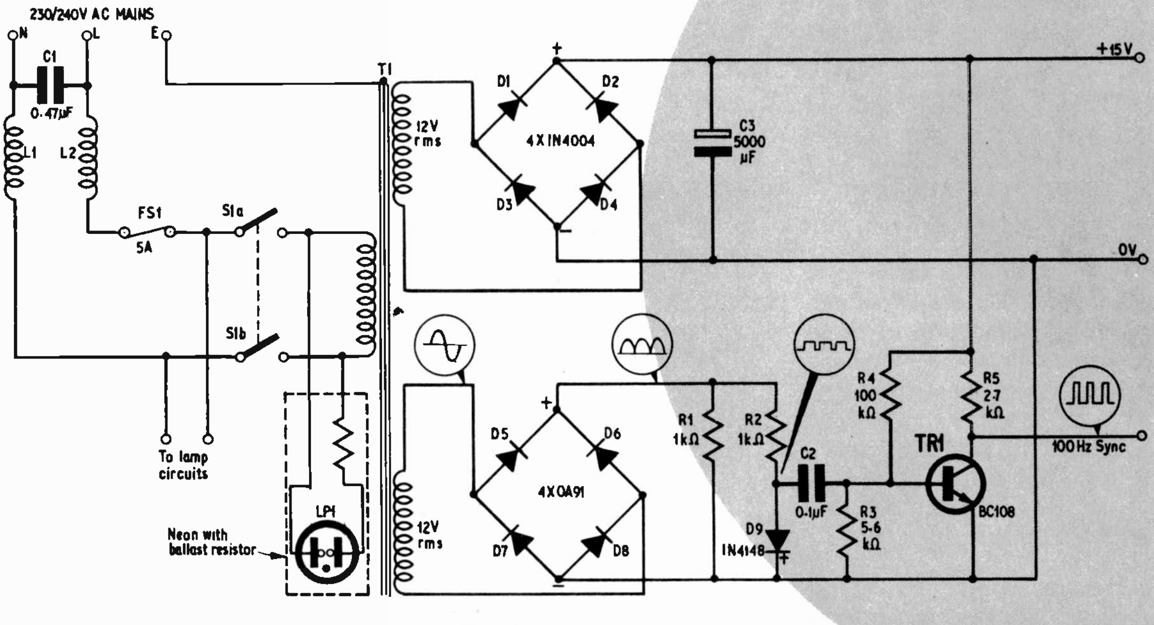


Fig. 3. Circuit diagram of the power supply and sync pulse generator

Considering a single channel; the arrival of this pulse fires the monostable multivibrator, the output of which rises to approximately +10V and dwells at this level for a period which is set either by the manual control or the input d.c. control signal. It is this dwell time that controls the phase angle of the final trigger pulse and is designed to be in the range of 2 to 9ms (this gives a range of firing angles of approximately 36 to 160 degrees).

After the dwell period the output of the monostable falls back to zero volts and this negative going transition is detected and amplified by the pulse shaper, which is coupled to the primary winding of a simple pulse transformer. This provides isolation between the mains and low voltage parts of the circuit. The secondary of this transformer is directly coupled across the cathode and gate of the thyristor or main terminal 1 and gate of the triac.

Trigger pulses will arrive at the transformer every 0·01sec and thus will fire a triac on every half-cycle. If a thyristor is used only alternate pulses will fire the device—pulses arriving during negative excursion half-cycles will be ignored.

POWER SUPPLY AND SYNC PULSE GENERATOR

As the power supply and sync generator are closely coupled to the mains transformer, both units are shown in Fig. 3. T1 is a straightforward mains transformer having two separate secondary windings each providing 12V a.c. One of the windings rated at 500mA is connected to a standard bridge rectifier comprising diodes D1, 2, 3, and 4. The smoothed output of this supplies sufficient power to drive all the circuitry required for the eight channels.

The inductors L1 and L2 together with C1 provide a satisfactory degree of interference suppression. The rating of fuse FS1 will depend on the total power the controller will eventually be driving. In the case of the prototype a 5A fuse was sufficient. Later we will deal with modifications necessary for higher power operation.

The main switch S1 only serves to isolate the electronics from the mains—it does not disconnect the main power to the lamps owing to problems in obtaining a suitably rated panel switch of reasonable mechanical proportions.

The second winding of T1 is connected to a bridge comprising four germanium diodes—D5, 6, 7, and 8. This provides a full wave rectified signal across the nominal load R1.

For those constructors having access to an oscilloscope, approximate waveforms are shown on the circuit diagram. Diode D9 is a small signal silicon type connected in a forward biased direction. The 600mV forward drop across this device serves to clamp the full positive excursion of the bridge producing a waveform closely resembling a square wave with fairly fast negative going edges. This waveform is inverted and its level restored to approximately 10V (off load) by transistor TR1.

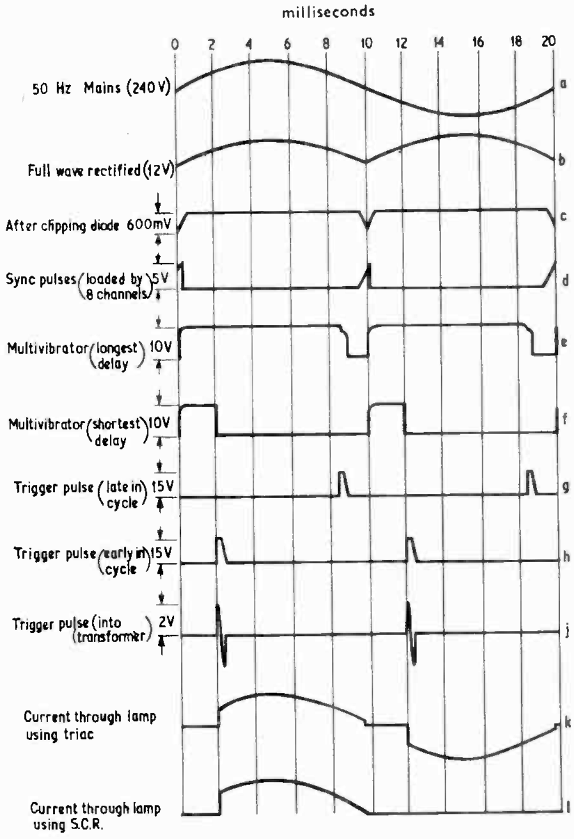


Fig. 4. Waveform timing diagram as measured on an oscilloscope. Typical amplitudes are shown. All levels are measured relative to the zero voltage rail. Waveforms (g) and (h) show the extremes of firing angle, 36 to 160 degrees

The output is a 100Hz sync pulse which is then applied to all the monostable stages for triggering the thyristors. On full load the amplitude of the positive going pulses at the collector of TR1 falls to approximately 5V.

The waveform timing diagram shown in Fig. 4 shows the relationship of sync pulses to the original mains waveform (a, b, c, and d).

However, due to the trigger sensitivity of the monostables (which require approximately 4 volts for reliable triggering) the monostable does not fire until the sync pulse reaches this voltage which occurs almost exactly at the moment the mains waveform crosses the zero voltage line (Fig. 4e).

MONOSTABLE AND TRIGGER CIRCUIT

Fig. 5 shows the circuit of the monostable and trigger for a single channel. In this system eight such circuits are required; for other systems more or fewer can be built.

TR3 and TR4 form the main monostable, these being cross coupled by C5 and R11. Sync pulses are applied to the base of TR3 via C4 and D10. In the absence of such pulses TR4 is normally "on", its base being returned to the positive rail by R9 and the parallel combination of VR1 (a preset potentiometer), VR2 (the manual control) and TR2.

On the arrival of a sync pulse at TR3 this transistor switches on rapidly; the negative going transition at its collector is transmitted via C5 to TR4 which turns off and stays off for the duration of the time constant of C5 together with R9, VR1, VR2, and TR2. R9 guarantees a minimum dwell time (in this case approximately 2ms); as will be seen later this corresponds to maximum lamp intensity.

This resistor can be safely reduced to 22kΩ if absolute maximum brightness is required, but if this is done the circuit begins to operate on the edge of stability. In actual fact, very little increase of light output was apparent by firing earlier in the cycle than 36 degrees which is what 2ms represents.

The maximum dwell time is set by VR1. This is necessary to prevent the possibility of the monostable "hanging on" into the next mains half-cycle. The effect of deliberately causing this to happen will be described during the setting up procedure. Maximum dwell time should be approximately 9ms for stability—this also allows for variations in mains frequency.

Having set the minimum and maximum dwell times, intermediate periods can be set by adjusting VR2 (the front panel control) or by causing TR2 to draw current. Voltage control of this dwell time is effected by drawing base current through TR2 by a voltage applied to the input of R6. It is important to note that the control voltage must be negative with respect to the positive rail as TR2 is a *pnp* transistor.

No control is effected until the input voltage exceeds the emitter-base forward voltage drop (500–600mV). As the input voltage increases the collector current of TR2 increases in proportion and thus linearly reduces the dwell time of the monostable. See Fig. 4e and 4f.

As it is the dwell time which determines the position of the ultimate trigger pulse within the mains half-cycle, it is the negative going excursion of the collector of TR4 that is used. This is differentiated by C6 and R13 before being applied to TR5 which provides the trigger pulse drive into the isolating transformer T2.

The output of T2 is directly connected across the cathode and gate of the thyristor or triac. The amount of gate current to the thyristor is determined by the tuned circuit C7 and T2 primary. If this gate current is insufficient for the device used C7 can be

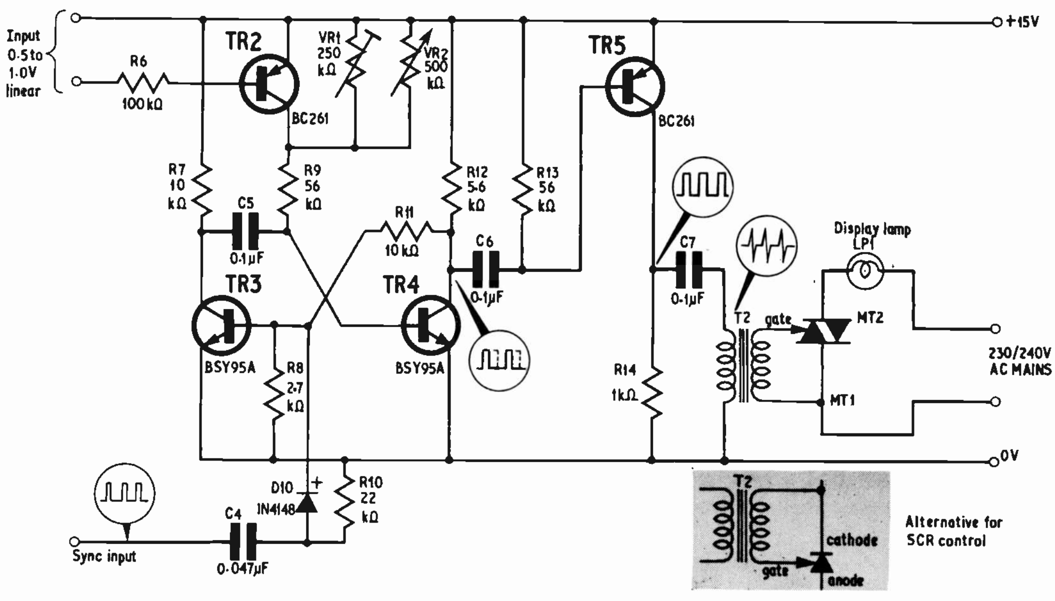


Fig. 5. Circuit diagram of the monostable timing and trigger for one channel

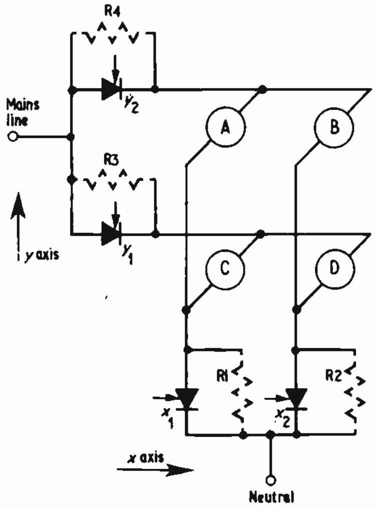


Fig. 6. Simple thyristor matrix of two by two. It is necessary to include the ballast loads (R1 to R4 shown dotted) in the form of 15 watt lamps. These will have a higher resistance than the lamps at the matrix nodes, but still low enough to provide at least 20mA holding current for the thyristors. Each lamp node should not be less than 40 watts to minimise interaction

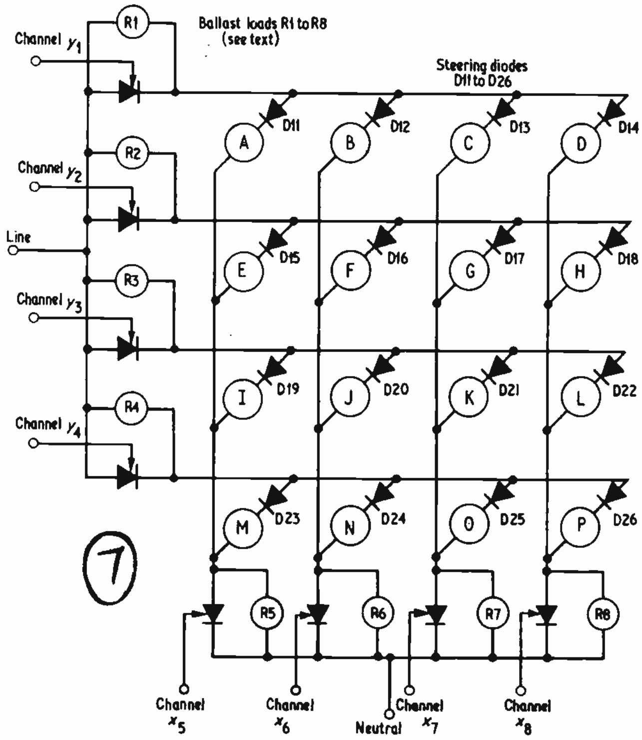


Fig. 7. A complete four-by-four matrix where symbols A to P represent the lamp nodes (40 watts each), symbols R1 to R8 represent the ballast loads (15 watt bulbs), D11 to D26 steering diodes to avoid interaction are rated at 600V 1A for each lamp node. Thyristors for channels 1 to 8 must each be rated at four times the current through each node.

increased to a value up to 0·2μF. Trigger current for the thyristors or triacs is not greater than 30mA 3V. Polarity of the output of T2 is not important owing to differentiation of the waveform.

TRIAC AND THYRISTOR MATRIX

It was mentioned earlier that a novel type of output was available from the controller, and it is worth discussing at this point as it requires a slight variation in thyristor orientation. If it is desired, each control channel can be used independently of any other, thus one can control up to eight lamp circuits. If this is all that is required then the following details can be ignored and the circuits wired up exactly according to Fig. 5.

Provided one is prepared to use thyristors, it is possible to obtain up to 16 lamp control channels from the eight basic trigger circuits. This is done by matrixing four of the channels against the remaining four.

The principle of the matrix is shown in Fig. 6, which represents four lamp circuits controlled by four thyristors (x1, x2, y1, and y2). One side of lamps A and B are commoned and taken to the cathode output of thyristor at y2; similarly one side of C and D is taken to y1. Conversely the free side of A is commoned with C and taken to x1; similarly with B and D to x2.

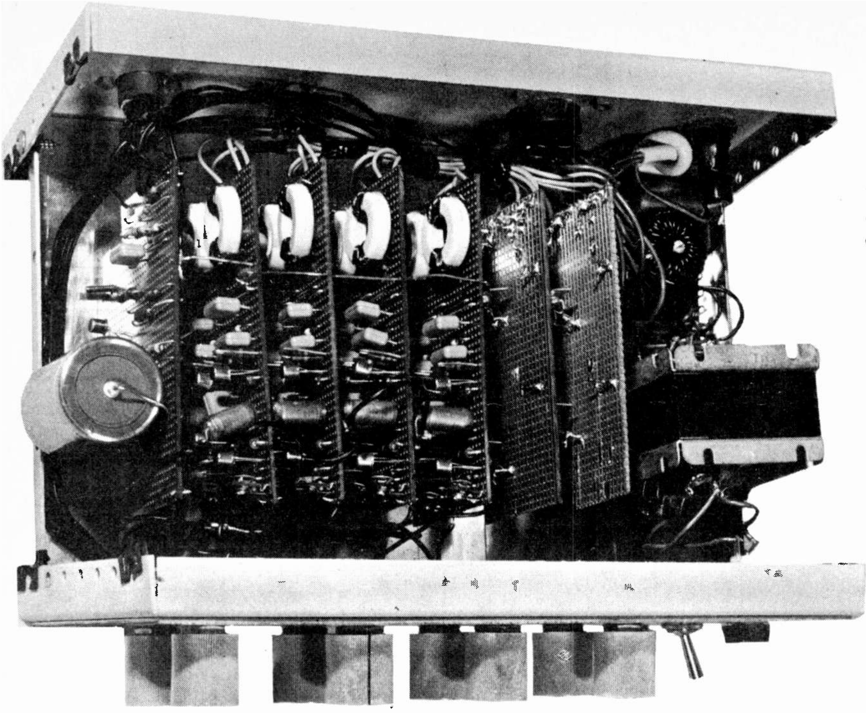
Note, however, that the commoned sides of A and C with B and D go to the anode ends of thyristors x1 and x2. The anodes of the thyristors on the Y axis are both taken to one side of the mains (say "line") and the cathodes of those on the X axis to "neutral". All the thyristors can be individually controlled by trigger pulses from the control channels.

If one ignores the fact that a thyristor needs a holding current to sustain conduction, one can simply say that if y1 and x1 are triggered, lamp A will go on; y2 with x1 and x2 will light A and B and so on. In practice, however, this simple concept will not work unless trigger pulses arrive at the x and y thyristors simultaneously.

Assume that y2 is triggered but neither x1 or x2; no current will flow through y2 and hence it will immediately extinguish at the end of the trigger pulse. If a trigger pulse was to arrive at x1 or x2 later but within the same half-cycle, neither of these would hold on.

HOLDING CURRENT

For the matrix to work we must provide some holding current when either axis switches. This holding current can be provided by the resistors shown dotted as R1 to R4 (Fig. 6). If either of the thyristors on the Y axis are now triggered they will



Top view of the controller chassis showing the circuit boards and power unit

draw current through either R1 or R2. Likewise for devices on the X axis through R3 or R4.

The values of these resistors must be carefully chosen so that they pass sufficient holding current, but not sufficient current for any apparent illumination of the main lamps A, B, C, and D, which are in effect in a complicated series parallel arrangement with the resistors. In operation the thyristors work by by-passing the resistors rather like toggle switches.

A few moments puzzling over a network analysis of the equivalent circuit under all combinations of switching will show that the problem is extremely complex. If the circuit was scaled up to a four-by-four matrix the problem could only be satisfactorily solved by computer.

Without going into the complicated mathematics it is sufficient to say that the problem can be solved in two ways:

1. The holding current resistors should be of very high resistance compared with the lamps, or
2. We allow current only to flow in one direction through the main lamps by using steering diodes.

The author has used both methods and quite definitely the diode solution, although more expensive, is by far the best.

Even with diodes one still has to provide holding current and the simplest solution to obtaining resistors of sufficient power rating is to use low power mains rated lamps (these can ultimately be incorporated as part of the display). This holding current is provided by 15W bulbs which allow a reasonable matrix effect if the main display lamps are not less than 40W each.

If diodes (of sufficient voltage and current rating) are also used they should be connected in series with each main lamp in the same direction as the thyristors.

LAMP LOADS

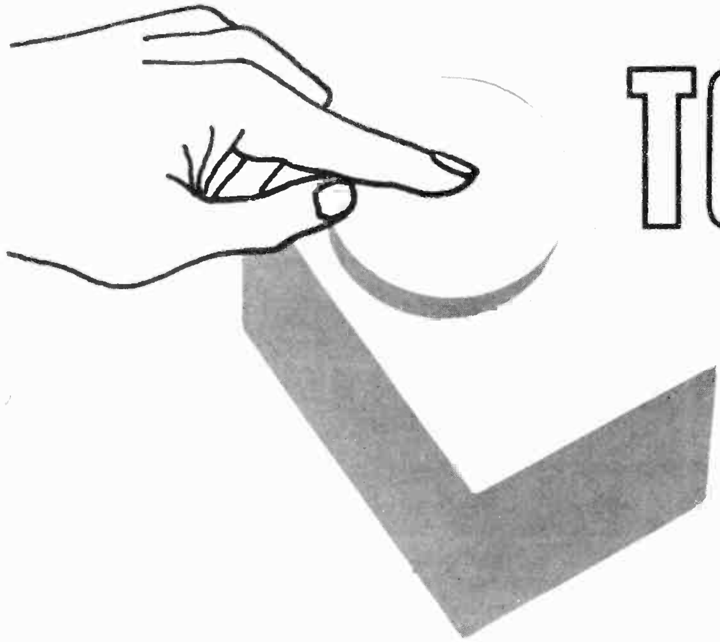
Using 40W bulbs in the main display, a perfect matrix display, with no parasitic interaction, is obtained. Fig. 7 shows the complete circuitry for the four-by-four matrix using diodes as recommended.

It is important to note that each thyristor on each axis must be capable of handling the load of all four lamps to which it is commoned. In this article we shall be considering 1A thyristors without heat sinks, thus the maximum current that may be drawn by each lamp node is 250mA (i.e. approximately 60W). This can easily be extended by using higher current rated thyristors mounted on heat sinks; however, for domestic use 16 lamps of 60W each are more than adequate.

No advantage is obtained by using triacs in the matrix when diodes are in use. They will, of course, increase the available light in the simple resistor only matrix but will exaggerate the interaction of current paths.

Next month: construction of the lamp control unit

P.E. *AURORA* AUDIO BAND SPLITTING FILTER UNIT FOR OPERATION WITH SOUND WILL BE DESCRIBED IN PART THREE



TOUCH SWITCH

by C. R. Bradley

THERE are many cases where it would be convenient to be able to switch equipment on and off by touch alone. The device described here enables any equipment to be switched merely by momentary hand contact with the sensitive touch plate.

Some advantages and possible applications for the switch are as follows. The sensitive plate can be made large and therefore easier to find and operate than a conventional toggle switch. Hence the touch switch could be useful for operation in darkness, or operation by blind or otherwise disabled persons. It can also serve as a cut out switch on potentially dangerous machinery as operation is quicker than either a toggle or push button switch. In some cases the touch plate could be an insulated metal part of the machine which is unsafe to touch; any bodily contact with the part would cause the machine to stop.

A further advantage of the touch switch is that little or no vibration need be caused by its operation. The author has found it convenient to mount a touch switch on his photographic enlarger. The large touch plate is easily found in the dark and if it is touched lightly there are no undesirable vibrations of the enlarger. There are also many applications for the touch switch in burglar alarm devices.

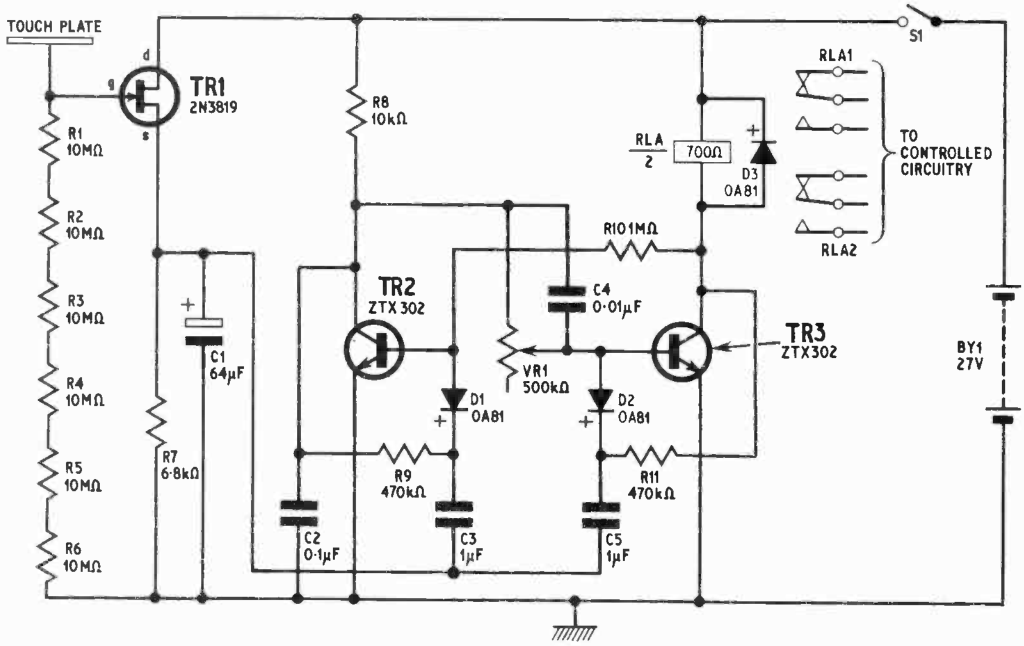


Fig. 1. Circuit diagram of Touch Switch

F.E.T. INPUT

The circuit of the touch switch is shown in Fig. 1. A field effect transistor, TR1, is used at the input to provide a very high input impedance, to the noise voltages developed across the resistor chain R1–R6 through contact with the touch plate.

The source, gate and drain electrodes of the *n*-channel f.e.t. are closely analogous to the cathode, grid and anode of the triode valve. The voltage drop across source load R2 biases the gate negative with respect to the source. With the values shown, the f.e.t. is biased close to pinch-off, corresponding to valve cut-off.

TOGGLE ACTION

On touching the touch plate, the stray noise introduced raises the mean drain/source current and the potential across C1 rises. When the touch is removed the potential falls. This negative swing is passed by C3 and C5 to cause the bistable circuit of TR2 and TR3 to change state.

When TR2 is conducting, its collector is close to earth potential and TR3 is biased off via VR1. TR2 is held in conduction by current through R10 and therefore this state is stable. The small current through the relay is insufficient to energise it.

If now a negative pulse is fed to TR2 base via C3 and D1, TR2 turns off. Its collector goes positive and TR3 is turned on via VR1. The collector of TR3 swings towards earth so that TR2 is no longer biased on. The circuit is now in its other stable state where there is sufficient current in the relay to energise it.

A negative pulse fed to TR3 base via C5 and D2 causes the circuit to change state again. The relay contacts switch the power to the equipment to be controlled. Thus the switch provides a touch-on, touch-off operation.

COMPONENTS . . .

Resistors

R1–R6	10MΩ (6 off)
R7	6·8kΩ
R8	10kΩ
R9	470kΩ
R10	1MΩ
R11	470kΩ

All ± 10% ½ watt carbon

Capacitors

C1	64μF elect. 40V
C2	0·1μF polyester
C3	1μF polyester
C4	0·01μF ceramic
C5	1μF polyester

Transistors

TR1	2N3819
TR2–TR3	ZTX302 (2 off)

Diodes

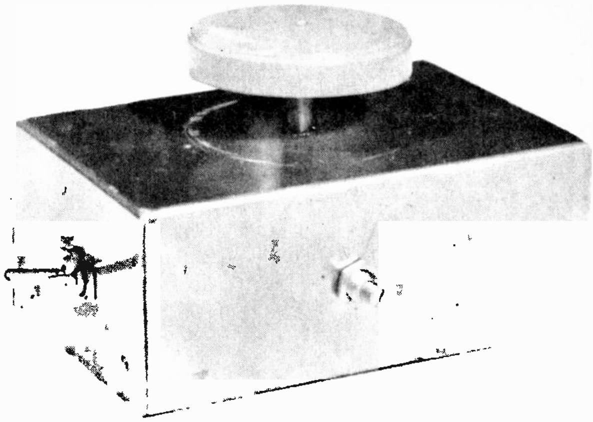
D1–D3 OA81 (3 off)

Relay

RLA 700Ω, 2 pole C/O relay type 43 (Radiospares) or type MH2 (Omron)

Miscellaneous

BY1–9V batteries (3 off), Veroboard 2½in × 3in 0·1in matrix, 6in × 4in × 2½in aluminium.



As TR3 has an inductive load, its turn on time has to be speeded up by the addition of C4. It is also protected by diode D3 against transient voltages induced in the relay.

The a.c. gain of TR2 is reduced by C2 to prevent relay chatter.

The times taken for C3 and C5 to charge through R9 and R11 respectively affect the rate at which the bistable states can be changed and these time constants are made large to ensure stable operation.

RESISTOR CHAIN

The large total value of the resistor chain R1–R6 was found to give good sensitivity. It is obtained by connecting six, 10 megohm carbon resistors in series and arranging for them to be self supporting to avoid leakage problems.

Higher resistance values will provide a higher input impedance and hence more sensitivity but there is a diminishing return as the f.e.t. gate impedance becomes more significant in comparison. If the resistance of R1 is made infinite, or in other words R1 is just an open circuit, the input impedance is so high that the f.e.t. responds to static charges.

Electrolytic capacitors cannot be used for C3 or C5 as these capacitors receive charges of opposite polarity in the two bistable states. Small paper or polyester types are suitable.

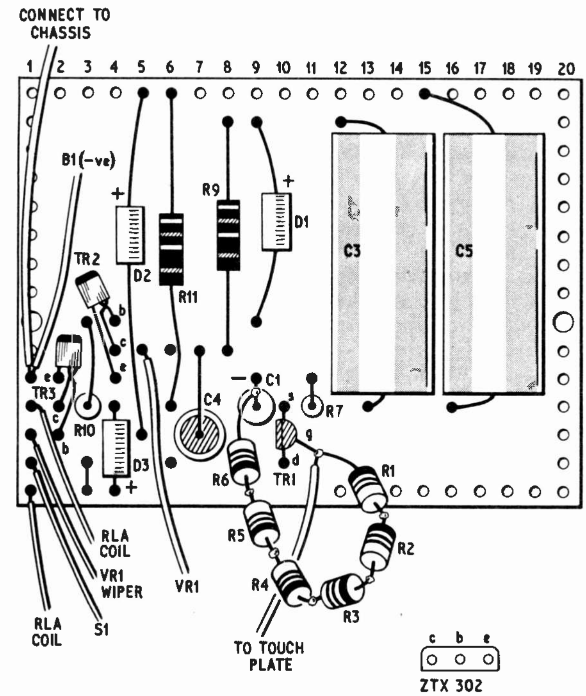
CONSTRUCTION

The circuit components are arranged on a small piece of Veroboard (Fig. 2) mounted inside an aluminium chassis as shown in Fig. 3. The chassis is connected to battery negative to provide screening for the circuit. Layout is not critical and the unit can be made smaller provided it is fully screened.

If mains equipment is to be controlled a piece of metal, bolted to the chassis, should be used to screen the relay contacts from the rest of the circuit.

The supply is made up of three 9V batteries connected in series to give 27V; the circuit will work well on any voltage between 18V and 30V.

A tin lid can be used for the touch plate. This is supported above the chassis by a short piece of Bakelite tube as it is important to maintain a high insulation and a low capacity between the touch plate and the chassis.



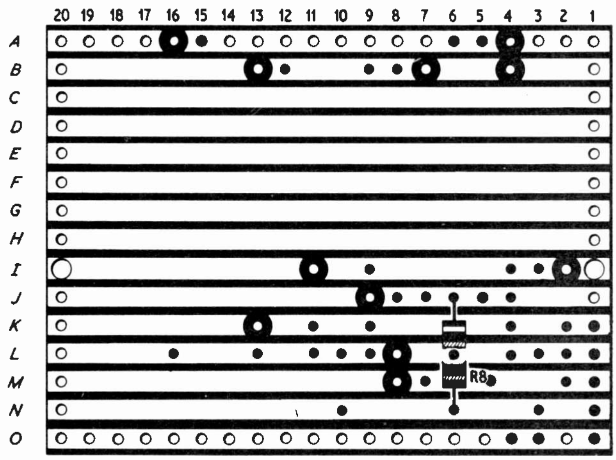


Fig. 2. Assembly and wiring details of topside and underside of Veroboard sub-assembly. Resistor R8 is shown on the underside, broken to reveal the connection at hole 6L for R11

For a more robust support Bakelite sheet can be used with Araldite for chassis fixing.

SETTING UP

When the wiring is complete connect the supply. Set VR1 to mid-position and switch on. The bistable will immediately go into one of its two stable states and the relay may energise.

Touch the touch plate to see if this will trigger the bistable. VR1 must be carefully adjusted to give proper action and equal "on" and "off" sensitivity and stability. If the resistance is set too high, TR3 will not conduct hard enough to keep the relay energised.

As VR1 resistance is reduced, a point may be reached where touching the touch plate causes the relay to chatter. Reducing the resistance a little more will give the proper operating point. If the resistance is too low the relay will remain permanently energised; if this should happen for all settings of VR1 it may be necessary to reduce R5 to 820kΩ or 680kΩ.

If the circuit fails to work, the f.e.t. stage can be checked by connecting a voltmeter across C1. Touching the plate should cause an increase in deflection.

The bistable can be checked by connecting a lead to battery negative and touching it to the base of whichever of TR2 and TR3 is conducting. This should cause the bistable to change state.

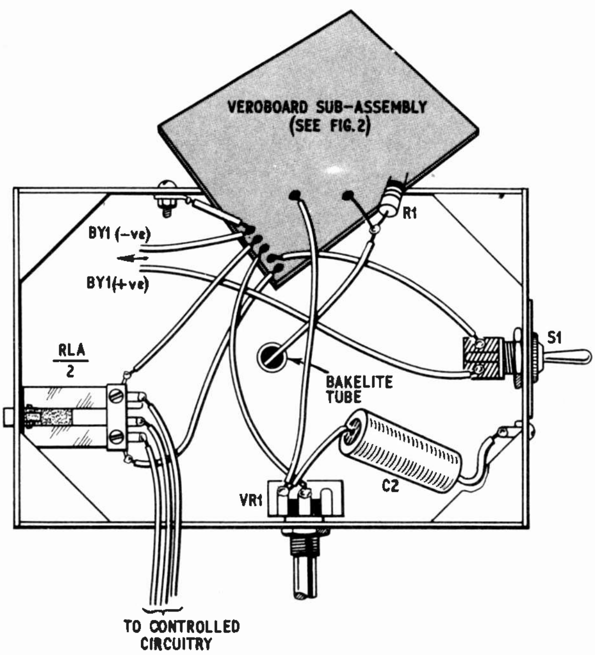
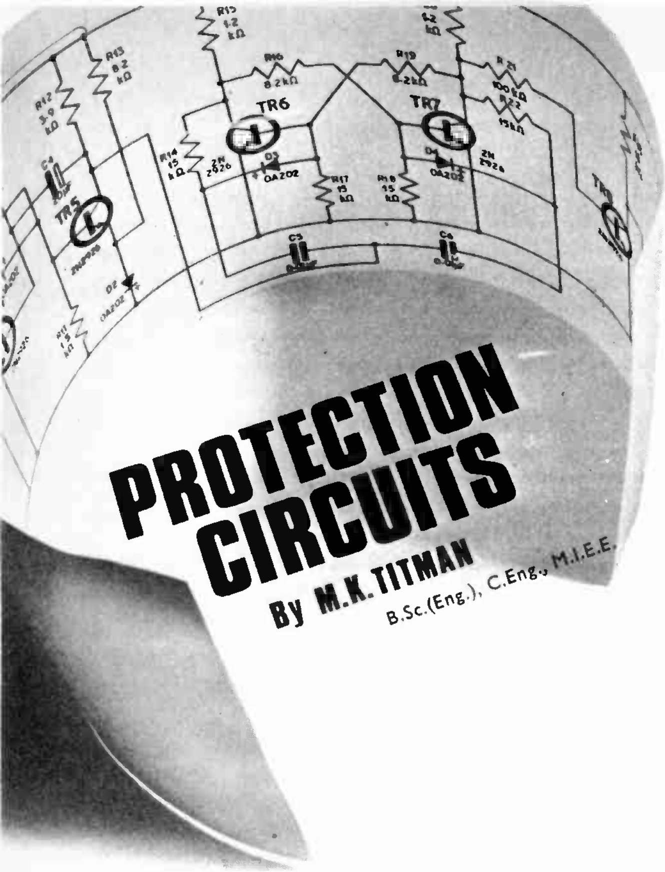


Fig. 3. Chassis mounted components and Veroboard wiring details. The precise details of connecting the relay contacts will depend on the circuit application

SENSITIVITY

When the switch is used in a building, it responds to the mains radiation transferred by bodily contact with the touch plate. When used away from mains wiring it responds to radio frequencies and is somewhat less sensitive. It will not work in a completely screened room or react to the touch of a person who is well "earthed".

If C2 is reduced in value or removed, the touch switch becomes slightly more sensitive and mere body proximity may be enough to cause switching. But under these conditions the setting of VR1 is extremely critical and the switch is less stable. ★



PROTECTION CIRCUITS

By M.K. TITMAN B.Sc.(Eng.), C.Eng., M.I.E.E.

With the increasing complexity of modern semiconductor circuitry, any form of power supply failure can be extremely costly. To forestall this, power supply and circuit failure protection circuits are commonly employed.

In general, overvoltage protection prevents damage to the fed circuit if the power supply voltage increases. Overcurrent and overpower protection prevents damage to the power supply if the fed, or external, circuit fails.

The two forms of protection circuit presented here are the self-resetting and crowbar circuits.

ZENER DIODE PROTECTION

Of the self-resetting overvoltage protection circuits, the simplest relies on a Zener diode. Fig. 1 shows a typical low power stabilised supply circuit used to power integrated circuits.

The output voltage is held at 5·1V and the supply current of 175mA is limited by the series resistor R_S.

If the stabiliser diode D_S failed and went open circuit, this would normally result in an increase in output voltage towards a peak value of 12V. However, with the protection Zener diode D_p connected the output voltage is held at 6·2V.

DIODE POWER RATING

For overvoltage protection of larger current stabilised supplies the power rating of the protection diode must be calculated.

In Fig. 1, the maximum current I_{Dp} likely to be taken by D_p is determined by the value of R_S. To evaluate this the following equation should be used.

$$I_{Dp} = \frac{V_{in} - V_{Dp}}{R_S}$$

where I_{Dp} = maximum diode current
V_{in} = supply voltage
V_{Dp} = Zener voltage
R_S = series resistance in ohms

Assuming an integrated circuit supply having an input voltage of 12V and an output rating of 5·1V at 1A, the resistor R_s would normally have a value of 4 ohms. Consequently the 6·2V protection Zener should be capable of carrying 1·5A continuously, and therefore a 10W, 6·2V Zener diode mounted on a heatsink would be required.

It should be noted that the power rating of the series resistor must be capable of 9W continuous dissipation.

From this it can be seen that the protection Zener diode must be capable of holding and dissipating the full output power of the supply, therefore it is only suitable for low power stabilised supplies.

As an example a 24V d.c. supply capable of delivering 1A would require a protection diode of 26 to 30W rating and clearly this is impractical. For higher power circuits, therefore, crowbar protection circuits are utilised.

CROWBAR PROTECTION

Crowbar protection circuits operate by effectively causing a short circuit across the supply until the line fuse ruptures. Unlike Zener protection where an intermittent fault would result in a return to normal working after the fault cleared, crowbar circuits positively isolate the faulty power supply.

This can be an advantage in very complex systems. Any failure condition can be used to operate the crowbar circuit and these include overvoltage, overcurrent and overpower.

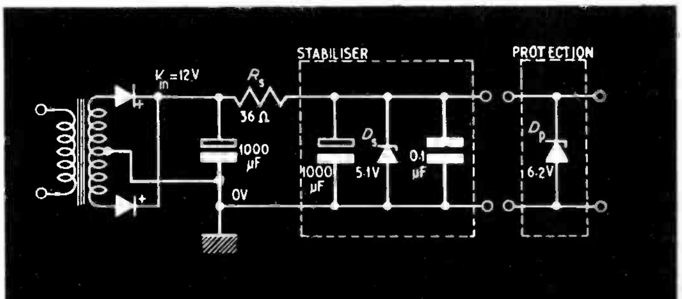


Fig. 1. Zener diode overvoltage protection

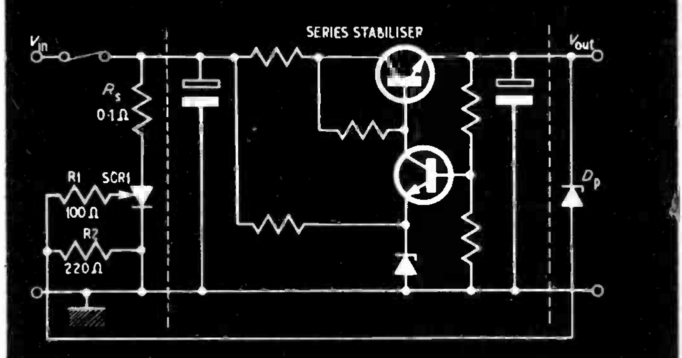


Fig. 2. Overvoltage crowbar protection

OVERVOLTAGE CROWBAR

In Fig. 2 is shown a typical overvoltage crowbar system operating in conjunction with a high power series stabiliser.

Any overvoltage at the output causes the sensing Zener diode D_p, to conduct, so passing current to the thyristor gate. The thyristor SCR1 switches on and causes a heavy current to flow through the fuse until it ruptures.

Since the circuit operates only for a very short period the Zener diode can be of 100mW rating as can the thyristor gate resistor.

The thyristor is chosen for its peak transient current rating which can be 25A to 100A for a TO-5 case thyristor. The series resistor R_s is a low value wire-wound resistor which simply limits the peak transient current.

Whilst an actual overvoltage condition must occur before the crowbar circuit operates, the overvoltage acts for a very short period.

Since the turn-on time of the thyristor is 10 to 20μs and following this a large current flows through the fuse, the supply voltage reduces almost immediately. Consequently the circuitry operated from the power supply receives an overvoltage transient of only 10 to 20μs duration which is usually insufficient time to cause circuit failure.

Because the ratings are based on transient effects, low cost components can be used.

OVERCURRENT CROWBAR CIRCUIT

One form of overcurrent crowbar circuit is illustrated in Fig. 3 and it can be seen that a certain amount of increased complexity, and therefore expense, is involved.

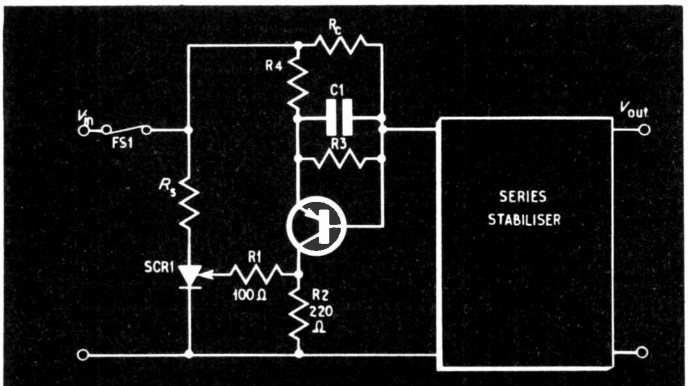


Fig. 3. Overcurrent crowbar protection

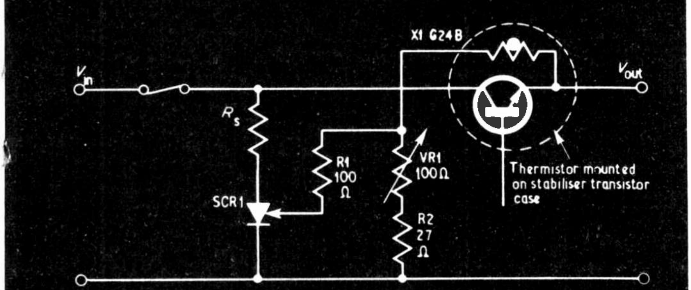


Fig. 4. Overpower crowbar circuit

The current level is sensed by resistor R_c which is chosen to give approximately 0·5 to 0·75 voltage drop at the fusing current. Generally the fusing current is chosen to be 150 to 200 per cent of full load current. When the current reaches this level the transistor conducts and operates the crowbar thyristor.

The resistor capacitor combination R4, R3, and C1 are incorporated to limit the speed of response of the circuit. This is a vital precaution since the capacitors in the stabiliser and following circuitry usually require a heavy switch-on charging current, consequently the time constant C_1R_4 must be longer than any switch-on surge current periods.

Typical component values using a transistor series stabiliser are R4 = 680Ω, R3 = 1·8kΩ, C1 = 10μF.

COMPARISON WITH A FUSE

With the increased complexity and difficulties inherent in the design of overcurrent trip circuits, the usefulness of this type of circuit is doubtful. For the vast majority of applications the simple fuse is adequate. However, occasionally this form of circuit is necessary for the protection of complex power equipment.

The main advantages over the simple fuse are a more definite fuse current, increased speed of response and greater reliability.

Reliability is perhaps the most important aspect, since the fuse incorporated with the crowbar circuit can be two or three times the rated current. This increased rating could well increase fuse life by three to ten times above the 1,000 hours usually quoted.

OVERPOWER CROWBAR CIRCUIT

The overpower crowbar circuit is seldom employed but can have very useful applications. The simplest form of circuit is given in Fig. 4 and consists of a thermistor for temperature sensing together with the thyristor crowbar.

In this example, the directly heated bead type thermistor is located on the surface of the series transistor of the stabiliser. Any excess power dissipation in the series transistor, such as produced by a short circuit, would result in overheating and consequent reduction in thermistor resistance. After a thermal delay period the minimum gate voltage will be exceeded and the thyristor triggers.

Since the body of the thermistor is isolated, any critical or expensive component in any part of the circuit can be monitored. Therefore this form of protection is extremely versatile.

Unfortunately, this form of protection requires a fairly large temperature change for reliable operation and is suitable only for non-critical operation. For more critical operation a single transistor comparator circuit can be used to give an accuracy of temperature measurement to ± 5 degrees Centigrade.

APPLICATIONS

The Zener diode protection circuits are only suitable for low power supplies, although they are useful for high current low voltage integrated circuit power supplies.

The thyristor crowbar circuits can be used for any size power supply, and it can be arranged for any type of fault condition to fire the thyristor. The crowbar circuits given can be combined to give a comprehensive protection device using a single thyristor, sensing Zener diode, thermistor and transistor. All the circuits are separate to the basic power supply and modifications to this are not required. ★

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.

STEREO TAPE CARTRIDGE

Offering 40 minutes and 80 minutes recording time, compared with the 30 and 60 minute version currently available, is the main feature of the new Scotch 8-track tape cartridges, type S-8TR-40 and S-8TR-80, from the **3M Company.**

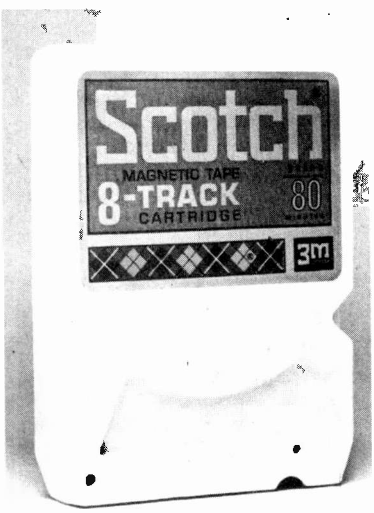
The Scotch 8-track cartridges may be used in any cartridge system having recording facilities and may, of course, be played back on any 8-track stereo equipment. The extra 10 minutes on the S-8TR-40 permits the complete recording of an average 12in. LP record.

Recommended retail prices are £1·50 for the 40 minute cartridge, and £1·80 for the 80 minute version.

MOULDED TRACK POTENTIOMETER

Potentionmeters, types T and TS, of all-moulded construction, including the bush and fixing nut, are announced by Plessey.

The type TS is identical to the Type T except that it incorporates a single-pole switch which is suitable for low voltage battery circuits.

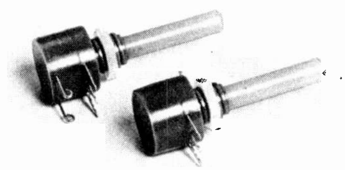


Scotch 8-track stereo tape cartridge from the 3M Company

The case is in two halves and is ultrasonically welded together to provide a completely insulated potentiometer.

These potentiometers are particularly suitable for portable transistor receivers and other equipment where a miniature moulded track potentiometer is required.

Full details and technical specifications can be obtained from Painton Electronic Components, Kingsthorpe, Northampton, NN2 6NA.



Plessey type TS and T miniature moulded potentiometers

FLASH TUBE

A new photographic flash tube, the Type CD13, has been introduced by the Electronic & Display Equipment Division of **Ferranti** as an addition to its range of tubes for photographic and similar applications.

A high intensity xenon-filled flash tube for electronic flash equipment, the CD13 produces a white light which is a good match to daylight and is suitable for "daylight" colour films. This device is a straight tube 210mm long.

Operating voltage of the tube ranges between a minimum 400V and a maximum 1,000V, and the typical operating level is 900V. The CD13 is not polarised and the charging voltage and discharge capacitor may be connected across the leads without regard to polarity.

Details of price and local stockists can be obtained from Ferranti Ltd., Electronic and Display Equipment Division, Gem Mill, Chadderton, Oldham, Lancashire.

CIRCUIT BOARDS

Quality printed circuit boards are now available for the circuits shown in the Mullard book "Transistor Audio and Radio Circuits". The boards manufactured by **Bribond Printed Circuits Limited,** Terminus Road, Chichester, Sussex, are made to the same standards as their industrial boards.

The boards are manufactured from high electrical grade s.r.b.p. laminate clad with 0·0015in copper. The copper tracks are tinned to aid soldering and give protection against oxydisation. To aid construction, the component identification is printed on the reverse in white.

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10W audio amplifier (p. 39) 66p
10W audio preamplifier (p. 42) 69½p

Price each including postage and packing.

LITERATURE

The new component catalogue from **A. Marshall & Son (London) Ltd,** is now available to readers. The catalogue lists many new items but probably the most interesting, to our readers, is the section on integrated circuits. This section contains one of the largest selections of I.C.'s available to the amateur we have seen. Apart from the English manufacturers there is a large range from American firms.

Request for copies should be addressed to, A. Marshall & Son (London) Ltd., 28 Cricklewood Broadway, London, N.W.2.

All the new editions of the component catalogues from **Henry's Radio, Home Radio (components), G. W. Smith & Co. (Radio),** and **LST Components** are up to their usual high standard and make a useful reference for the workshop.

Of particular interest to designers is a revised designers' guide to mercury and alkaline manganese primary power systems published by **Mallory Batteries.**

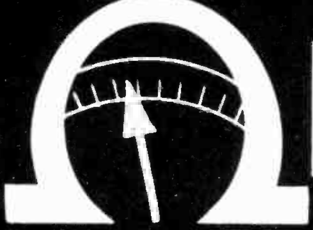
In addition to describing the two primary cell systems, the guide explains their advantages under widely differing environmental conditions.

It provides detailed specifications of over 100 different cells with the object of giving designers such basic information as capacity, nominal voltage and dimensions.

The designers' guide is also available in French and German and full details can be obtained from Mallory Batteries Ltd., Gatwick Road, Crawley, Sussex.

Containing more than 70 new products, ranging from an 8-track stereo cartridge player for cars to a multi-meter for test engineers, **Eagle International's** new 45-page catalogue is now available from Eagle International, Coptic Street, London, WC1A LNR, price 20p.

Divided into sections on hi fi equipment, hi fi accessories and peripherals, radio and tape equipment, office intercoms, public address, test equipment, electronics and accessories, the catalogue carries illustrations, detailed specifications and prices of over 400 products.



DESIGN OF OHMMETERS

BY H.A.COLE, C.ENG. M.I.E.R.E.

THERE are many ways of making an ohmmeter circuit; the most popular circuits can be reduced to either of two basic types which, for convenience, we will designate A and B.

In the A-type circuit (Fig. 1), a battery is connected in series with a fixed resistor (R1), a variable resistor (VR1), and the indicating meter (M1). R_m is the internal resistance of the meter and R_t, the total resistance in the circuit, is equal to $R_1 + R_{VR} + R_m$.

SIMPLE MEASUREMENT

The unknown resistor (Rx) is connected between the two ohmmeter terminals X and Y, which places it in series with the rest of the circuit. To determine the value of Rx, the X and Y terminals are first shorted together (so as to simulate Rx = 0 ohms); VR is then carefully adjusted so that M1 just indicates full-scale-deflection (f.s.d.). This procedure is called zeroing the ohmmeter, and is necessary to compensate for ageing of the battery.

The short-circuit between X and Y is then replaced with Rx and the meter indication, which will now be less than f.s.d., gives an indication of the value of Rx; the greater the value of Rx, the smaller the deflection.

CALIBRATION

To illustrate how this circuit works, let the battery voltage V_b equal 1·5V and let the f.s.d. of M1 equal 50μA. When the ohmmeter is zeroed, VR1 must be adjusted so that the meter current (I_m) equals 50μA, which means that $R_t = \dfrac{1{\cdot}5\text{V}}{50\mu\text{A}} = 30\text{k}\Omega$. Leaving R_t set at 30kΩ, now connect to the X and Y terminals, an unknown resistor (Rx) of such a value that I_m is reduced to 25μA (mid-scale). From Ohms law,

$$I_m = \frac{V_b}{R_x + R_t} \qquad (1)$$

or

$$R_x = \frac{V_b}{I_m} - R_t \qquad (2)$$

$R_x = \dfrac{1{\cdot}5}{25 \times 10^{-6}} - 30 \times 10^3 = 30{,}000$ ohms which is the same as R_t.

This is the first important point to notice about the A-type circuit; the mid-scale resistance value is equal to the value of R_t corresponding to R_x = zero.

Knowing that V_b equals 1·5V, and that R_t equals 30kΩ for I_m = 50μA (R_x = 0), a table of R_x for corresponding values of I_m can be compiled by substituting values of R_x in equation 1 above (Table 1).

From this table a suitable ohms scale may be produced, which can then be marked on the meter dial face; this is illustrated in Fig. 2, for a few values of R_x.

TABLE 1

Resistor on test R_x (ohms)	Meter current I_m (μA)
0	50 (f.s.d.)
100	49·8
1k	48·4
10k	37·5
30k	25
100k	11·52
1M	1·5
Infinity	0

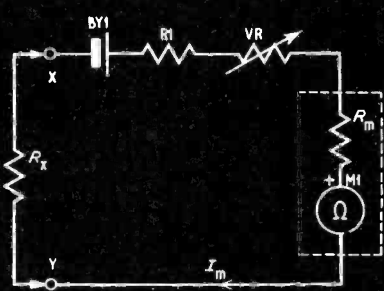


Fig. 1. "A"-type circuit where the battery, meter and variable resistor are all in series

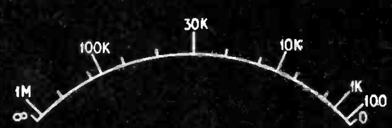


Fig. 2. Typical dial calibration for the example described with Table 1

SCALE CRAMPING

Note that zero ohms ($I_m = 50\mu A$) occurs at the right-hand end of the scale, and that infinite resistance ($I_m = 0\mu A$) corresponding to R_x = open-circuit, occurs at the left-hand end.

The scale is also non-linear, following a line of $1/R$. It appears severely cramped at the high-resistance end and open at the low resistance end. In fact, if we assume $1\mu A$ to be the smallest discernible deflection of the meter pointer (corresponding to 2 per cent of f.s.d.), then we can say that the largest measurable resistance with this particular circuit is about $1{\cdot}5M\Omega$, using equation 2. Even so, cramping is so severe in this region of the scale that anything greater than about $1M\Omega$ is almost unmeasurable.

To measure greater resistance values with this particular circuit (without changing to a more sensitive meter), it is necessary to increase the value of V_b.

INCREASING RANGE

Increasing V_b from 1·5V to 15V increases the measurable resistance by ten times, and also the value of R_t required for the zero-ohms setting from $30k\Omega$ to $300k\Omega$, as is the mid-scale resistance indication.

The advantage of providing a tenfold increase in the value of V_b means that a single ohms scale can be used for a two-range ohmmeter, the readings corresponding to the higher range being multiplied by ten by the user. This is common practice; typical basic two-range ohmmeter circuits might look like those shown in Fig. 3.

In Fig. 3a, separate VR controls are provided, whereas in Fig. 3b a single VR control is shared by the two ranges. The advantage of having separate controls means that once the two ranges have been zeroed properly it is possible to change from one range to the other without having to re-zero each time. The only disadvantages of having two controls are additional expense and greater panel space needed to accommodate them.

In the case of one control types of circuit, it is usually fairly coarse in operation, i.e. small adjustments bring about comparatively large changes in the meter indication, which makes zeroing rather difficult.

We have recently seen that the required value of R_t for the OHMS × 1 range ($V_b = 1{\cdot}5V$) is $30k\Omega$, and that for the $\Omega \times 10$ range ($V_b = 15V$) it is $300k\Omega$. The value of VR1 in Fig. 3b should be made as small as possible for the OHMS × 10 range, so that it is no larger than absolutely necessary when it is used for the OHMS × 1 range (a resistance value which is small compared with $300k\Omega$ is likely to be large when compared with $30k\Omega$).

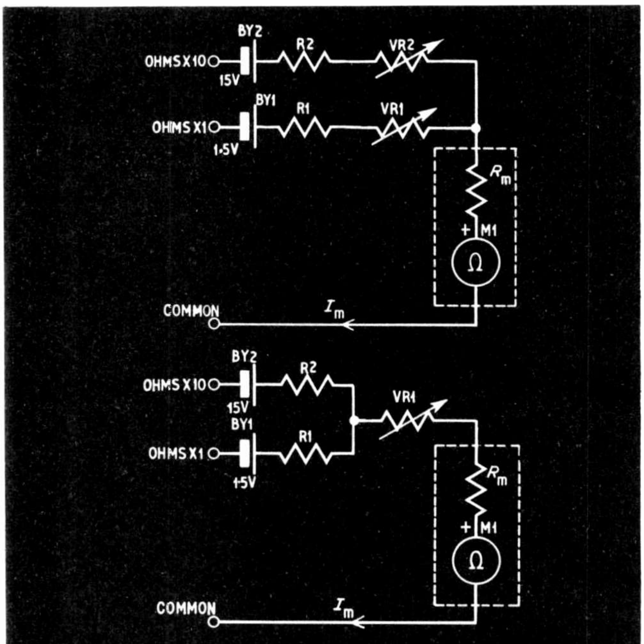


Fig. 3. Basic two-range ohmmeter circuit with (a) two separate controls and (b) one common control

BATTERY AGEING

The batteries used in most ohmmeter circuits are of the carbon-zinc type, a type which is notorious for the variations which occur in its terminal p.d. throughout its life. Because of this, when a new battery is purchased, its terminal p.d. is quite likely to be higher than its nominal voltage, even when delivering a small load current.

In time, however, even if not used, its p.d. will fall and its internal resistance will increase considerably—so much so that it will be unable to deliver the required voltage for the circuit. When it has reached this state the battery is considered as being fully discharged and should be replaced.

AGEING COMPENSATION

In view of this, the resistance of VR1 must be sufficient to compensate for changes in V_b ranging from about 13V to 16V on the OHMS × 10 range, and from about 1·3V to 1·6V on the OHMS × 1 range.

Taking the OHMS × 10 range first; when V_b is 16V, the value of R_t required to limit I_m to f.s.d. ($50\mu A$) when zeroing the ohmmeter is

$$R_{t(max)} = \frac{16V}{50\mu A} = 320k\Omega.$$

Similarly, when $V_b = 13V$

$$R_{t(min)} = \frac{13V}{50\mu A} = 260k\Omega.$$

It is the difference between these two required values of R_t which must be compensated for by VR1; the value of VR1 should therefore be $60k\Omega$.

Since this is not a standard value for a potentiometer, we must either accept a value of $50k\Omega$, which means we won't be able to compensate completely for all changes in V_b, or one of $100k\Omega$, which would be much too coarse when used on the OHMS × 1 range (R_t for the OHMS × 1 range is only $30k\Omega$). The sensible thing to do then is to select the $50k\Omega$ value and to accept the limitation on V_b compensation.

RANGE RESISTOR

The next thing to do is select suitable values for R1 and R2. Now, since $R_{t(max)}$ for the OHMS × 10 range is $320k\Omega$, and VR1 is $50k\Omega$, then $R2 = (320-50)k\Omega = 270k\Omega$—which happens to be a preferred value resistor.

Unfortunately, we run into another problem here, and that is the selection tolerance of R2. For cheapness a ±20% type could be used, but the value of VR1 (which itself will have a tolerance of ±10%) would have to be large enough to compensate for tolerance differences in R2 (±20% of $270k\Omega = \pm 54k\Omega$), as well as for changes in V_{b_2}.

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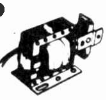

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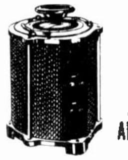

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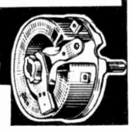

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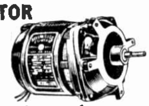

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To be able to do this, VR1 would have to be made 100kΩ, which is unacceptably large for the OHMS × 1 range. The simplest solution would be to use a closer tolerance resistor for R2 and accept a reduction in the compensating ability of VR1. Ideally, this should be of ±1% tolerance before an acceptable result is obtained.

OHMS × 1 RANGE RESISTOR

Having settled on the value of R2 in Fig. 3b, we must now turn our attention to the OHMS × 1 range and determine the value of R1.

Since V_{b1} is one-tenth of V_{b2}, then the corresponding values of $R_{t(max)}$ and $R_{t(min)}$ for maximum and minimum values of V_{b1} will be one-tenth of those values determined for $R_{t(max)}$ and $R_{t(min)}$ for V_{b2}. For the OHMS × 1 range then, $R_{t(max)} = 32\text{k}\Omega$ and $R_{t(min)} = 26\text{k}\Omega$.

This means that VR1 for this range, should ideally be equal to the difference between these two values, i.e. 6kΩ. However, VR1 has already been selected as being 50kΩ which is nearly ten times greater than 6kΩ and VR1 is already greater than the largest value ever required for R1.

In this case we don't need R1 at all since VR1 (50kΩ) is more than big enough to cope with all required values of R_t. However, if R1 is dispensed with altogether, there would be no built-in protection for the meter if VR1 should inadvertently be set to zero. By insertion of a large value for R1, the operation of VR1 is even coarser than it is already (it is almost ten times greater than it need be).

Resistor R1 must be made large enough to provide a substantial degree of overload protection for the meter, and yet small enough to have little effect on the sensitivity of VR1.

If the meter current is limited to a value equal to ten times the f.s.d. current (most meters will just about stand a 10 : 1 instantaneous overload) then the overload current will be 500μA and the corresponding value for R_t (assuming VR1 is set to zero, and V_{b1} is at its highest value of 1·6V) will be equal to $\dfrac{1{\cdot}6\text{V}}{500\mu\text{A}} = 3{\cdot}2\text{k}\Omega$. Then, $R_1 = R_t - R_m = 1{\cdot}7\text{k}\Omega$. The nearest preferred value is 1·8kΩ.

INDICATION ACCURACY

Before leaving the A-type ohmmeter circuit, it is important to note a very serious drawback concerning its indication accuracy. The validity of the mid-scale indications (the OHMS × 1 range is 30kΩ, and on the OHMS × 10 range it is 300kΩ) only applies when the battery voltages are 1·5V and 15V, respectively. See what happens to the indications when the battery voltages are first high, and then low; this need only be done for one ohmmeter range because the overall effect will be the same for both ranges.

Taking the OHMS × 1 range, and a $V_{b(min)}$ value of 1·3V, the value of R_t required to achieve f.s.d. (50μA) is 26kΩ. The value of VR1 will be adjusted during the zeroing procedure so that it equals 26kΩ.

From earlier deductions, the value of R_t required to bring about f.s.d., is also equal to the value of an external resistor (R_x) required to bring about half-f.s.d. (25μA). Consequently, the mid-scale indication of the OHMS × 1 range when V_b is 1·3V (instead of 1·5V) is 26kΩ, instead of 30kΩ, i.e. 4kΩ below normal. This represents an indication error of about −13%, which is almost the same as the corresponding reduction in the value of V_b.

For a $V_{b(max)}$ value of 1·6V (about 7% above the 1·5V normal value), the indication inaccuracy will be about +7%.

From these calculations we may deduce that the indication accuracy of the A-type ohmmeter circuit (quoted at mid-scale) is correct only when V_b is equal to 1·5V, and that the inaccuracy of this indication will vary from about +7% when the battery is new, to about −13% when it is ready for replacement. These facts are worth knowing, especially when using the ohmmeter to select a close tolerance resistor.

This completes the examination of the A-type ohmmeter. The reasons for going into its circuit in such detail were to illustrate the difficulties in reaching a suitable compromise for the component values, and to highlight its undesirable indication inaccuracies.

PARALLEL POTENTIOMETER OHMMETER CIRCUIT

The B-type of circuit (Fig. 4) is basically very similar to the A-type circuit shown in Fig. 1, except that the variable resistor VR1 is connected in parallel with the meter (M1) instead of in series with it. The zeroing procedure is exactly the same except that, in this case, the meter current (I_m) is adjusted to f.s.d. by shunting the excess current (I_s) through VR1.

The total circuit current (I_t) is equal to the sum of I_s and I_m ($I_t = I_s + I_m$), and is therefore greater than the corresponding value of I_t for the A-type circuit in which I_t was always equal to I_m. This type of circuit therefore consumes more power than the previous type.

The B-type circuit, for the same number of components, is much more flexible than the A-type and the zeroing control VR1 is much smoother in operation. The reason for this, as you will see, is that almost any value can be chosen for VR1, which means that it may

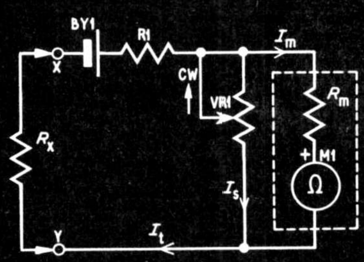

Fig. 4. "B"-type circuit where the variable resistor is in parallel with the meter

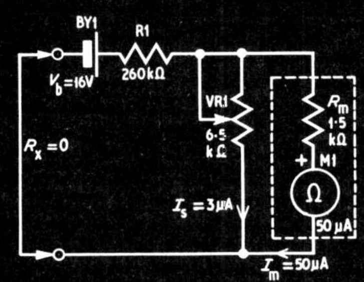

Fig. 5. Component values for the "B"-type circuit to allow for change of battery voltage

be used to determine the overall resistance range of the ohmmeter; in addition to its normal role of compensating for changes in V_b.

BATTERY V_b COMPENSATION

Let us first consider the fundamental requirement of compensating for a change in V_b, assuming a nominal value of 15V for V_b and a mid-scale resistance indication of 300kΩ (the same as the corresponding indication for the A-type circuit).

Since the battery voltage V_b is likely to change from about 13V (for old battery) to about 16V when renewed, I_m will increase from 50μA (13V/260kΩ) to 61·5μA (16V/260kΩ). In order to compensate for this change in I_m, VR1 must be set to such a value that it will bypass the excess 11·5μA at present flowing in R_m.

The value of VR1 should be 50/11·5 or approximately 4·33 times greater than the value of R_m; VR1 should therefore be 6·5kΩ. This is illustrated in Fig. 5.

What we have just done is to determine the minimum value that VR1 is ever required to have in order to compensate for the maximum likely value of V_b. One obvious advantage with this type of circuit is that no matter how large V_b might be, the excess current can always be fully absorbed by VR1 since its value can, if necessary, be reduced to zero—thereby bypassing all the current.

VR UPPER LIMIT

There is no upper limit for the value of VR1 since we have already shown that I_t can never exceed 61·5μA (with R1 = 260kΩ), and that setting VR1 to 6·5kΩ can take care of that current which is in excess of the 50μA required by the meter.

It is, however, necessary to employ a reasonably large value for VR1 so that when set to its maximum value its shunting effect on R_m is negligible. This is important in order to ensure that 50μA f.s.d. is still possible when V_b is approaching its minimum value of 13V. If VR1 is set to a maximum value of 10kΩ (by using a 10kΩ variable resistor), then I_m would equal 43·5μA when V_b = 13V and 6·5μA would flow in VR1, giving a total (I_t) of 50μA.

This means that it would not be possible to obtain f.s.d. when V_b had fallen to 13V. Looking at it another way, we can say that the minimum value of V_b which can be tolerated with a 10kΩ value for VR1 is about 15V. The circuit as it stands, therefore, isn't going to be very useful because the battery will need replacing as soon as its potential has fallen to 15V; a value which is only a little less than its value when new.

COMPROMISE

The alternatives are to reduce the value of R1, or increase the value of VR1. If the value of R1 is reduced, then the mid-scale indication of the ohmmeter will also be reduced. On the other hand, if VR1 is increased then its rate of adjustment will be more coarse, making it difficult to zero the ohmmeter, particularly when the battery is new and a comparatively low-value setting is required for VR1.

The final choice for VR1 is a compromise between mid-scale resistance indication and ease of zeroing adjustment. A useful rule-of-thumb in selecting a value for VR1 in this type of circuit is that its value should not exceed about ten times the value of R_m (the resistance of the meter). In the example we have just considered, R_m is 1·5kΩ, therefore VR1 should not exceed 15kΩ. The initial selection of 10kΩ for VR1 appears to be quite reasonable; the compromise required in this example must be made with the value selected for R1. This may be done as follows.

SET MID-SCALE INDICATION

If a value of 10kΩ is selected for VR1, then the maximum acceptable value for R1 may be determined by assuming a $V_{b(min)}$ value of 13V. With I_m = 50μA (f.s.d.), then 7·5μA (I_s) will flow in VR1 (determined from $I_s = R_m \times I_m/R_{VR1}$, making I_t equal to 57·5μA. R_s is determined by $V_{b(min)}/I_t$, which equals 13V/57·5μA=226kΩ (220kΩ is a preferred value).

The mid-scale indication of the ohmmeter is thus 220kΩ, which is not very different from the corresponding indication of 260kΩ determined for the A-type circuit when V_b equalled 13V.

In the B-type circuit, however, R_1 is fixed at 220kΩ irrespective of the variations which occur in V_b, since the parallel combination of VR1 and R_m is always small enough to be neglected. This is very different from the A-type circuit in which the mid-scale indication changed from 320kΩ to 260kΩ (due to adjustment variations in VR1) when V_b changed from 16V to 13V.

This is a very important observation since it shows that the B-type circuit is inherently more accurate than that of the A-type. Actually, this statement ignores the relative abilities of the two circuits to compensate for variations in the internal resistance (R_b) of the batteries. However, R_b is relatively small in the low-current circuits considered so far, and may therefore be ignored.

RANGE SELECTION

Now consider the second feature of the B-type circuit—the ability to select a particular resistance range by suitable choice of VR1.

We have just seen that a 10kΩ value for VR1 sets the mid-scale resistance indication at 220kΩ. Assuming a low-resistance range with a mid-scale indication of about 1kΩ (30 times smaller than that obtainable with the corresponding A-type circuit) when $V_{b(min)}$ = 1·3V, then $I_t = \dfrac{V_{b(min)}}{(R_1 + R_p)}$ where $R_p = \dfrac{R_m \times R_{VR}}{(R_m + R_{VR})}$.

The value R_p is now comparable with R_1 and cannot be ignored; at least, not just yet. Since the mid-scale indication is 1kΩ, then $(R_1 + R_p)$ must equal 1kΩ. Thus, $I_t = \dfrac{1\,\mathrm{k}\Omega}{1{\cdot}3\mathrm{V}}$ = 1·3mA. When the meter is indicating f.s.d. (I_m = 50μA), the current (I_s) which flows in VR1 must equal $(I_t - I_m)$, i.e. I_s = 1·3mA − 50μA = 1,250μA. The value of VR1 required to absorb this amount of current is therefore equal to $I_m \times R_m/I_s$ = 60 ohms.

This is the maximum value that VR1 is ever likely to require. Now, since this value is so small compared with R_m (1,500Ω), the value of R_p can be assumed to equal 60 ohms. Furthermore, since R_p is also very small compared with $R_1 + R_p$, i.e. 1kΩ, we may further assume that R_1 equals 1kΩ. The value required for VR1 when $V_{b(max)}$ = 1·6V and when I_m = f.s.d. (50μA) is equal to $I_m \times R_m/I_s$ = 48 ohms.

This is the minimum value that VR1 is ever likely to require. From these two sets of calculations, VR1 is required to vary between 48 and 60 ohms, depending upon the value of V_b; a 100 ohms variable resistor would therefore be a very satisfactory choice.

When using such a resistor value, the minimum setting of 48 ohms would represent a setting of 48 per cent of maximum, which would yield very smooth adjustment during the zeroing procedure. The circuit for this particular ohmmeter is shown in Fig. 6.

TWO-RANGE OHMMETER CIRCUIT

The B-type circuit can also be used to provide two resistance ranges and, like the A-type circuit, this may be achieved by using two batteries and a single zero-adjustment control. In order to make a more direct comparison with the A-type circuit (Fig. 3), a B-type two-range circuit will be designed using battery voltages of 15V and 1·5V, attempting to achieve the same approximate mid-scale indications.

The mid-scale indication for the OHMS × 10 range of the A-type circuit, using $V_b = 15V$, was found to be 300kΩ. The nearest approach to this figure using the corresponding B-type circuit, and a value of 10kΩ for VR1, was 220kΩ.

By replacing V_b of the B-type circuit with a battery of 1·5V, so as to produce a OHMS × 1 range, then the mid-scale indication will be reduced by a factor of ten, making $R_1 = 22k\Omega$. The mid-scale indications are, therefore, not widely different from those of the A-type circuit.

However, as was explained when the A-type circuit was examined, the zeroing adjustment of VR1 on the OHMS × 1 range of that circuit was expected to be very coarse, because of the compromise which had to be made concerning the choice of value for VR1. Let us now see what the sensitivity of the zeroing adjustment is like in the B-type ohmmeter.

The sensitivity is all right on the OHMS × 10 range because VR1 was selected to make it so.

LOW RESISTANCE SETTING

On the OHMS × 1 range, the lowest resistance setting required for VR1 occurs when $V_{b(max)} = 1·6V$; the total current (I_t) in the circuit during the zeroing procedure is equal to $V_{b(max)}/R_1 \simeq 73\mu A$. In this condition, therefore, the value of VR1 must be adjusted so that it absorbs the $23\mu A$ which is in excess of I_m, the f.s.d. current of the meter.

Since $I_s = 23\mu A$, and $I_m = 50\mu A$, then the required value of VR1 must equal $I_m \times R_m/I_s = 3,260$ ohms. A setting of this value represents 33 per cent of $R_{VR(max)}$, which represents a substantial angular rotation of the control shaft· the zeroing adjustment will, therefore, be quite smooth in this worst-case condition, and will be even better when the battery is relatively new. The circuit diagram of this particular two-range ohmmeter is shown in Fig. 7.

SHUNT OHMMETER

In the shunt ohmmeter (Fig. 8), the indicating meter M1, is connected directly across the input terminals in parallel with the unknown resistor (Rx). The circuit is normally used for measuring very low resistance values (typically 0·01 to 2,000 ohms), and is therefore ideally suitable for measuring the winding resistances of coils and transformers.

The resistance scale differs greatly from the other types of ohmmeters so far examined in that it reads from left-to-right instead of from right-to-left, i.e. zero ohms corresponds to zero deflection and infinite resistance corresponds to f.s.d.

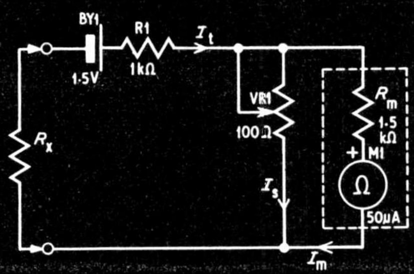

Fig. 6. Single-range parallel control ohmmeter circuit

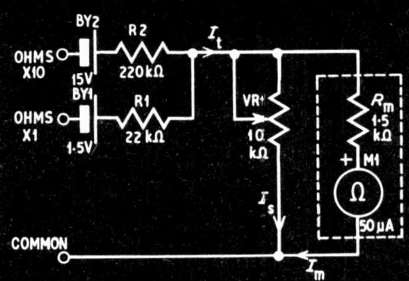

Fig. 7. Two-range parallel control ohmmeter circuit

SET ZERO

The zeroing procedure is very similar to that adopted for previously described circuits, except that it is carried out with the input terminals open-circuit (corresponding to infinite resistance) instead of with them short-circuit.

To zero this type of ohmmeter, the input terminals are left open and VR1 is adjusted until the meter indicates f.s.d. (VR1 and R1 have the same purpose as in previously described circuits, and their values are determined by the same procedures.) Having done this the unknown resistor (Rx) is then connected to the input terminals. This causes the meter current (I_m) to be bypassed to some extent and a reduced indication results; the degree of the reduction depending upon the value of Rx. If a short-circuit is connected to the terminals then all of I_m is bypassed and zero indication results.

RANGE SELECTION

The range of the ohmmeter may be changed by connecting an internal resistor across the meter. This reduces the effective sensitivity of the meter and hence more total current (I_t) is required to achieve f.s.d.

On the OHMS × 1 range no ranging resistor is added and the mid-scale resistance indication is equal to the meter resistance R_m, i.e. 1,500 ohms. Thus, if a resistor (Rx) of the same value as R_m is connected to the terminals, then I_t will be shared equally between Rx and the meter; $25\mu A$ will flow in each.

In order to produce the OHMS ÷ 10 range provided for in Fig. 8, an internal resistor R2 must be connected across the meter so that the parallel combination of R2 and the meter is equal to $R_m/10$, or $\frac{R_2 \times R_m}{R_2 + R_m}$.

Rearranging this expression and substituting known values, we get $R_2 = R_m/9 = 1,500/9 = 166·6$ ohms.

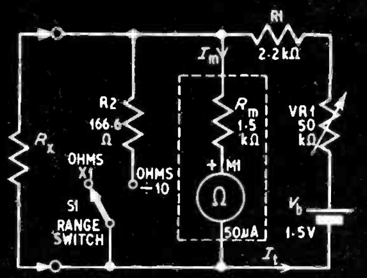

Fig. 8. Shunt ohmmeter in which the meter is connected directly across the terminals and the range selector

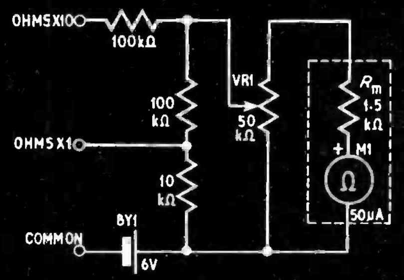

Fig. 9. Constant resistance ohmmeter

The same result may be achieved by using the expression

$$R_2 = \frac{R_m}{n-1},$$

where n is the number of times that the f.s.d. is to be multiplied. When operating on this range, I_t is increased by a factor of ten (500μA), 90 per cent of which flows in R_2, and the mid-scale indication equals $R_m/10$ or 150 ohms.

CONSTANT RESISTANCE OHMMETER

In the constant resistance type of ohmmeter (Fig. 9), the variable resistor VR1 is connected in such a way that the total resistance of the circuit is maintained near-constant as VR1 is adjusted to compensate for changes in V_b. This is accomplished by connecting VR1 across the meter in such a way that it is used as a potentiometer.

Adjusting VR1 in one direction causes more resistance to be added in series with the meter and a lower value of resistance to be connected in parallel with Rx; the reverse occurs when VR1 is adjusted in the opposite direction. This arrangement maintains an almost constant total circuit resistance, and hence the accuracy of the indication is very little affected by the setting of VR1.

Fig. 9 shows a two-range ohmmeter based upon this type of circuit. Only one battery is used and the mid-scale indications on the OHMS × 1 and OHMS × 10 ranges are 10kΩ and 100kΩ, respectively. The zeroing procedure is conventional and is carried out with the input terminals short-circuited; the ohmmeter scale reads from right-to-left.

This completes this examination of various ohmmeter circuits; there are a great many other types of circuits but these are, in many cases, simply variants of those just described. ★

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Results of developments so far, have shown these tubes, which are interchangeable with 1 inch vidicons, to be mechanically, thermally and electrically very rugged, with high sensitivity throughout the visible and infra-red range. The Sidicon has considerably less lag than conventional vidicons and much higher sensitivity. The nature of the targets allows full high-vacuum processing, so ensuring a long life expectancy.

Brain Box

A SMALL sensitive electronic amplifier no larger than a packet of cigarettes is helping surgeons at the London Hospital, Whitechapel, to trace brain activity during operations for Parkinson's disease.

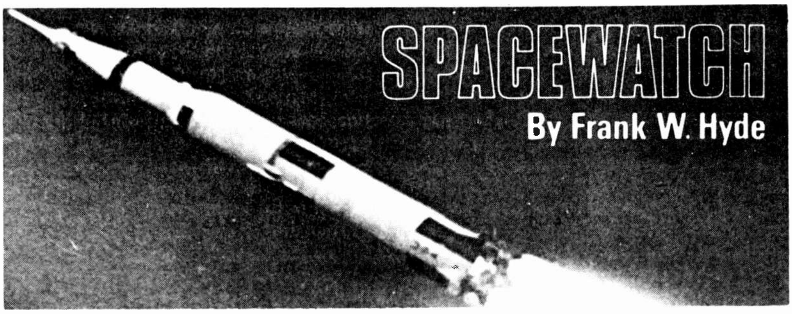
This is achieved by picking up and monitoring very small signals from the brain through an electrode implanted in it. The amplifier enables the surgeon to track with greater accuracy the exact portion of the brain in which he is working while carrying out this extremely delicate operation.

Made by the British company, Fenlow Electronics Ltd., it is the first miniature data amplifier the firm has produced for medical use. Using f.e.t.'s the amplifier is constructed to stringent safety specifications and costs only £40.

Transportable Tactical Centre

THE photograph below shows test pattern symbols on the screen of a lightweight display console being checked with a microscope at Hughes Aircraft Company, America, to verify their sharpness and clarity. The console, along with high-speed computers and other electronic equipment, is being built by Hughes for the U.S. Air Force Electronic Systems Division's 407L programme, an advanced concept of tactical air control.

The equipment will be housed in inflatable, modular operations centres that can be transported anywhere in the world and set up in a matter of hours. Hughes is producing 31 of these tactical centres along with two training systems designed to give the Air Force flexible and mobile response to fast-changing battlefield situations.



WHAT THE ASTRONAUTS SAW

All crews of the *Apollo* missions reported seeing flashes and streaks before their eyes even when closed. It is supposed that this is the result of the passage of ionised cosmic ray particles through the head.

It has been suggested that the light comes from the passage of the high energy particles through the jelly-like medium in the eyeball where light has a lower velocity. Another explanation is that it is the impact of the particles on the retinal cells.

The particles also affect the astronauts' space helmets which are made of a polycarbonate plastic. This plastic is of the long-chain polymer class and as a result of radiation the molecules are broken up. It is known in biological systems that ionising radiations damage cells by disturbing the replication of long-chain molecules.

It has been found that the damage to the space helmets can be studied by etching the streaks caused by the particles. Silicone casts can be made of the holes in the plastic and the rate of etching indicates the degree of ionisation that takes place. The shape of the rubber allows the measurement of the ionisation from point to point along the track. Comparison with the effects of known ions enables the particular particle to be identified.

RADIO TELESCOPE

Germany's new 100m radio telescope, the largest steerable dish in the world, is nearing completion at Effelsberg some 40km from Bonn. The site is a deep valley in an area of minimum interference.

The design of this telescope has made use of the most advanced principles of structural engineering to ensure that in all positions of the dish the effects of loading both static and variable cause the least departure from paraboloid form. It is expected that the surface accuracy will hold to less than 1mm.

The actual construction of the reflecting surface is interesting, the inner section of 60m diameter is formed from an aluminium sandwich with a honeycomb inner unit bonded to the outer formed sheets. Trial measurements show that the r.m.s. accuracy of the surface of this construction is of the order of 0·22mm.

The next 20m of the surface is covered by formed sheets of aluminium supported by aluminium sections. The standard of accuracy reached in this section of the dish is 0·27mm. The outer section of this ring of panels is connected to the rest of the surface, made up of 6mm square stainless steel mesh panels, by perforated aluminium panels to maintain the aerodynamic conditions required. The accuracy of the outer mesh is about 0·55mm.

The overall efficiency of the telescope is expected to be capable of operation down to a wavelength of 5cm. The central 60m section will, it is hoped, enable wavelengths of 8mm to be used.

Round the outer rim of the dish a collar has been added to reduce the effects of local interference.

FOCUSING ACCURACY

The focus to diameter ratio is midway between that of the Jodrell Bank and Parkes telescopes. Jodrell Bank Mk1 is 0·25 and Parkes 0·41 with the German dish at 0·3.

The Gregorian system has been adopted which enables both prime focus and secondary focus work to be carried out. For prime focus operation a tube will project through the centre of the sub-reflector to house a prime focus receiver. The intention is to use multibeam methods of observation and as many as nine feeds will be available at the secondary focus. Space receivers at wavelengths of 6cm, 11cm, and 13cm will be provided at the secondary focus.

With such a sophisticated type of radio telescope it is not surprising that the receiving installation is very elaborate. Cryogenically cooled amplifiers and low noise front ends are being provided.

The timing system will use a rubidium clock as reference for the universal oscillator in line measurements for Pulsar timing and very long base line observations. Continuum measurements will be made by Radiometers.

COMPUTER CONTROL AND PROCESSING

Data processing is also very elaborate and the basic data processor and steering computer is an ARGUS 500 by Ferranti. This digital computer will co-ordinate transformations, control the telescope drive and process real time data.

From a control desk an observer can choose the astronomical co-ordinates he needs and the method of scanning. The computer will then carry out the transformations and instruct the drives of the telescope in the necessary velocities in azimuth and elevation.

Since this occupies only a portion of the computer cycle, time is available for storing of data on magnetic tape, operate a fast line printer and Calcomp plotter and have time available for some on-line data processing.

SUPPORT FOR THE GENERAL THEORY OF RELATIVITY

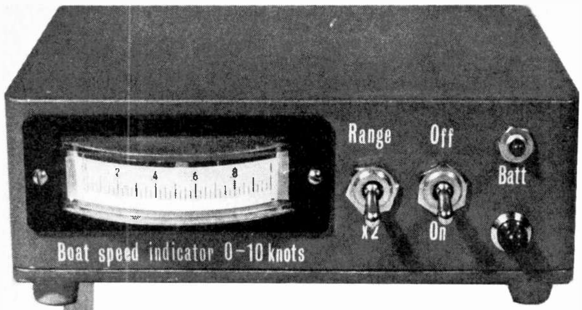
Working with *Mariners 6* and *7* probes, the team at the Jet Propulsion Laboratory led by Dr J. Anderson have obtained data which, they claim, confirms Einstein's predictions with an accuracy of 2 to 4 per cent.

Previous work by Muhleman and Shapiro using the passive radar technique by bouncing signals off planets close to the sun's limb showed an accuracy of 5 per cent.

The first results with active radar are now available from the 210ft dish at Goldstone. A narrow beam of radio signals at 250kW is sent out to impinge on *Mariner 6* or *7*, which are now some 250 million miles beyond the sun. The spacecraft collect the signals, amplify them, and transmit them to the dish at Goldstone. The round trip takes about 43 minutes and can be timed within a microsecond.

The most important source of error is the very considerable dispersion of radio waves by the sun and the results depend on the type of model of the sun's atmosphere that is used.

Dr Anderson's results conflict with the gravitational theories which show about 7 per cent error.



BOAT SPEED INDICATOR

By M. KENWARD

OWNERS of small boats, both power and sail, often find the need for a boat speed indicator. The speed indicator is useful for a variety of reasons including engine tuning, propeller selection, water skiing, sail trimming, arrival time estimation, and the obeyance of speed limits. The device described here uses a potentiometric transducer in a simple circuit to produce a linear speed reading on a moving coil meter.

TRANSDUCER DESIGN

One of the most difficult problems when designing and building a speed indicator is to arrive at a transducer design that is effective, reasonably accurate, yet easy to construct, using limited resources. The design finally arrived at uses a horizontal underwater probe that is turned about its fixed end by the pressure of water moving past it. The probe rotates the shaft to which it is affixed which in turn revolves a potentiometer (VR1) in Fig. 1 by means of two gears. These gears are used to increase the angle by which VR1 revolves, thus decreasing wear on the potentiometer and making for greater accuracy; the probe will only turn through 90 degrees.

A spring is used to give torsional resistance to the probe. Providing this spring has a good number of turns, the torsional resistance will be similar at all probe angles.

The transducer is housed in a suitable round plastics container, the top of which is screwed to a brass plate that is soldered or brazed to the shaft. This gives some degree of water protection to the unit, although the transducer will not be completely waterproof unless the container is carefully sealed after installation. A high quality sealed, carbon track potentiometer is used for VR1.

CIRCUIT THEORY

From the description of the transducer it will be noted that the resistance of VR1 is varied with the speed of the boat. The variation of resistance will not be linear as the area of the probe exposed to the flow of water effectively reduces as the probe revolves about the shaft; this gives a variation corresponding to $\text{Cos}^2\theta$ (where θ is the rotated probe angle).

With the boat stationary, and the probe at right angles to the fore and aft axis of the boat, the maximum value of resistance will be across output leads a and b (Fig. 1) from the transducer. As the boat speeds up the resistance will be reduced and reach its lowest possible value when the probe is in line with the fore and aft axis of the boat. By inserting potentiometer VR1 in the circuit shown in Fig. 1, the variation can be arranged to give an almost linearly increasing reading, directly proportional to boat speed, on meter M1. However, this reading is only proportional to speed for probe angles up to 45 degrees—due to the shape of the $\text{Cos}^2\theta$ curve. Thus the transducer is only used in this range of angles.

As stated, the resistance of VR1 is varied as $\text{Cos}^2\theta$. The curve of $\text{Cos}^2\theta$ is shown in Fig. 2 as graph (a). If we arrange for the circuit to give a meter reading that varies to $\text{Sine}^2\theta$, the two variations will cancel and give a meter reading corresponding linearly to boat speed. Graph (b) is the actual graph of meter reading against probe angle, taken from 0 to 45 degrees; graph (c) is the result of (a) minus (b). Graph (c) is not quite a straight line—as it should be for complete accuracy—but is within 0·3 of a knot or 5 per cent of the true reading, which ever is the greater, and it is felt that this is sufficiently accurate for most purposes.

The boat speed indicator circuit could, of course, have been made to give a perfect straight line for (c), but this would make it more complicated and expensive to build. If greater accuracy is required a graph such as (c) can be plotted for the completed unit over the full range of speeds, and this graph used for correcting the speed indicated.

A times 2 range is provided to give greater meter movement at low boat speeds and in this mode the accuracy of the unit will depend mainly on the transducer construction.

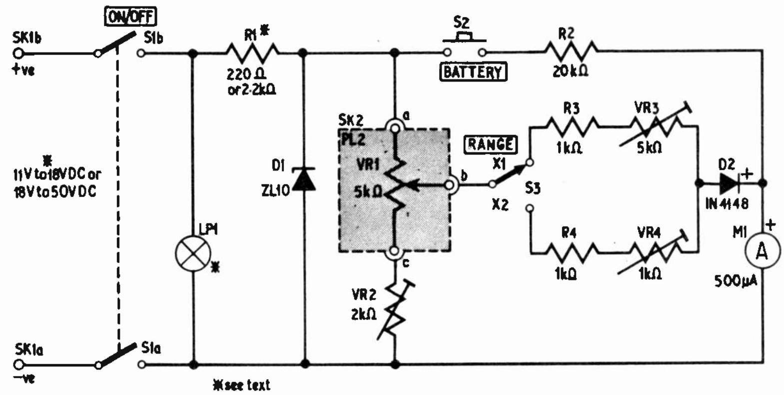
CIRCUIT OPERATION

The input voltage is stabilised by R1 and Zener diode D1 so that variations in battery voltage will not affect the circuit function unduly.

The resulting 10V is applied across VR1 and VR2 and the varying voltage at VR1 wiper is taken via range switch S3 to a voltmeter circuit. The volmeter circuit consists of the appropriate range resistors—R3 and VR3 or R4 and VR4—diode D2 and the 500μA f.s.d. moving coil meter M1. The diode is used as a low voltage Zener; its breakdown voltage in the forward bias condition is 0·6V. This means that up to 0·6V can be present across D2 without the meter indicating any current. Once the breakdown voltage is exceeded the diode resistance drops to a low value and the circuit acts essentially as a normal voltmeter.

Potentiometer VR2 is preset to give a reading of 0·01 milliamps on M1 with the wiper of VR1 turned towards VR2 end; this indicates that D2 is just beginning to conduct and as soon as VR1 is varied M1 will indicate the voltage present at its wiper.

Fig. 1. Circuit diagram of the boat speed indicator. Reference is made in the text to the supply voltage, R1 and LP1. The tinted panel indicates the potentiometer used in the transducer.



COMPONENTS . . .

Resistors
- R1 220Ω *or* 2·2kΩ (see text)
- R2 20kΩ
- R3 1kΩ
- R4 1kΩ
- All ¼W, ±10% carbon

Potentiometers
- VR1 5kΩ high quality sealed carbon lin (see text)
- VR2 2kΩ
- VR3 5kΩ } wirewound trimmers
- VR4 1kΩ

Diodes
- D1 ZL10 1·5W, 10V Zener
- D2 1N4148 silicon

Switches
- S1 D.P.D.T. toggle
- S2 S.P.S.T. pushbutton
- S3 S.P.D.T. toggle

Miscellaneous
- M1 500μA f.s.d. moving coil meter (S.E.W. edgewise type)
- SK1/PL1 Two pin DIN plug and socket
- SK2/PL2 Three pin DIN plug and socket
- LP1 Miniature indicator lamp and holder (voltage to suit supply)
- Veroboard 2⅝in × 3¾in × 0·15in matrix
- Diecast case 6¾in × 4¾in × 2¼in
- Connecting wire, transducer connection wire—3 core plastics covered mains lead; supply connection wire—2 core plastics covered mains lead.
- 6B.A. fixings
- Foam rubber, paint and Letraset

The action of D2 provides the required circuit response to variation of VR1.

Switch S2 and resistor R2 provide a circuit voltage checking position that will indicate, by way of M1, when the battery voltage is too low to operate the circuit. Resistor R1 will be either 220 ohms or 2·2 kilohms to accommodate supplies of 11V to 18V or 18V to 50V d.c. respectively; LP1 will, of course, have to be the correct voltage for the supply.

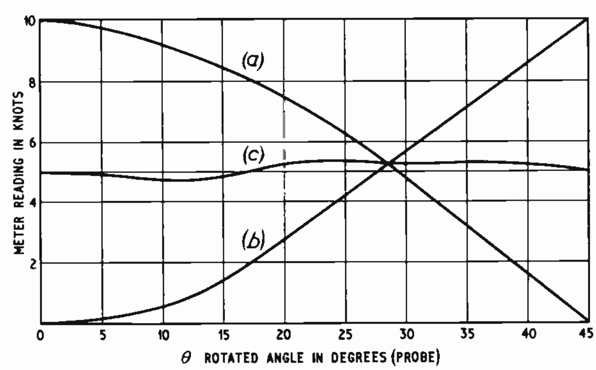
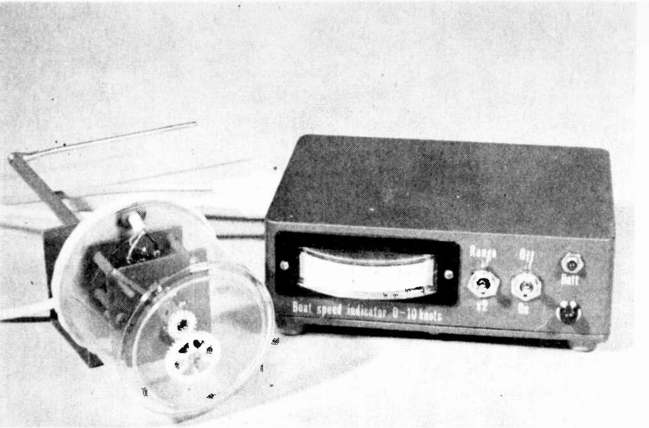


Fig. 2. Graph of probe rotation against meter reading (b) subtracted from the Cos²θ graph (a) to give the resultant curve (c). For an accurate instrument curve (c) should be a straight line



TRANSDUCER CONSTRUCTION

The transducer must be constructed of materials that will not be affected by water; in the prototype brass was used throughout. The shaft is a model boat propeller shaft and the gears are nylon, 2 to 1 ratio, also supplied for model making. The torsion spring can be any $\frac{1}{2}$in diameter coil spring that is of fairly light construction. Particular attention should be paid to accuracy since any unnecessary friction or play in the unit will result in inaccurate and erratic readings when in use.

The gears should be arranged to mesh closely and there should be as little play in the potentiometer bearings as possible; because of this a metal encased potentiometer may prove best in this application—this can be sealed with epoxy resin or paint if necessary. Before using the transducer all surfaces should be protected with paint or varnish, the shaft and potentiometer bearing packed with grease and the container sealed with a rubber ring.

Details of the transducer are given in Fig. 3. Three $\frac{1}{8}$in diameter brass rods are used to position the two plates; one of these rods forms a locating pin to ensure correct orientation of the probe with respect to boat axis.

The other two pins form rotation limiters for the arm connected to VR1 and a spring anchoring point. The locating pin slides into a hole in the mounting bracket (shown in Fig. 3), that is fixed to the transom of the boat. The complete transducer can be lifted clear of the water, for breaching purposes or mooring, without completely removing the unit.

TRANSDUCER ASSEMBLY

Assembly of the transducer may prove slightly tricky, but is fairly easy once the correct sequency is known. When all parts have been made to the details shown in Fig. 3 the three rods can be soldered or brazed to the lower plate—the one with no potentiometer mounting hole. The locating pin should be affixed so that its top end is about $\frac{1}{16}$in above the position of the upper plate—determined by the depth of VR1. The remaining two pins are mounted so that their lower end is flush with the underside of the lower plate.

Next, VR1 should be mounted on the upper plate approximately in the centre of the slightly elongated hole. It is not necessary to tighten the fixing fully at this stage since the horizontal position of VR1 will have to be adjusted. Fit the spacers over the pins and place the two plates together, holding them with the two screws and two further spacers; the case lid should not be included under the screw heads at this stage.

The next operation is to mount the small gear on the potentiometer using the spindle coupler. The shaft can then be inserted through the two plates and the larger gear attached by tapping the brass bush 4B.A. and screwing it to the spindle.

SHAFT ALIGNMENT

The vertical position of the shaft can now be adjusted so that the two gears align—a small washer should be inserted under the large gear—the shaft is then soldered or brazed to the lower plate. The two screws can be removed and the case lid slid over the shaft and locating pin and the whole thing screwed together. The rotation limit arm is inserted so that with the arm touching the anti-clockwise limit pin, VR1 is turned so that it is a few degrees off its fully anti-clockwise position. VR1 can now be adjusted so that the two gears mesh correctly and its fixing tightened fully.

The torsion spring can now be fixed, the spindle revolved so that slight torsion is applied and, with the mounting bracket in place, the probe bolted in position. A washer should be included between the shaft and the probe and the probe fixed so that there is no vertical play on the spindle. The probe is made by hammering flat one end of a $\frac{3}{16}$in diameter brass rod, shaping and drilling the flattened end.

INDICATOR CONSTRUCTION

The four resistors, the two diodes, D1, D2 and VR2, VR3 and VR4, are mounted on a small piece of Veroboard, as shown in Fig. 4. Veroboard is used as it provides good support to the components and is not badly affected by water, as some tag panels are.

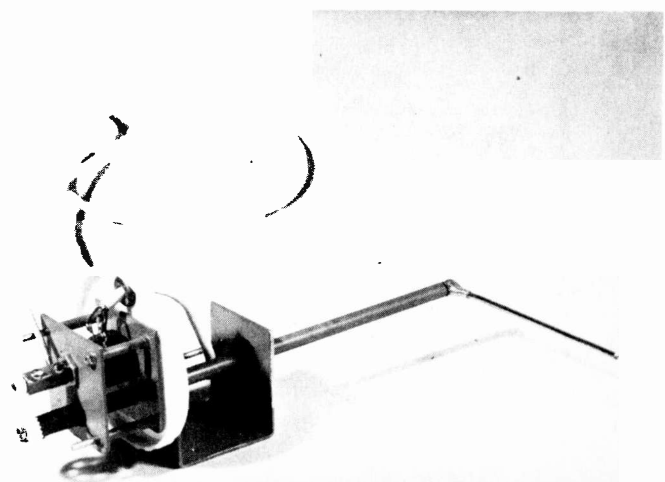
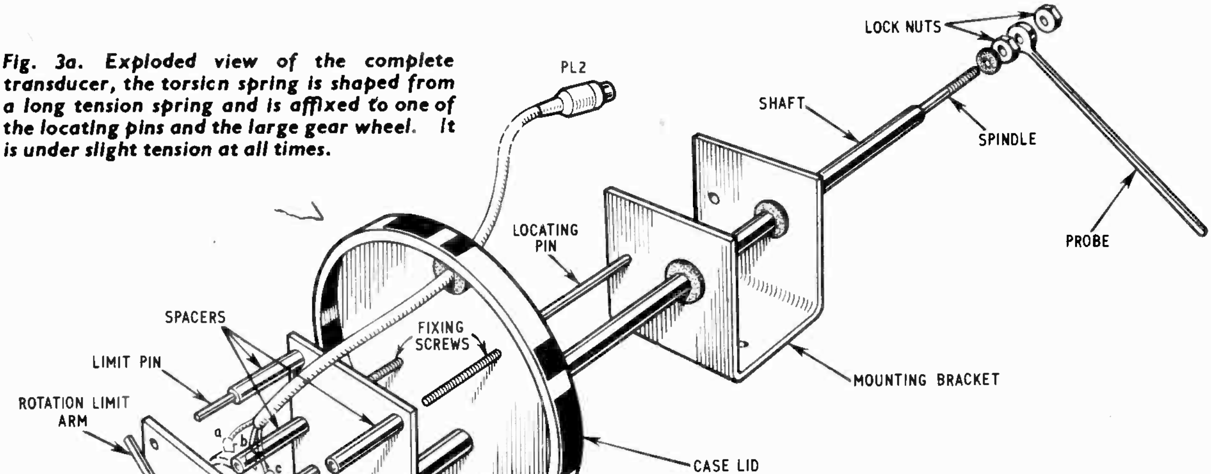


Fig. 3a. Exploded view of the complete transducer, the torsion spring is shaped from a long tension spring and is affixed to one of the locating pins and the large gear wheel. It is under slight tension at all times.



TRANSDUCER MATERIALS. . .

16 s.w.g. brass plate, 2in × 10in—for plates and bracket; $\frac{1}{8}$in diameter brass rod, 8in—for pins; $\frac{3}{16}$in diameter brass rod, 6in—for probe
Model boat propeller shaft and spindle—see text
Model makers' nylon gears 2 : 1 reduction with $\frac{1}{4}$in diameter brass bushes
Spindle coupler $\frac{3}{4}$in long, for $\frac{1}{4}$in diameter spindles
Spacers $1\frac{1}{4}$in × $\frac{1}{8}$in internal diameter, brass (4 off)
6B.A. screws $1\frac{1}{2}$in long (3 off) for fixing screws and rotation limit arm
Case, 3in internal diameter plastics container with flat screw top
Spring $\frac{1}{2}$in diameter tension spring of light construction at least $1\frac{1}{2}$in long.
Grommets (3 off)—2 to suit shaft and 1 for connection lead; 4BA and 6BA nuts and washers

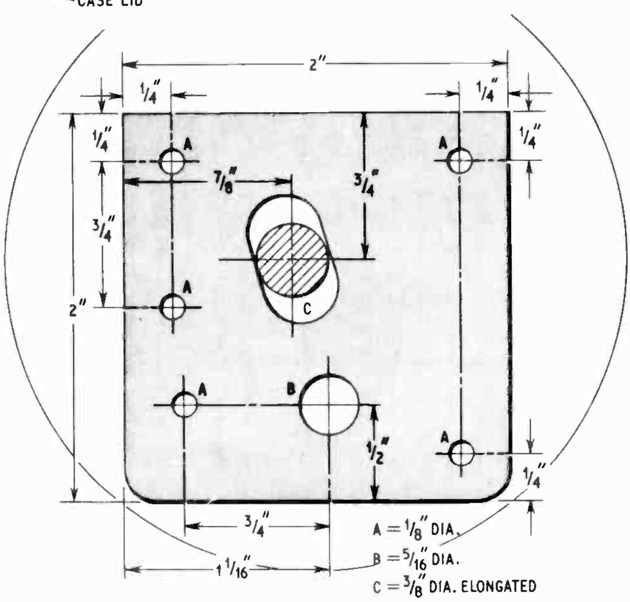


Fig. 3b. Drilling details of the transducer plates. The distance between the two plates is determined by the depth of the potentiometer body—thus rod and spacer length will vary. Two plates are required and these should be drilled while clamped together. The elongated hole is only drilled through one plate. The position of the plates when mounted inside the case is indicated

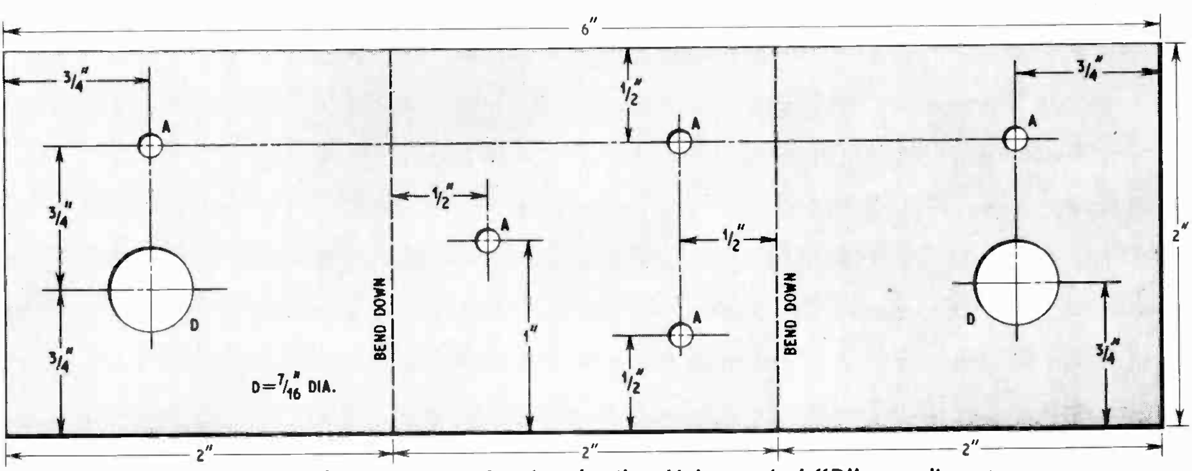
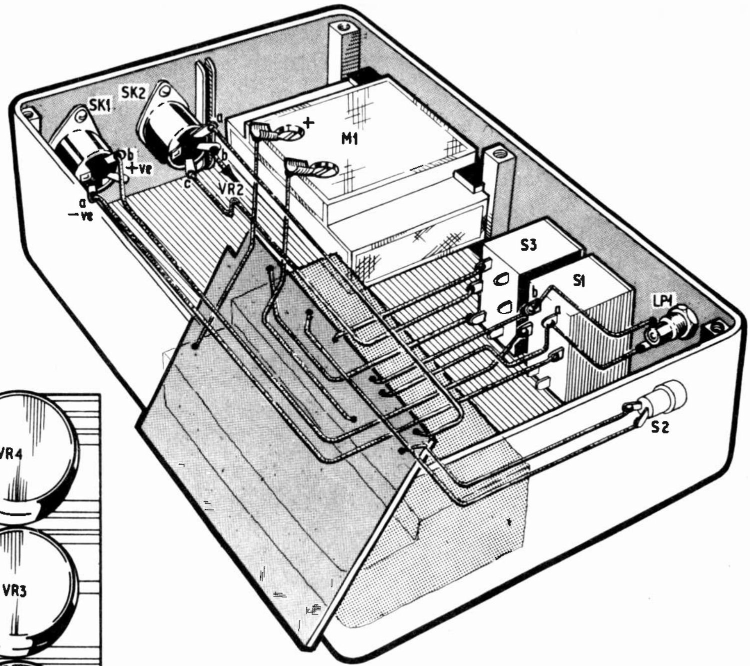
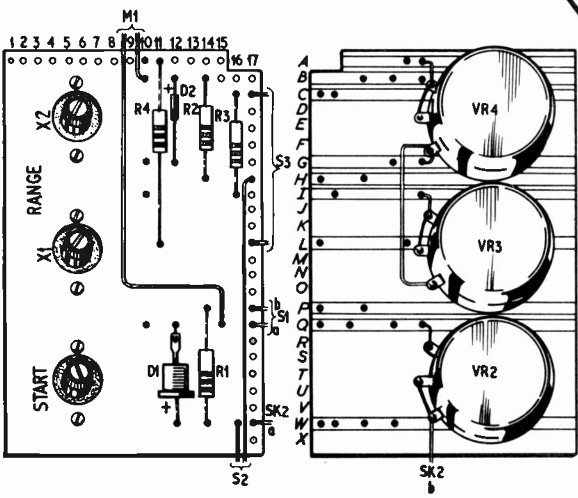


Fig. 3c. Transducer mounting bracket details. Holes marked "D" must line up when the bracket is bent, their size will depend on the shaft and grommet diameter

Fig. 4. Veroboard layout and wiring diagram. The potentiometers may be designated as shown on the board, for easy identification during setting up and calibration

Fig. 5. Layout and wiring diagram of all components mounted in the die-cast case. The lid to the case forms the base of the unit and the view shown is of the underside with the base plate removed





The remainder of the components are mounted directly to the die-cast case used to house the unit, see Fig. 5. This case should be carefully painted inside and out, after drilling, to prevent it being corroded by salt water; the base plate should be sealed with rubber strips. Sockets are provided for the leads to the transducer and the supply; these leads should be of good quality plastics insulated flex.

The meter is mounted on a rubber pad to provide some shock protection and prevent water from entering the case. The meter specified has no external apertures and the mechanical zero is adjusted through a hole in the top of the case which is plugged with a small piece of rubber when not in use. The Veroboard is mounted by sandwiching it between two pieces of foam rubber.

Layout and wiring of all components mounted in the indicator case is shown in Fig. 6. Internal batteries may be used if a larger housing is provided; in this case LP1 should be omitted to conserve the battery.

INSTALLATION

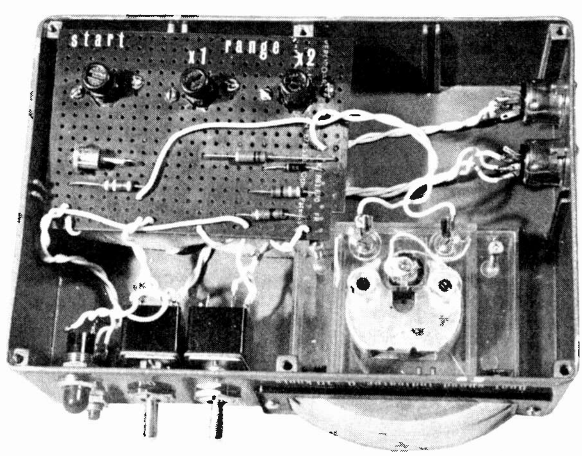
The mounting bracket is fitted to the transom of the boat so that the lowest part of the bracket is about 1in above the highest possible water line. The bracket should be fitted well away from propellers on power craft or any obstruction that could interfere with the water flow.

The length of the shaft used will depend on the type and speed of the boat. The prototype, which was intended for a sailing dinghy, used a 9in shaft, but power yachts may require a greater length to keep the probe below and the unit above, the water level at all speeds (the transducer body should also be clear of the water when going astern).

The indicator unit can be fitted in a convenient position and a good quality piece of 3 core mains lead made the correct length and wired to PL2. The transducer could be fitted through the bottom of larger craft but a special adaptor will have to be manufactured for this.

CALIBRATION

The first step in calibration of the unit is to mark the correct supply level on M1. To do this a d.c. voltmeter is used to measure the voltage across D1; this voltage should be 10V—providing the battery is in good condition and D1 is functioning. Once this has been checked S2 can be depressed and the reading of M1 noted and marked on the scale or meter face; VR1 should be in circuit at its stationary position for this operation.



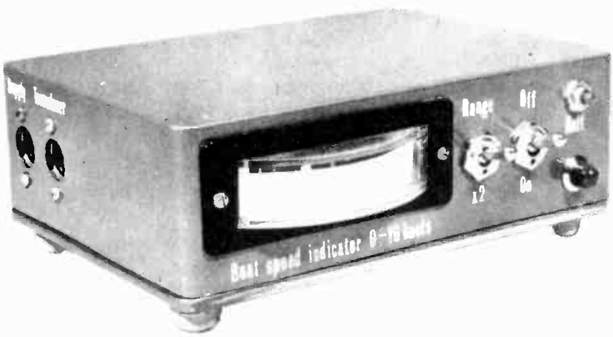
Switch S3 can then be set to the first range (× 1) and VR2 adjusted so that the meter shows a reading of $10\mu A$. Once this is done the meter can be zeroed when the circuit is energised, using the mechanical zero adjustment.

The maximum possible speed of the boat should be estimated and this speed marked at the full scale deflection point on M1. The scale should then be divided equally to indicate the intermediate speeds. With the probe rotated through 45 degrees, VR3 should be set to indicate full scale deflection on M1.

INITIAL SETTING

Initial setting of VR3 can be made without installing the unit. Once this is completed the unit should be installed for further calibration in the boat in which it is to be used, in the correct position with the transducer lead of the required length.

Initial calibration is by means of variation of probe length and diameter (prototype used a 4in shaft of $\frac{3}{16}$in diameter brass) and torsion spring. Probe diameter may easily be increased by sliding a length of plastics flex insulation over it. Fine calibration may be effected by adjustment of VR3. The unit should be calibrated as near the maximum speed as possible, since this is the point at which the circuit is most accurate (refer to Fig. 2).

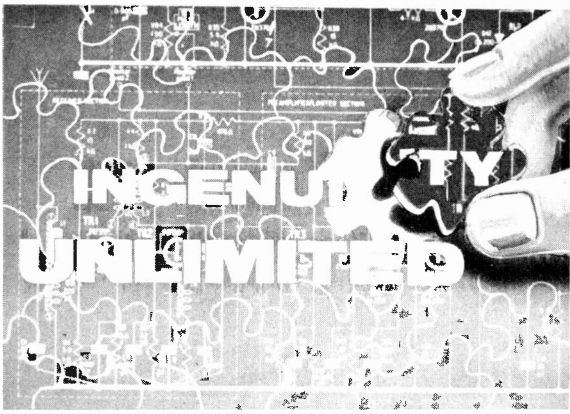


There are two ways of speed calibrating the unit: by comparison with another speed indicator or by timing the boat over a measured distance. If the second method is used the measured distance should be as large as practicable and the boat speed held constant by means of the indicator, any error can then be adjusted after a second run in the opposite direction.

To calibrate the times 2 range it is only necessary to hold the probe in such a position that half full scale deflection is indicated with S3 in the ×1 position; then switch S3 to ×2 (with the probe in the same position) and adjust VR4 to give full scale deflection on M1. When this has been done the probe fixing can be soldered over, to protect it and prevent it becoming corroded, and finally painted.

Designations may then be added to the unit as required, using Letraset, and given a coat of clear varnish to protect them. The unit is then ready for use.

If it is found that the meter is too sensitive to slight variations in speed or that the needle tends to flicker in use, the movement can be damped by placing a 2,000μF 15V electrolytic capacitor directly across the meter terminals—observing polarity. ★



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.

DIGITAL DICE

PERHAPS your readers would be interested in the following circuit for an Electronic Dice.

The circuit is basically three binary stages with feed-back to give a count of six, being driven at high frequency by a free running multivibrator. When the count is stopped by pressing the display button S1 the output of the six counter is fed via gates to light lamps LP1 to LP6, giving a display in the familiar dice combinations, i.e. with the centre lamp only lit for a "one", the six outer lamps for a "six", etc. The dice requires only four decoding circuits; the first of these decides "even or odd"—if the count is odd only the centre lamp lights. The next gate decides "not one" which lights two diagonally opposite lamps (except during a one). A third gating circuit decides four, five or six and lights the two remaining diagonally opposite bulbs on these counts. The final gate decides "six" and lights the two remaining bulbs on this count. A little thought will show that these combinations will automatically light the proper number of bulbs in the correct pattern for each dice position. The block schematic diagram of the dice is shown in Fig. 1; Figs. 2, 3, 4 and 5 show the sections of circuitry, Fig. 2 being the driving multivibrator; Fig. 3 is the divide by 6 counter; Fig. 4 shows the five gates that together form the three gateing circuits and Fig. 5 shows the lamp driver circuits.

The display panel is made up of a square of holes drilled in the positions shown in Fig. 6. A piece of coloured translucent perspex is fitted over a blanking panel, so that only the illuminated lamps can be seen as spots of light on the perspex.

If required, the dice may be built up as a double unit in which case the divider board, gates and lamp display should be duplicated and the second divider board input driven from point "D" on the first divider board; this ensures independent displays on the two dice.

The circuit may be powered either by a nine volt dry battery or by a d.c. nine volt, one amp, mains power supply. The mains power supply is preferable due to the current drain of the lamp display.

J. D. CROFT,
Warrington, Lancashire.

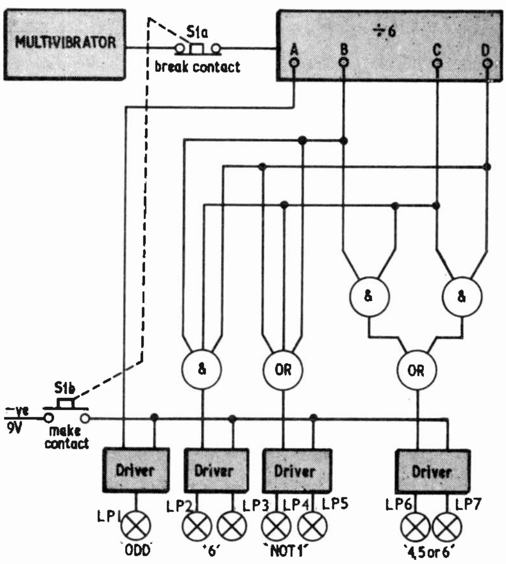


Fig. 1. Block diagram of the electronic dice

Count	Output from ÷ counter				Binary
	A	B	C	D	
1	NEG	POS	POS	POS	0 0 0
2	POS	NEG	POS	POS	0 0 1
3	NEG	POS	NEG	POS	0 1 0
4	POS	NEG	NEG	POS	0 1 1
5	NEG	POS	NEG	NEG	1 1 0
6	POS	NEG	NEG	NEG	1 1 1

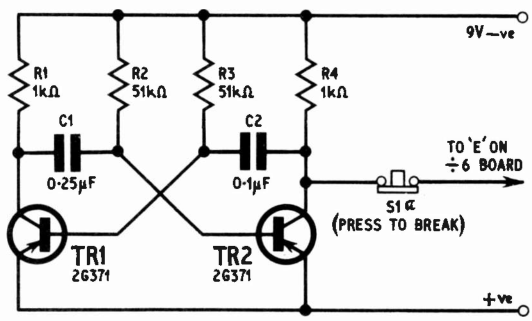


Fig. 2. Multivibrator driver for the dice

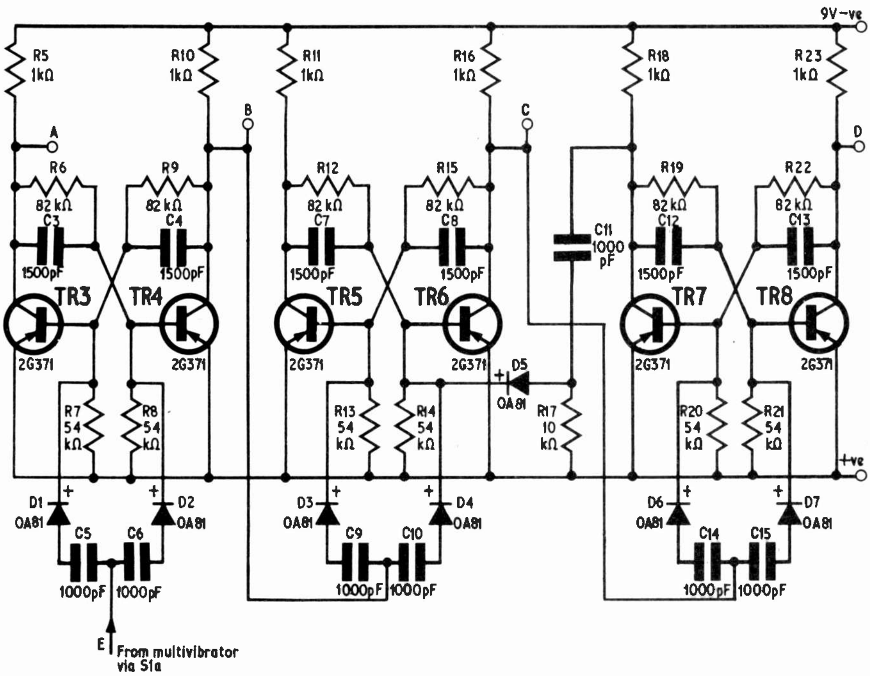


Fig. 3. The divide by six counter

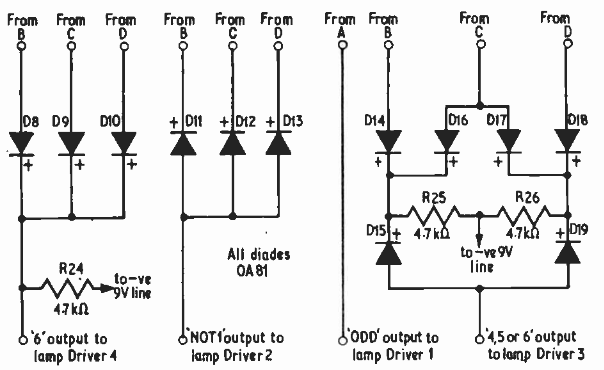


Fig. 4. Gate circuits used in the dice

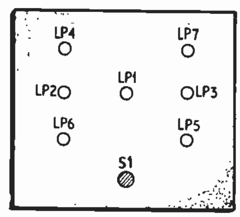


Fig. 6. Lamp and switch positions

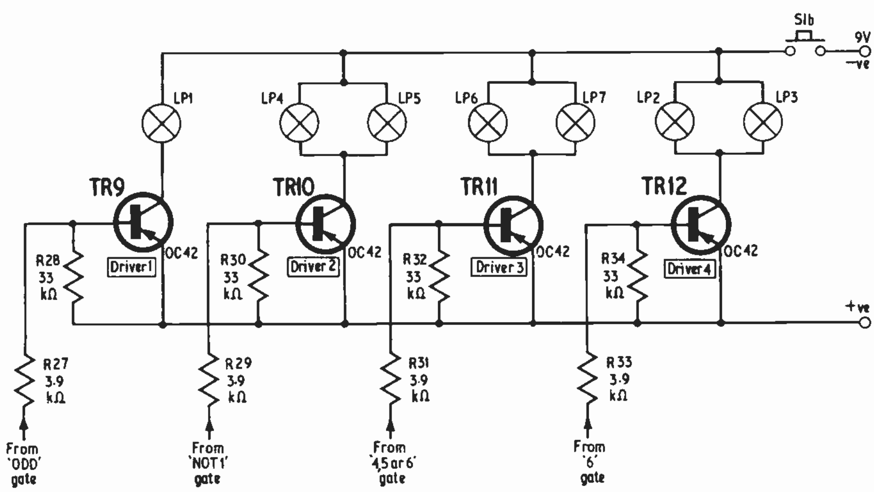


Fig. 5. Lamp driver circuits; all lamps 6·3V 0·04A

It is often required to obtain a staircase waveform output from 1, 2, 4, 8 counter or logic outputs. The methods usually used are combinations of integrators and diode pumps of various descriptions. The circuit used here, however, is purely digital and the minimum of design application and components are required. The components used may be four transistors, used as single input gates, four Zener diodes and a load resistor. All of the components could probably be incorporated economically on a single i.c.

For operation of this circuit, I will refer to the circuit diagram (Fig. 1) where the resistors R1, R2, R3, and R4 ensure that the transistors TR1, TR2, TR3 and TR4 are saturated when the inputs 1, 2, 4, and 8 are at logic "1", (which must be 10V or more in this circuit).

In "0" output condition the transistors TR1, TR2 and TR3 and TR4 will all be saturated and the output will be at a level of $V_{ce(sat)} \times 4$ above zero volts or ground, this gives a level of approximately 1·2V. Now assume input 1 is taken to zero volts or ground, TR1 will thus switch off; the voltage across which will rise until D1 Zener diode break-down level is reached. This break-down voltage level is selected to be 1 volt plus the $V_{ce(sat)}$ of TR1, this will give a step of 1 volt at the output. The voltage $1 \times V_{ce(sat)}$ is added to each Zener voltage to maintain linear 1 volt steps at the output, as without taking this into account the voltage output will vary depending on the number of transistors saturated or not.

Assume the inputs to be obtained from a binary counter then input 2 will become zero and input 1 will go to a positive voltage. Thus TR1 will saturate shorting out Zener diode D1, but TR2 is now switched off—the voltage across which rises to the Zener break-down voltage of D2. This has been selected as 2 volts plus $V_{ce(sat)}$ of TR2 which gives an output level of 2 volts above the zero level of $V_{ce(sat)} \times 4$.

This is continued for inputs 1 and 2 where both TR1 and TR2 are switched off which allows the output to rise by 3 volts i.e., D1 plus D2, and like-wise all the way along the chain of a 1, 2, 4, 8 counter or other input.

The output will start at $V_{ce(sat)} \times 4$ (which is zero) and ascend in one volt steps until the output voltage reaches ten volts, our count of ten plus $V_{ce(sat)} \times 4$, this gives a total of 11·2 volts, and it goes without saying the steps may ascend in level by reversing the logic input levels.

The beauty of this circuit is that it is entirely independent of frequency and voltage levels, providing V_{CC} does not fall to below the sum of the total Zener voltage levels, i.e. V_{CC} may be 100 volts (if the components will take it) and the output levels obtained will not vary considerably from those when V_{CC} was at 12 volts. So it can be seen that the only design consideration is one of upper operating frequency which is dependent upon the components used and not so much the circuit; by selecting the appropriate Zener voltage levels this circuit may be used on various coded outputs quite easily.

D. W. Lloyd,
Stotfold, Herts.

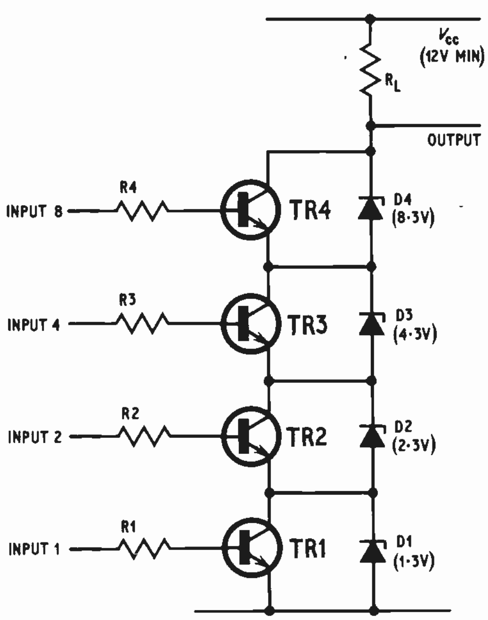


Fig. 1.

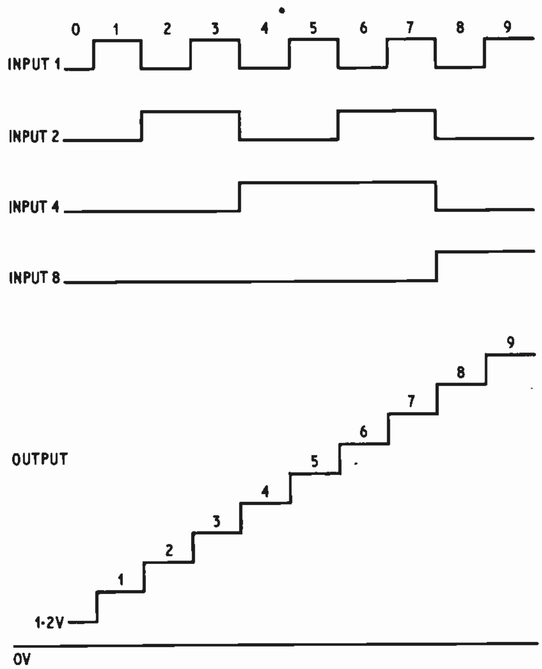


Fig. 2.

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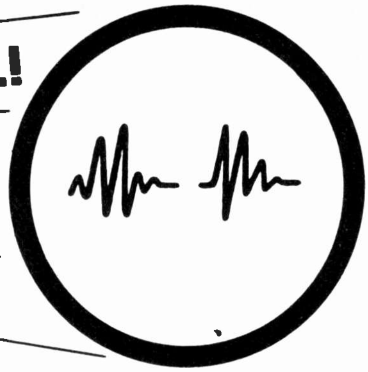

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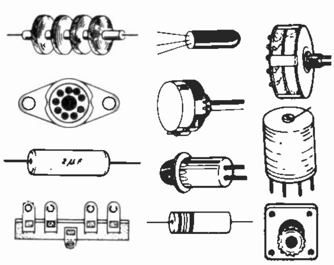

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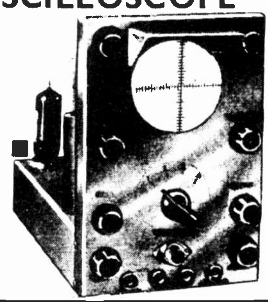

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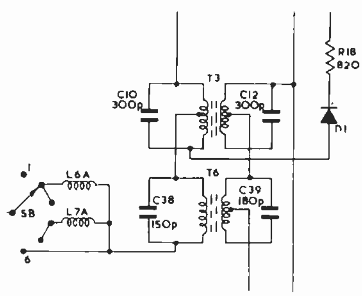

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MARKET PLACE

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.

LOUDSPEAKERS AND ENCLOSURES

An increasing number of cost conscious hi fi enthusiasts are home constructing loudspeaker systems from the expanding range of multi-unit kits and individual loudspeakers now available.

One of these multi-unit kits is the Peerless 20-3 from **P. F. & A. R. Helme.** This is a 3-way system consisting a low frequency "woofer" loudspeaker with rubber roll surround, a mid-range speaker, a "tweeter" high frequency speaker and a printed circuit board crossover unit.

Recommended for amplifiers of 10 to 40 watts, the maximum power input of the system is 40 watts. The frequency range is claimed to be 40 to 20,000Hz and the crossover frequencies are 1,500 and 6,000Hz. All speakers have voice coils wound on an aluminium coil former and have standard impedances of 4, 8 or 16 ohms.

The Peerless 20-3 kit costs approximately £18·87 and full details will be supplied by A. F. & A. R. Helme, Summerbridge, Harrogate, Yorkshire, HG3 4DR.

For those readers who do not feel sufficiently proficient to make their own enclosures, **Messrs. Omar Skinner & Sons** produce ready built enclosures to makers' specifications for the more popular systems.

The enclosures are soundly constructed and available in a variety of finishes. The baffle boards are cut to order and they claim they can supply an enclosure for every need.

Our photograph shows the Omar Skinner enclosure for the four loudspeaker **EMI** 750 kit. The 750 kit consists of a bass, mid-range and two treble speakers, which together are capable of handling 20 watts and cover the frequency range of approximately 30-20,000Hz. A crossover unit with a choice of switching frequencies, wiring harness and full instructions is included and the complete EMI 750 kit costs £27·50.

Details of enclosures may be obtained from Messrs. Omar Skinner & Sons, Warfield Park Workshops, Warfield Park, Bracknell, Berkshire, and enquiries for information on EMI loudspeaker kits and enclosures should be addressed to EMI Sound Products Ltd., Blythe Road, Hayes, Middx.

TOOL KITS

During the last few years manufacturers have been gradually gearing themselves to continental specifications and component practices when designing equipment. The result of this gradual changeover has meant that numerous pieces of equipment have contained both U.K. and continental components, i.e. Phillips, Allen, and standard screws.

One of the problems encountered by this situation is the lack of necessary tools when carrying out service repair work. **Special Products Distributors** seem to have recognised this problem and are now introducing the well-known Xcelite tools from America to the British market.

The first tools to be marketed are a 19-piece screwdriver kit, 14-piece socket set and a 5-piece screwdriver kit.

The XL-70 19-piece kit contains a selection of Allen keys, slotted and Phillips screwdrivers, reversible ratchet and extension handle. The ratchet can be attached to the extension handle for added torque if required. This kit is particularly useful for television service engineers.

The 1001 14-piece socket set includes sockets from $\frac{3}{16}$in. to $\frac{1}{2}$in., 2in. extension, reversible ratchet and extension handle.

Included amongst the sockets are two 10-point sockets, $\frac{1}{4}$in. and $\frac{5}{16}$in., which are dual purpose to fit both square and hexagonal nuts. The reversible ratchet in this kit is fully enclosed to keep out dirt and grit.

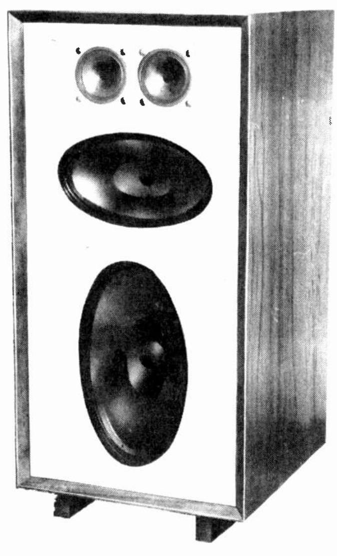
The XL75 5-piece kit is contained in a plastics wallet and is a small set of slotted and Phillips screwdrivers with an offset ratchet handle, again extremely useful for working in awkward and confined spaces.

The XL70 screwdriver kit costs £6·25, the 1001 socket set costs £7·18 and the XL75 costs £2·10.

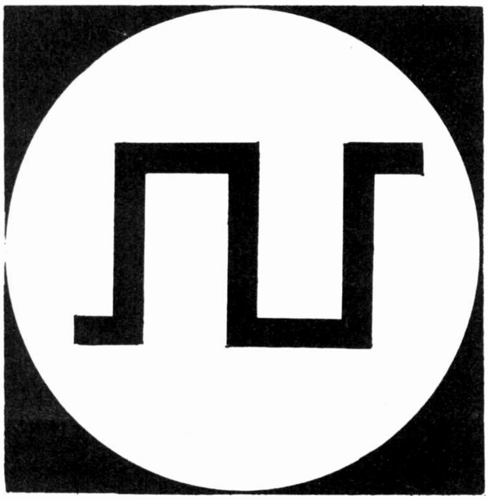
Both the XL70 and the 1001 kits are housed in moulded high impact plastics cases. Full particulars of these tools are available from Special Products Distributors Ltd., 81 Piccadilly, London, W1V 0HL.

Peerless 20-3 kit from P. F. & A. R. Helme

EMI 750 kit housed in an Omar Skinner enclosure



The 1001, XL75 and XL70 kits marketed by Special Products Distributors



DOORBELL YODELLER

K. J. Turvey, B.Sc.(Eng.)

THIS article describes the construction of a completely electronic door bell which is simple, cheap, and does not require accurate adjustment. The rhythm and melody are continually changing so that each time the bell push is depressed a different sound is produced.

CIRCUIT BLOCKS

In the block diagram of the unit shown in Fig. 1, the 250Hz multivibrator produces the basic note. The base resistors controlling the frequency are divided into two so that the two low frequency (1Hz) multivibrator circuits can short circuit the upper resistors. A total of four notes is thus obtained using only three switching circuits.

Since the multivibrator circuits run asynchronously the rhythm will be continually changing which means that a different tune will be obtained each time the bell push S1 is depressed.

The output from the 250Hz multivibrator is fed via an AND gate to amplifier A2 to drive the loudspeaker LS1. The signal is allowed through the gate when the monostable is pulsed, the duration of which may be adjusted between 0·5 and 12 seconds.

A buffer amplifier, A1, precedes the monostable stage and provides the triggering action when the bell push is used.

DETAILED OPERATION

Transistors TR3 and TR4 in Fig. 2 form the main astable circuit which provides low frequency calculated by $1/0{\cdot}7[C_3(R_6+R_7)+C_4(R_8+R_9)]$Hz.

In order that diodes D1 and D2 effectively short circuit R6 and R8, R7 must be greater than R6 and R9 must be greater than R8.

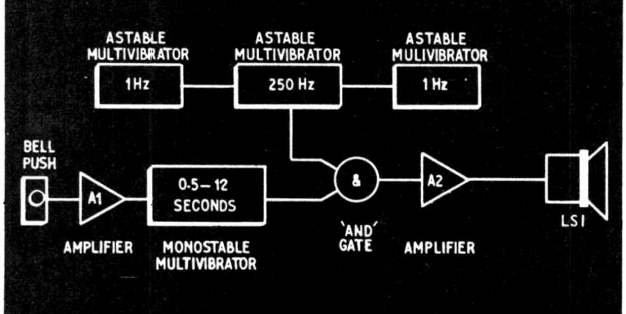


Fig. 1. Block diagram of Doorbell Yodeller

TR5 and TR6 form another astable circuit working at a very low frequency of about 1Hz. With R12=R13 and C5=C6 the frequency is given by $1/1{\cdot}4\ C_5R_{12}$Hz.

When TR5 is hard on, the collector is almost zero volts and diode D2 is back biased since the junction of R8 and R9 is always positive. When TR5 is cut off the collector is +6V and D2 is forward biased which effectively short circuits R8 and consequently changes the operating frequency of the 250Hz astable.

The action of TR1/TR2 astable circuit is identical to this but is applied to D1.

GATING THE OUTPUT

The output is taken from TR3 collector and gated at the input of the amplifier A2 by diode D3. With the bell switch not made TR11 in the monostable circuit will be normally hard on and thus the collector will be nearly at zero volts. Here the diode D4 is forward biased and the junction of R28 and R29 will be held at zero volts irrespective of the input to D3.

TR9 is held on by the positive voltage appearing at the junction of R19 and the lamp. When the bell push is depressed the base of TR9 is brought to nearly zero volts so that it switches off.

With TR9 cut off, the collector will change from zero volts to +6V. This positive going voltage turns TR10 on via C10 and R23 thus triggering the monostable action of TR10 and TR11. TR11 is turned off and the collector changes to +6V which reverse biases diode D4, so allowing D3 to pass the output of TR3 to the amplifier A2.

Irrespective of whether the bell push is maintained depressed or not the monostable action will end after a time given by 0·7×C11×(VR1+R25). In this period a short burst of notes will be obtained. With VR1 set to zero the duration will be approximately 0·5 seconds. Set to maximum resistance it will be about 12 seconds.

R21 is included to reduce the voltage to the astable and monostable circuits so that 6V working capacitors can be used. C9 decouples the astable circuits.

POWER SUPPLY

The circuit diagram of the power supply is shown in Fig. 3. Here the total current required will depend, in the main, on the rating of LP1.

If a Friedland bell push is used the lamp voltage will probably be 8–15 volts. Thus a 12 volt transformer would be suitable.

The prototype was powered from a 12-0-12 volt transformer and using a Friedland Type 'A' lamp the following measurements were made.

Normal current	150 mA
Bell operating	500 mA
Bell push held depressed	1·2 amps

Components . . .

Resistors

R1	1kΩ	R11	1kΩ	R21	220Ω ½W
R2	22kΩ	R12	22kΩ	R22	1kΩ
R3	22kΩ	R13	22kΩ	R23	100kΩ
R4	1kΩ	R14	1kΩ	R24	1·8kΩ
R5	3·3kΩ	R15	6·8kΩ	R25	2·2kΩ
R6	22kΩ	R16	150Ω	R26	22kΩ
R7	33kΩ	R17	10Ω 2W	R27	1·8kΩ
R8	27kΩ	R18	15Ω 2W	R28	1kΩ
R9	33kΩ	R19	15Ω 10W	R29	1kΩ
R10	3·3kΩ	R20	5·6kΩ		

All 10%, ¼W carbon except where stated

Potentiometers

VR1 47kΩ Vertical preset
VR2 25Ω Preset

Transformer

T1 12V 2A centre tapped (Douglas MT71)

Capacitors

C1	32μF elect. 6V	C7	250μF elect. 15V
C2	32μF elect. 6V	C8	250μF elect. 15V
C3	0·01μF	C9	250μF elect. 6V
C4	0·01μF	C10	0·1μF
C5	32μF elect. 6V	C11	250μF 6V
C6	32μF elect. 6V	C12	5,000μF elect. 15V

Transistors

TR1–TR7 BC108 (7 off)
TR8, OC28
TR9–TR11 BC108 (3 off)

Diodes

D1–D4 OA90 (4 off) D5–D8 RS50AF (4 off)

Miscellaneous

S1 (see text), LS1 3–15 ohms loudspeaker,
Veroboard 0·1in matrix 4½in × 6in and 2½in × 5in.

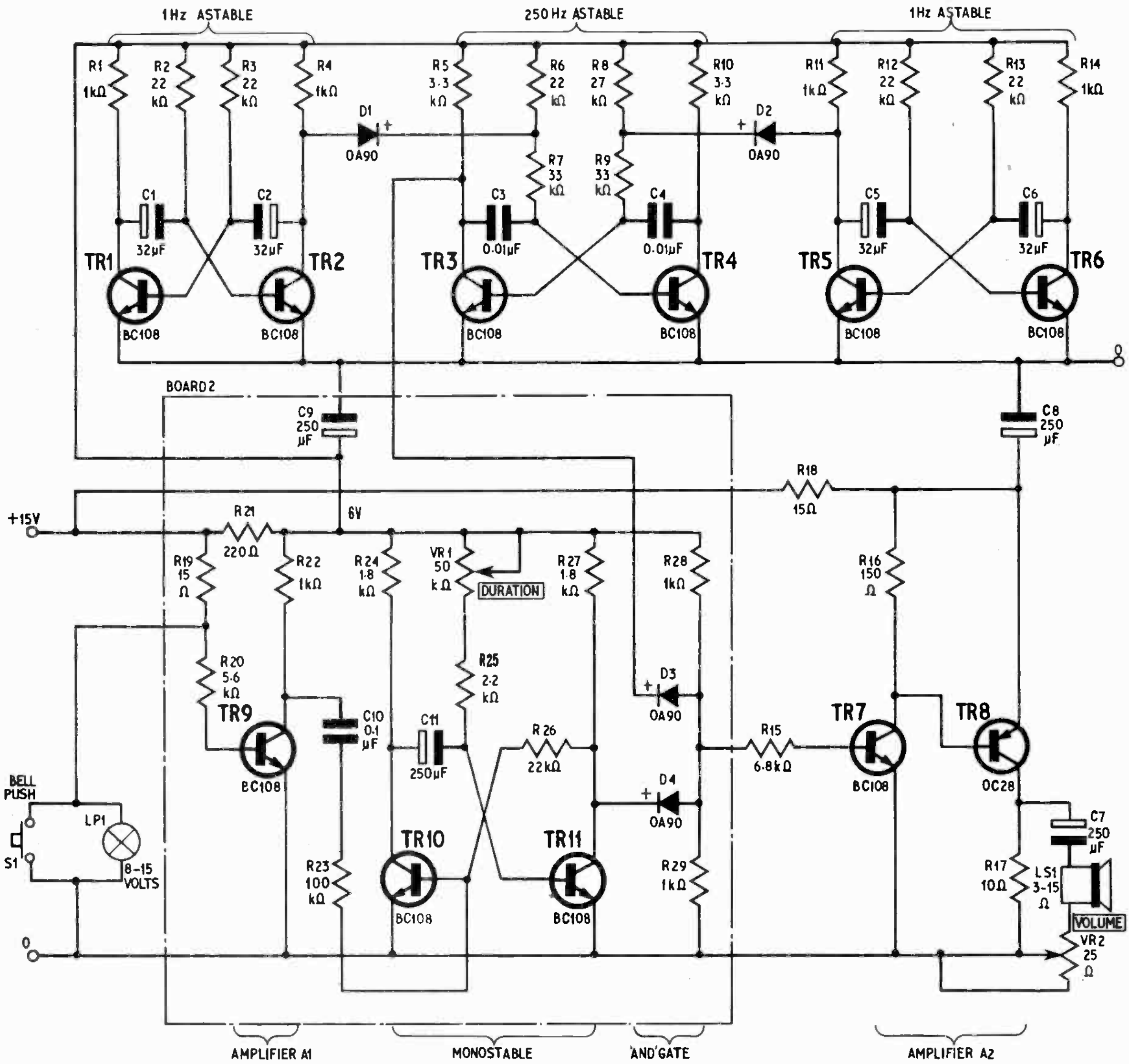
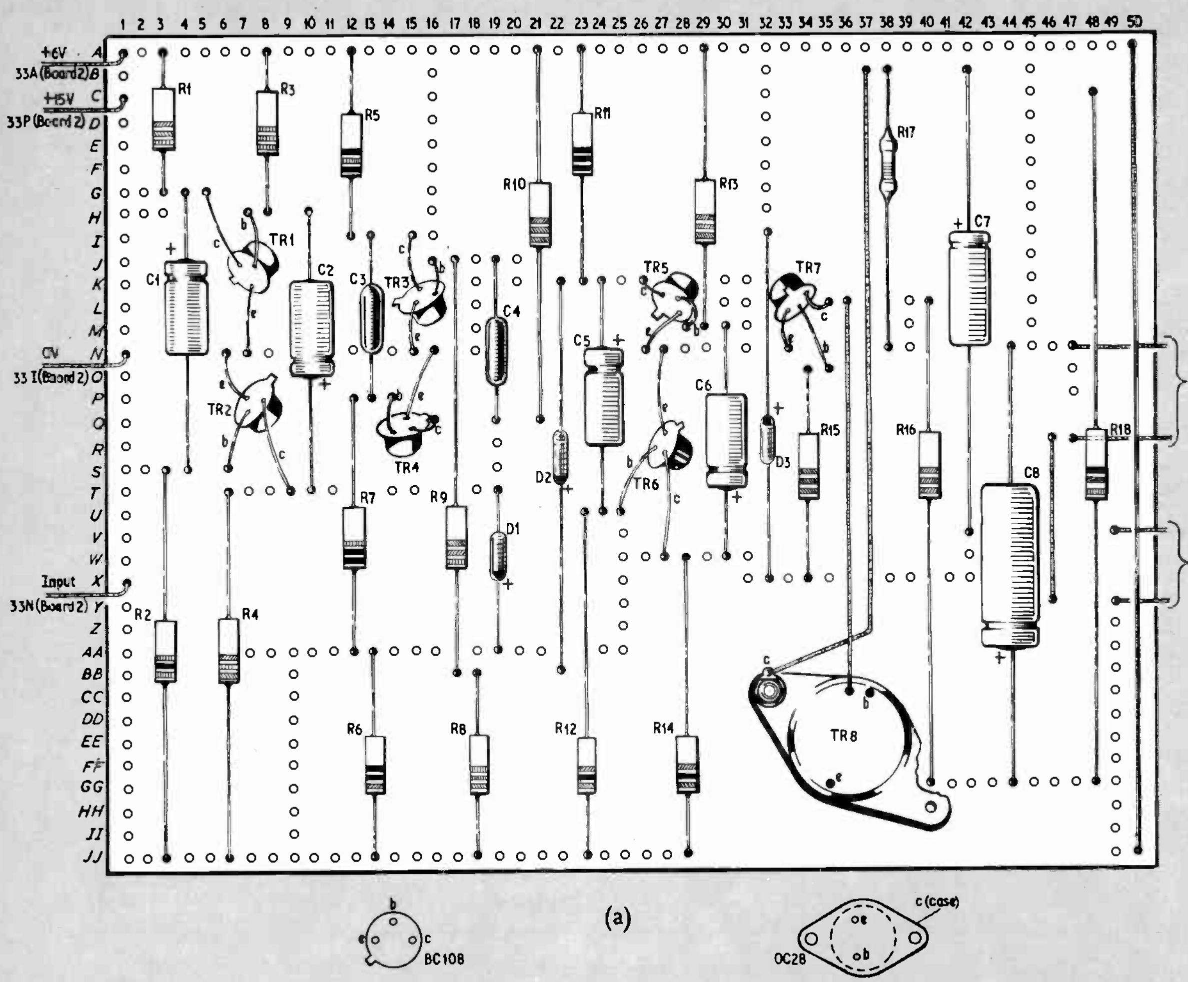
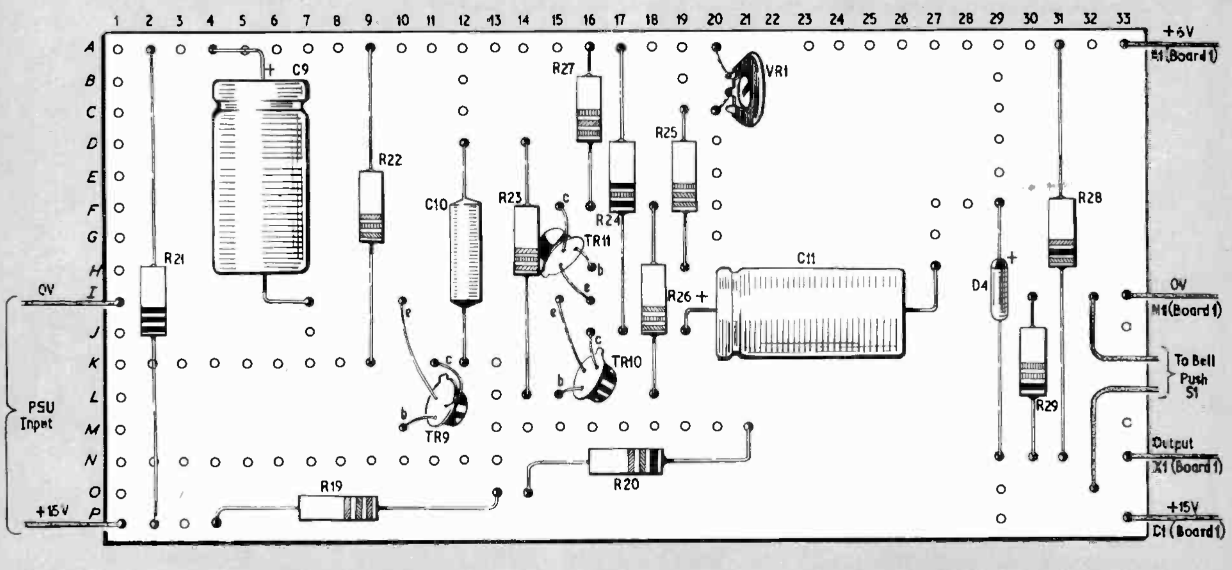


Fig. 2. Circuit diagram of Doorbell Yodeller



(a)

Fig. 4. Component assembly of (a) the astable and amplifier circuit; (b) the monostable and switching amplifier. Assembly may be combined on a single Veroboard



(b)

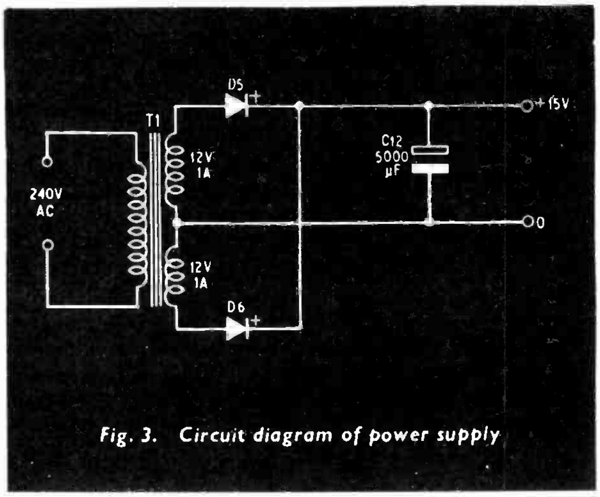


Fig. 3. Circuit diagram of power supply

CONSTRUCTION

In the prototype the astable and amplifier circuits were built on a piece of 6in by 4½in Veroboard as given in Fig. 4. Here there is ample room for the components and no breaks in the copper strip are required.

A 2½in by 5in Veroboard is used for assembling the monostable circuit and switching transistor TR9. The reason for this separate board construction is because the monostable is dispensable since it only provides an interval of tones, the period of which can be set by VR1.

Since there is nothing critical in the layout, single board construction for the complete circuit, including power supply, can be made.

CHECK OUT

If the completed unit fails to function with the supply applied, the following check out procedure should be undertaken.

First disconnect D4 to isolate the monostable. If a tone is not apparent, connect a headset via crocodile clips between TR3 collector and emitter. No sound points to either TR3 or TR4 being defunct.

If the stage is alright, apply the 'phones to TR7 and TR8 collectors, in that order, to determine the offending transistor.

To check the operation of the low frequency astables, a voltmeter should be connected to the collectors. This method can be used to establish the switching action at TR9 collector, the swing here being between 0 and 6V when the bell push is depressed.

Once the circuit is functioning correctly R6 can be replaced by a preset potentiometer if any time adjustment is required.

VARIATIONS

As already mentioned the monostable section could be omitted. Simply omit TR10, TR11 and their associated components. Also omit C10 and R23 and connect the collector of TR9 directly to D4.

If an illuminated bell push is not used connect a 100 ohm resistor across the bell push contacts. This can be done on the component board.

If the monostable action is not required and a non-illuminated bell push is used, connect TR3 collector directly to R15, the base resistor of TR7. The bell push may then be used to connect the dc supply to the circuit. A 6 volt transformer could be used in this case.

A wooden box, or metal case, can be used for housing the completed circuitry, here the only external control item will be the potentiometer VR2. ★

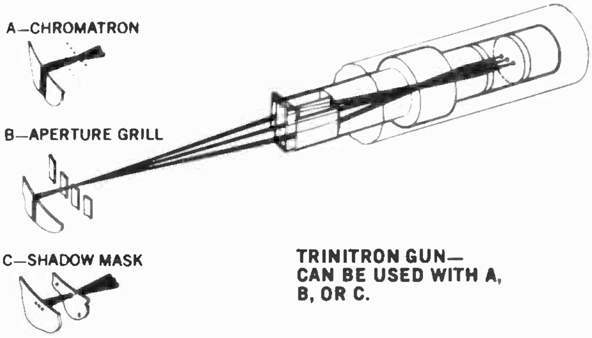
NEWS BRIEFS

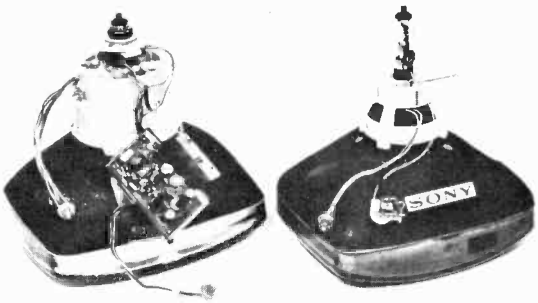
Trinitron T.V.

A NEW colour television tube—called the Trinitron has been announced by Sony Ltd. The tube uses only one electron gun that projects three electron beams; the beams are converged and focused through two large diameter electron "lenses" and a pair of deflectors. Because a large diameter single "lens" can be used to focus all three beams from the Trinitron gun, greater brightness and better focus are claimed to be achieved.

The tube (shown below next to a conventional tube) also utilises a new colour selection method named "Apeture Grill" which uses a vertical slotted grill and vertical lines of phosphers rather than the holes and dots of the normal shadowmask tube. The single gun can also be used with either a shadowmask tube, or a chromatron tube, as can be seen from the drawing below.

The new tube has been incorporated in a 13in screen colour television which, when recently demonstrated to the press, gave a good account of itself. The set will be on the market in this country in April '71 and will retail at just under £200. It will be interesting to see if Telefunken A.E.G. are prepared to allow Sony to market this set, if it infringes their patent on the P.A.L. colour system, without a legal fight. It is not yet possible to say if the set infringes P.A.L. patent since Sony will give no technical circuit data, it will also be interesting to see if Sony can make larger screen sets—even if, as they state, they do not wish to market them in this country.





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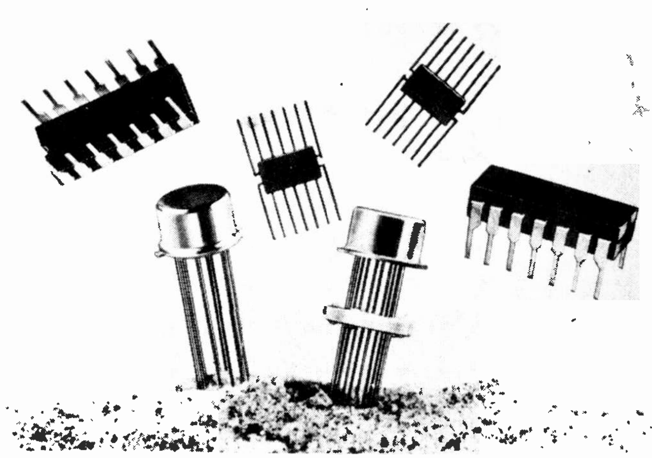

PART TEN—By R. W. COLES

METAL OXIDE SILICON LOGIC (MOS)

It was mentioned in an earlier article in this series, that a further two logic families have been elevated to positions which rank them alongside the three originally basic groups RTL, DTL, and TTL.

This article concerns itself with the first of these two comparative newcomers, Metal Oxide Silicon Logic, usually referred to simply as MOS.

MOS DEVICE CAPABILITY

MOS logic is a very different family from any of the others discussed, both in fabrication and application. Instead of conventional bipolar transistors, insulated gate field effect devices are employed, and in general no linear resistors or diodes are used at all.

MOS is used with negative supply voltages of up to 30V, with consequently large logic swings which render the mixing of this family with, say, TTL a complicated business usually requiring special "interface" circuitry.

Registers and gates in the MOS range will not run at the high speeds associated with TTL either, a limit of 1 MHz being common in the specification of a shift register package.

In the light of all these apparent disadvantages one may well ask why anyone should bother with these devices at all, and the answer to this is that MOS is very simple indeed to produce, an advantage which makes it possible to incorporate vast quantities of logic elements on a single chip, and still achieve an economic yield.

A bipolar device, whether it be a single transistor or an MSI counter, requires well over one hundred process steps in its manufacture from a silicon "chip". An MOS circuit on the other hand is produced in less than forty steps of comparable complexity, which means less chance of manufacturing discrepancies and a correspondingly lower reject rate on circuits of the same magnitude as their bipolar counterparts.

Usually this improvement is used to advantage to enable large logic arrays, such as dual 100-bit serial shift registers, to be built on one chip, rather than duplicate the bipolar circuits. This slant towards large scale integration (LSI) is also helped by the fact that an MOS transistor, being a low current, high impedance device, takes up only about one fiftieth of the chip area that a typical bipolar device needs.

MOS techniques are beginning to revolutionise many areas of logic design because of this capability of producing complete systems in one package. As an example, a recently introduced three digit multimeter uses a single LSI MOS chip which contains all the analogue-to-digital conversation logic and display decoding required, all in a 16-pin dual in-line package.

STRUCTURE

Transistors of the MOS type have been around for some time now, and have appeared in many designs, in particular the "front ends" of communications receivers, and high impedance input stages for audio amplifiers. Readers will be more familiar with them as field effect transistors (f.e.t.).

Just as there are *pnp* and *npn* bipolar devices, so there are *p*-channel and *n*-channel f.e.t.s, but in this case there is a further division into "enhancement" and "depletion" modes of operation, giving four device types in all. MOS logic circuits generally employ *p*-channel enhancement mode devices, although there is a recent form which uses complementary (*p*- and *n*-channel) logic on the same chip. The difference between *p*- and *n*-channel devices will be obvious to most readers, but "enhancement" and "depletion" may call for some explanation.

Fig. 10 shows the operation of these two devices in diagrammatic form. F.e.t.s have three electrodes known as the source, the drain, and the gate, and in the MOSFET the aluminium deposition known

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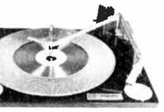

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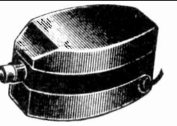

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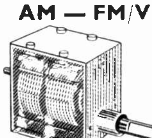

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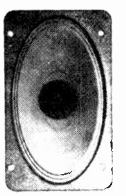

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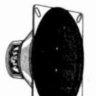

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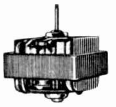

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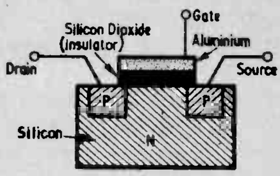

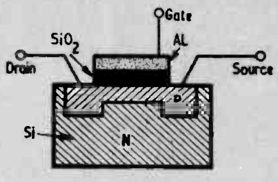

Fig. 10.1a. P-channel enhancement mode device

Fig. 10.1b. P-channel depletion mode device

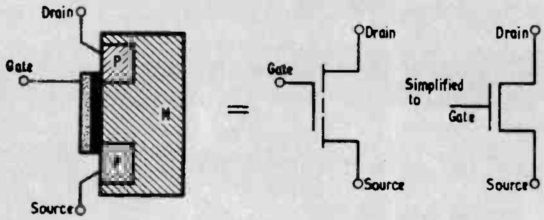

Fig. 10.2. Construction of the f.e.t. in MOS logic (left) with theoretically correct and simplified versions of the circuit symbol

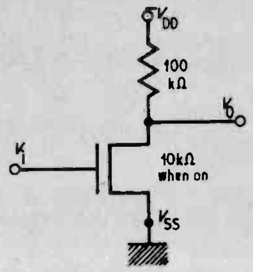

Fig. 10.3a. Logic inverter with discrete resistor as a load

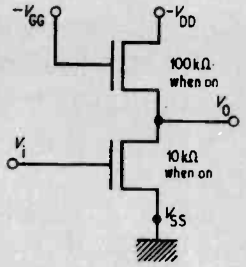

Fig. 10.3b. Using an MOS transistor in place of the resistive load

as the gate is insulated from the other sections of the device by a layer of silicon dioxide. There is therefore no d.c. current flow into or out of the gate, and the input impedance is extremely high, only the field set up by the gate voltage is used to modulate the current flow from source to drain.

When the gate voltage is such that there is a current flow between the other two terminals, a "channel" is said to exist between them. It is the type of bias necessary to form this channel which sets the difference between the enhancement and depletion devices.

ENHANCEMENT MODE

In the enhancement mode a channel does not exist between source and drain until an appropriate gate bias is applied, whereas in the depletion mode a channel exists with zero gate bias, and a bias has to be applied to cut off current flow. In Fig. 10.1a, for example, the *p*-channel enhancement mode device requires a negative bias on the gate before it will form a channel, but in Fig. 10.1b the *p*-channel depletion mode device will have a channel unless the gate is biased positively.

Of these two types the enhancement device is more suited for use as a logic switch, because it is off until turned on by a negative bias from a previous stage.

Fig. 10.2 compares the construction of the f.e.t.s used in MOS logic with the correct circuit symbol and the simplified version usually employed for logic circuits.

THRESHOLD VOLTAGE

The MOS device is commonly used in logic circuitry as a switch, and performs very well in this role. On resistance can be varied by the manufacturer by altering the geometry of the device, but is usually chosen to be about 10 kilohms, whereas off resistance is closer to the ideal open circuit than can be approached with bipolar devices, and is typically 10^{11} ohms.

Fig. 10.3a shows a single MOS used with a discrete resistor to form a logic inverter. As the gate voltage is increased negatively, a point is reached when the device resistance drops to the on value, reducing the output voltage to a low level, which would have the effect of turning off any following stage. The actual voltage at which an MOS turns on is referred to as the "threshold voltage", and it usually lies at about 3V. The threshold is not very abrupt, however, so this is only a nominal value.

Using conventional diffused silicon resistors in an MOS i.c. would unfortunately take up a great deal of space on the chip, losing the size advantage of the MOS active device. A diffused resistor such as is used in TTL circuits would in fact be about 1,000 times larger than a single MOS.

MOS TRANSISTOR AS A LOAD

To sidestep this problem the arrangement in Fig. 10.3b is employed. Here another MOS transistor is used as a load resistor, only in this case the device geometry is chosen to give an on resistance of the required 100 kilohms. The gate of this load element can either be wired permanently to the $-V_{DD}$ negative supply, holding the device permanently on, or all the gates of devices used for this purpose can be brought out to a $-V_{GG}$ common line which is held at a voltage even more negative than $-V_{DD}$. This also has the effect of keeping the load on. A third alternative uses these devices as "clock-line" switches as we shall see later.

BASIC GATE CIRCUITS

Because of the "ideal switch" characteristics of MOS, biasing problems, a feature of bipolar designs, do not arise. MOS devices are used almost as simply as relay contacts or toggle switches in gate circuits, making them very simple to understand, once the initial unfamiliarity of the symbols is overcome.

Fig. 10.4 shows some examples of gates made with MOS alongside their relay equivalents. With this family there is no "standard" gate, both NOR and NAND logic are used as it suits the designer, though it is normal practice to define gates in the negative logic convention, unlike TTL. There really seems little need to explain the action of the gates in Figs. 10.4a and 10.4b; with the understanding of an MOS transistor action and the relay version to refer to, readers will be able to work this out for themselves, with the knowledge of logic systems given earlier in this series.

Fig. 10.4c demonstrates how easy it is to expand MOS logic. Here two NAND gates are used in the wired-OR configuration, to generate the AND/OR/INVERT function. Interested readers may like to compare this very simple arrangement with the equivalent TTL circuitry.

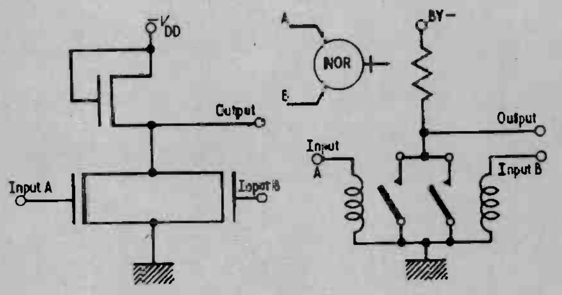

Fig. 10.4a. MOS NOR configuration

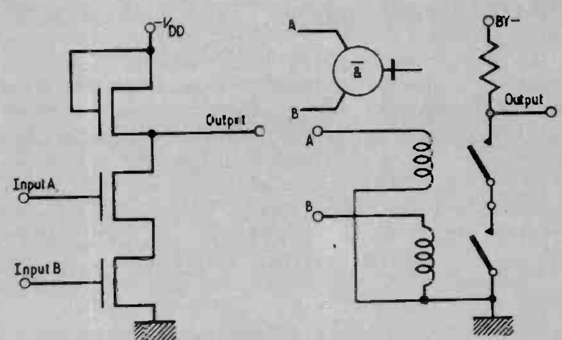

Fig. 10.4b. MOS NAND configuration

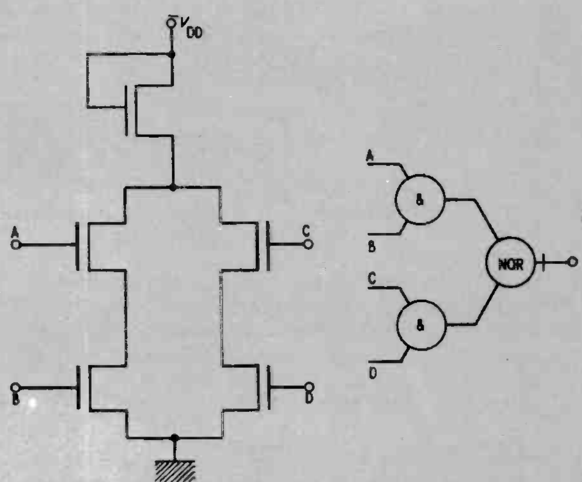

Fig. 10.4c. MOS wired-OR configuration (AND/OR/INVERT)

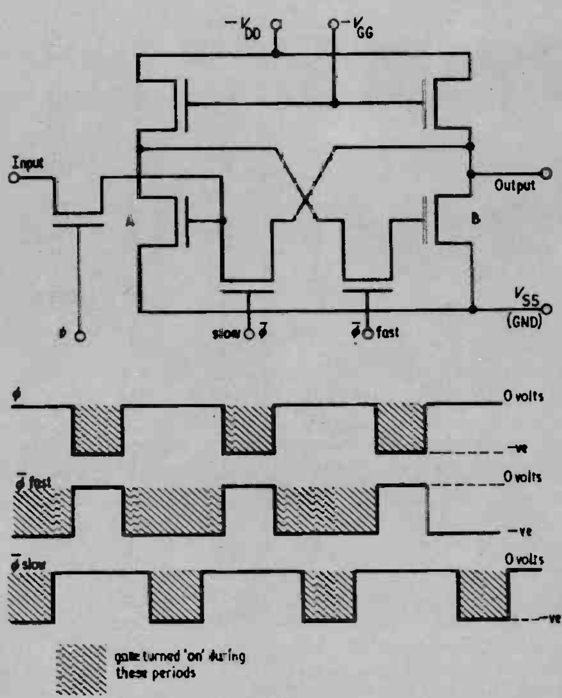

Fig. 10.5. Static shift register cell and clock waveforms

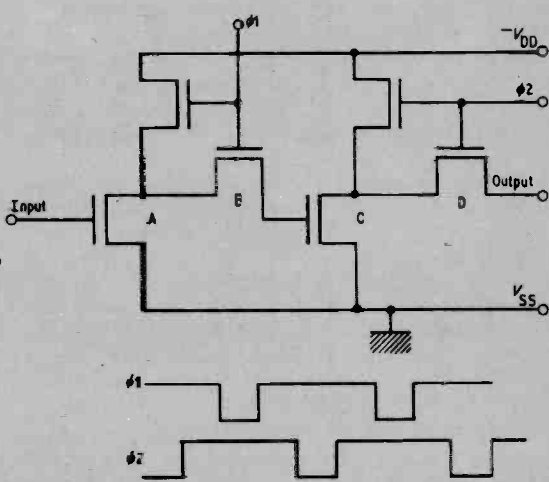

Fig. 10.6. Dynamic shift register cell and clock waveforms

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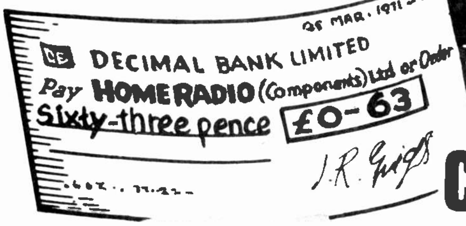

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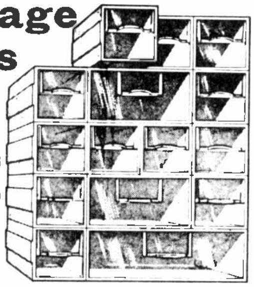

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SHIFT REGISTERS

MOS is rarely used to build general purpose flip-flops such as the JK type, although a manufacturer's catalogue may contain a single device of this sort to enable a system to be built entirely of MOS. It is included for the sake of completeness, and it is unlikely that these devices could stand on their own merit for economic reasons.

As we have already seen, the strength of MOS lies in its ability to be produced in the LSI form, and this advantage is put to good use in the range of shift registers available. Shift registers in this family are mainly of the "serial-in/serial-out" type, and their operation may be either static or dynamic.

The static type of register uses more devices per stage than the dynamic type, but data is stored by means of cross-coupled flip-flops, and there is no minimum clock rate. Dynamic registers use the capacitor inherent in the gate construction to store data, and are not capable of storing information indefinitely as a result. A minimum clock frequency of about 1kHz at 25°C is common for these registers which are used in continuously circulating applications such as delay lines.

The unit storage cells in both types of register bear little or no relation to the circuitry employed in any of the bipolar logic forms.

STATIC REGISTER

The emphasis in MOS is on simplicity at the expense of clock circuit complexity. Fig. 10.5 shows the circuit used for a static register cell; the cross coupled flip-flop configuration is immediately apparent.

In all, three separate clock waveforms are necessary to operate this circuit, although in an LSI chip it is usual to have a circuit which generates all these from a single external timing waveform. The ϕ clock corresponds to the external waveform and $\bar{\phi}$ fast is the ϕ clock inverted, $\bar{\phi}$ slow comes on sometime after $\bar{\phi}$ fast, and usually, although not necessarily, ends before it. Fig. 10.5 shows some typical waveforms.

A negative logic level would be transferred from the input to the gate of device A when ϕ comes on, and this would turn on A, pulling its output to ground. As soon as ϕ goes off, $\bar{\phi}$ fast comes on and transfers the ground on the output of A to the gate of B which starts to turn off. During this operation $\bar{\phi}$ slow comes on and the rising negative at the output of B is transferred to the gate of A, holding it on. If the clock is stopped with ϕ off (and hence $\bar{\phi}$ fast and $\bar{\phi}$ slow on) data can be stored indefinitely.

The gate of an MOS transistor can be considered to be a capacitor, the insulating silicon dioxide layer acting as the dielectric, and the aluminium and silicon acting as the plates. This capacitor is of very low value, perhaps 0·5pF, but because of the extremely high input impedance of an MOS device any charge stored on this gate capacitor will take quite a long time to leak away. (Remember that time constant equals C times R.)

DYNAMIC REGISTER

In the dynamic register this effect is used to store digital information, but because the charge will eventually leak away in any event, it is necessary to quote a minimum clock frequency which is temperature dependent.

Fig. 10.6 shows the circuit of one cell of a dynamic register, and as can be seen there is no cross-coupled flip-flop, only two gated inverters. The load MOS devices are used as switches controlled by the clock, and further devices gate information between stages. The clock waveforms $\phi1$ and $\phi2$ are in antiphase and must not overlap.

Assuming a negative input to the cell shown, this will be stored on the gate of device A, and will turn it on as soon as the $\phi1$ clock comes on. While $\phi1$ is present, the output of A will be pulled to ground, and this level will be gated through B to C, the gate capacitor of which will now hold a "ground" charge.

With no negative stored on its gate, C will not turn on when its load is enabled by $\phi2$, and the output gated through D will be the negative we started with delayed by one clock period.

Dynamic registers may seem pretty useless at a first glance because they cannot stand still and must keep their contents moving, but in fact there are many occasions when this is not a disadvantage.

When this is so the dynamic register has several points in its favour. First, it is about twice as fast in operation than the static type; secondly, because the loads are clocked, at low frequencies the power consumption of each cell is extremely low, typically 10 microwatts at 10kHz. This last feature is due to the fact that power is only dissipated when the gate capacitors are charged, which makes the power consumption frequency dependent. At 1MHz a power drain of 1 milliwatt per bit is common.

APPLICATIONS

MOS circuits are still in their infancy, but are certain to be one of the most important advances ever to be made in the world of data processing and allied fields. Their biggest impact will be in the consumer area, and it will not be long before our homes will have the benefit of a "domestic" computer made possible by the advent of cheap MOS LSI.

A home computer could become adaptable to the telephone (which has push button dialling) so that by ringing our own number from a remote call box, and then dialling a coded message, we could instruct the computer to cook the dinner or turn on the central heating. At work the desk calculator could replace the slide rule, giving answers to all arithmetic problems at the touch of a few keys, and electronic digital test equipment such as frequency counters and digital voltmeters will shrink to pocket size.

On the way home in our car, exhaust emission will be nullified by electronic fuel injection, and the wheels will be unable to lock and skid because of another electronic system. Relaxing in our home we will be able to programme the hi fi system to sooth us in any way we fancy without leaving our armchair or sorting through piles of records.

All these things are possible now, but it will be MOS which makes them economically viable for the many.

AVAILABLE MOS I.C.'s

Many readers may be hoping for some MOS circuits which are available to do a practical job in amateur projects right now. Talk of dual 100-bit shift registers in a TO-5 can will, perhaps, only interest those who like to build, or dream about, the amateur built computers of the future.

MOS circuits of simple nature are beginning to appear, and, as an example, look at a couple of Marconi-Elliott i.c.s which are intended for use in electronic organs, the MA60 and the MA70. These two devices are housed in TO-5 cans and operate from -26V. Inputs and outputs are compatible with DTL and TTL.

The MA60 contains six binary dividers arranged as two chains of three, each chain has three outputs, divide-by-two, four, and eight. If the two chains are used in series, a total division of 64 is obtained. The MA60 is shown in Fig. 10.7.

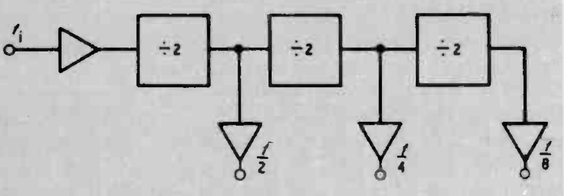

Fig. 10.7. Block diagram of the MA60 i.c. divider

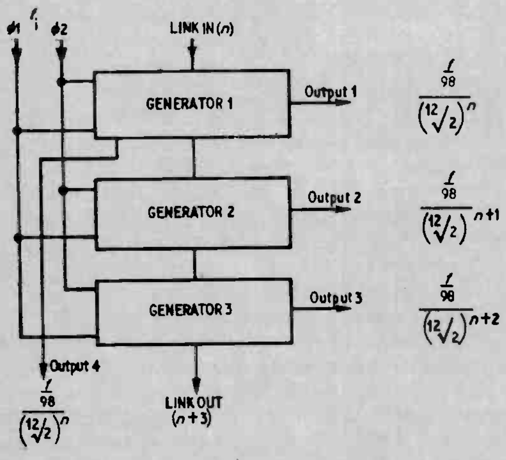

Fig. 10.8. Block diagram of the MA70 i.c. divider

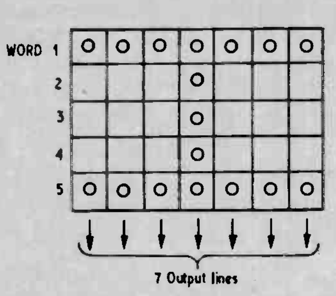

Fig. 10.9. Display programme for one character (letter H) of the Texas read-only memory

The MA70 is rather more complex than the previous device and is intended to produce three separate semitones from a single oscillator. MA70 can be cascaded if required, and when used in conjunction with the MA60 they enable complex organs to be built on a single p.c.b. The block diagram is given in Fig. 10.8.

These are circuits available to amateurs, and they do give a hint of MOS capabilities, but to get a glimpse of advanced applications, it is necessary to return to computer and process control electronics which are finding that MOS memories are becoming increasingly attractive.

COMPUTER MEMORY CIRCUITS

In the past the main memory in a computer has been built using ferrite core matrices, or core stores. This type of memory is of the "random access" type, as it is possible to address any location and read or write into it immediately.

Another type of memory used is the magnetic drum, which provides bulk storage but which is rather slower to address because the revolving drum may have to make a complete revolution before the correct data location is available.

Some memories are programmed during manufacture by the wiring in of diodes where data is required, these are used as fixed programmes to control computer sub-routines, or sometimes as "tables" to store constants. These memories are of the "read-only" type, and cannot be written into.

MOS LSI techniques are now being used to simulate all three of these memory systems, and the solid state versions are proving to be superior on many counts. As an example, the Texas TMS-2A-4824-MH read-only memory contains 2,240 bits of data which are programmed during manufacture to provide the information necessary to produce 64 alphabetical and numerical characters on a c.r.t. display.

Each character is stored as five seven-bit words which are used to modulate a dot matrix on the tube face. Fig. 10.9 shows how one of the characters is stored and formed. When a particular dot location has to be brighted up on the display a "one" is stored in the memory, each dot position is displayed in sequence, and the information to be displayed is used to address the correct character location.

This type of circuit can also be programmed to customer requirements to contain any information required, a set of sine tables for example, or a sequence programme for an industrial machine.

DEVELOPMENTS

MOS technology is being continuously improved, and these improvements are making this type of circuit ever more easy to use.

"Silicon gate" MOS devices are now being made with threshold voltages low enough so that they can be driven directly from bipolar logic, without the need for the voltage interface circuits that were necessary with the earlier types. The silicon gate technique uses polycrystalline silicon instead of aluminium for the gate electrode, and apart from giving lower threshold voltages, this also reduces the capacitance inherent in the construction and allows higher operating speeds.

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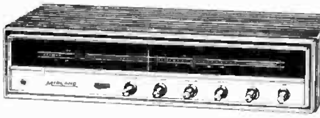

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Function	AM, FM, FM Stereo, Phono (Stereo indicator light)	AM, FM, FM Stereo, Ceramic, Magnetic, Aux.
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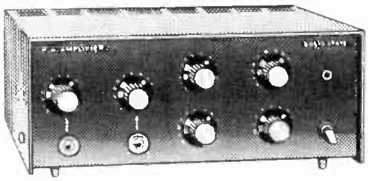

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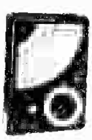

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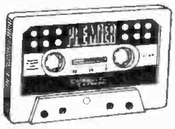

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The RCA COS-MOS family uses both *n*- and *p*-channel MOS f.e.t.s on the same chip, providing circuits that will run from 5V positive supplies with extremely low quiescent power consumption and a speed of up to 5MHz.

The latest introduction to the MOS field is a processing system which uses low temperature doping by bombardment with ions. This process is rather complex and expensive at present but it produces circuits which will operate at the same sort of speed as TTL, a great improvement.

PRACTICAL POINTS

MOS devices come in a wide range of package outlines, especially the more complex circuits which require large numbers of pins. Hermetically sealed packages are almost universally used, because the normal MOS chip needs to be well protected from contamination, and this rules out the simple plastic d.i.l. packages. The TO-5 can is very popular because this style can provide enough pins, and for the more complex devices a type of ceramic d.i.l. package, or a flatpack is employed.

PRECAUTIONS WHEN HANDLING

Because of the extremely high input impedance of the MOS, it is possible for a static charge on the gate to exceed the breakdown voltage of about 60V, and so short out the silicon dioxide layer and ruin the device. Some circuits use protective Zener diodes to prevent this, but it is advisable to be sure by consulting the data sheet. Leakage from an unearthed soldering iron could provide the minute current necessary to destroy a device. It is often recommended that pins should be shorted together whilst in store, to prevent static build up.

Next month: Emitter Coupled Logic (ECL)

OVER THE CHANNEL

By B.B. RAFTER

ONE OF the extra pleasures for the electronics enthusiast going abroad is the chance to observe the effect of electronics on daily life abroad, particularly if one can stay for any length of time in a foreign household. This I was privileged to do recently—just over the channel.

It is very interesting to see high-definition French television on 819 or 625 lines and note the clarity and excellence of the picture as well as the fact that the French programme directors are as hard put as ours to fill the screen with sixty minutes of excellence per hour.

It was interesting for me to meet two French clergymen-schoolmasters, who are fervent radio amateurs, and to visit their "shacks" from where they work the world on 2 metres. Incidentally, I did not know before that for this amateur band the French authorities do not require proficiency in morse; merely the equivalent of the City & Guilds written examination.

APPLIED ELECTRONICS

In the line of applied electronics the Continentals are not slow to make use of the automation made possible by modern techniques. It is probably now well known that in the Renault factories most of the production of major parts, such as the boring of engine cylinder blocks, is performed and controlled by electronically based automative processes.

At the other end of the scale I recently noticed a most effective use for the light-controlled relay that has done so much to automate town-lighting systems, lift doors, car parking lights and the rest. I went into the "Messieurs" in a newly completed and finely appointed hotel in Montreux, Switzerland and, on approaching the sanitary porcelain, noticed, coming from a metal panel in the wall, the unmistakeable "clack" of a well fed relay slamming shut. The noise coincided with a flush of clean water where it would do most good. On looking down, I noticed that my calves had interrupted a light beam aimed at a photo-cell in the side wall and, presumably, the relay thus activated had turned on a plunger-tap

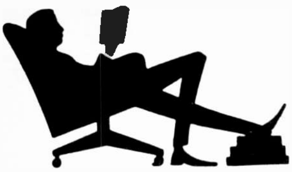
GAS LIGHTER

Another gadget I noticed in three separate French households I stayed in this year was a new form of gas lighter, driven direct from the mains. The lighter looks like a small, six inch long, plastic torch, with a perforated brass cap where the light bulb should be and a press-button switch on one side. When Madame wishes to light the gas ring, she takes this little "torch", applies the perforated head to the burner and presses the button. The lighter produces a noise like a rattle-snake and a bright spark inside the head immediately lights the gas.

Enquiries in two households as to how this device worked drew shrugs, no solid information, and no enthusiasm in response to my wish to take it to pieces. Finally, in the third family I met sympathy—from the clergyman ham, who affirmed that it worked like an electric bell, but was dissuaded from dismantling it there and then by his sister, who kept house for him. However, I was later able to obtain such a lighter, and no sooner had I returned to my home den than I took it to pieces and found that it does, indeed, work like an electric bell, as my friend had said.

The d.c. resistance of the coil in the specimen examined was 150 ohms, wound from 42 s.w.g. wire. At 230 volt mains a current of about 1·5 amp is broken at the contact bosses and for such slender wire, the sheer temerity of the concept might at first appear alarming. It must be remembered, however, that with such a healthy spark the gas is lit immediately, so that the button switch is released after a few seconds and no fuses blow.

Anyway, these lighters are in use in thousands of French homes, are on general sale at the equivalent of approximately 37½p each and their construction must therefore be presumed to have the approval of Electricité de France, the central electricity authority of France. ★



BOOK REVIEWS

TAPE RECORDERS

H. W. Hellyer
Published by Fountain Press
239 pages, 8½in × 5½in. Price £2·25 (45s)

WRITTEN by the author of the Tape Recorder Servicing Manual, this, in like vein, is an essentially practical book that sets out to educate the reader painlessly into tape recorder techniques and simple maintenance.

From an opening chapter sketching the birth, development and growth prospects, the author embarks on a very readable breakdown on machine principles, naming of parts and functions, all being punctuated with some valuable workshop observations.

Guidelines to recorder and microphone choice will no doubt appeal to prospective buyers although it seems the yardstick axiom of "You only get what you pay for" must eternally prevail.

Chapters on maintenance for both tape and deck are very well illustrated. A final chapter on tests and measurements embraces choice of service equipment, bench tips and typical measurement hook-ups for determining wow and flutter, distortion levels and signal to noise ratios, etc.

All in all, a must for any user of tape recorders, as it affords a useful reference that is very easily dipped into. G.G.

FOUNDATIONS OF WIRELESS AND ELECTRONICS Eighth edition

By M. G. Scroggie B.Sc., C.Eng., F.I.E.E.
Published by Iliffe Books
521 pages, 8¾in × 5½in. Price £3 (60s)

THERE must be thousands who have built their hobby, or even their career, upon Mr. M. G. Scroggie's "Foundations". First published in 1936, this well known work has re-appeared in new editions from time to time. The present edition, the eighth, is noteworthy for the addition of "electronics" to the title. This is justified by the inclusion of two new chapters providing brief but useful accounts of such subjects as waveform generators and computers.

Apart from this extension of its range, the general character and arrangement of the book has not changed over much, and wireless transmission and reception remains the dominant theme. But much of the material has been completely re-written, and semiconductors have now nearly, but not entirely, ousted thermionic valves.

Those not already familiar with Mr. Scroggie's classic can be assured that no previous knowledge of radio or electronics is assumed. The text excels in clarity and exposition, and there is little demand upon mathematics. Starting with first principles of electricity and circuit elements, the book proceeds to electronic devices, both thermionic and semiconductor, and explains their function in straightforward descriptive terms. Only in chapter 12 does the going become tough (as the author warns the reader) when transistor and valve equivalent circuits are evolved. Full understanding of this chapter is not, however, vital at the elementary stage.

The application of all the foregoing principles is demonstrated with stage by stage description of the various processes involved in a radio communications system. The principles of cathode ray tubes, television and radar are also outlined.

The two new chapters provide a sound, concise introduction to the many other uses of electronics which stem mainly from pulse switching techniques, as distinct from the generation, detection, and amplification of sinusoidal signals. F.E.B.

RADIO VALVE AND TRANSISTOR DATA

Compiled by A. M. Ball
Published by Butterworth & Co. Ltd.
232 pages, 10¾in × 8¼in. Price £0.75 (15s)

SUBSTANTIALLY revised and added to, this is the ninth edition of a very popular reference on valve and semiconductor electrical characteristics.

Additions to the previous contents list are colour tubes, f.e.t.s, tunnel diodes and i.c.'s, the latter including both digital and linear references.

Full marks must be given for the choice of a larger type face in the data presentation. This has meant, inevitably, some considerable pruning in obsolete device information, so don't just throw away that older edition as it will prove to be a valuable complement.

I suppose that in a work of this nature, errors can occur, but those that I found are inexcusable.

In the Amplifier Triodes section, the headings g_m and r_a should be transposed. The data for the PCC89 given in the Mullard Valve Data Book includes the description "Variable-mu frame-grid double triode".

In the Integrated Circuits section, the pin layout diagrams (p.199) do not include identification of mode connections. If one has to refer to manufacturers' data for this, then there was little point in including the technical data. It should also be made clear which view is shown in the drawings.

Finally, it would be very much easier to locate transistor types on the data pages if some semblance of alphabetical order were adopted. G.G.

BEGINNERS GUIDE TO RADIO Seventh Edition

By Gordon J. King
Published by Newnes-Butterworths
194 pages. 7½in × 5in. Price £1

THIS book is an updated version of an original of the same title by F. J. Camm, it is not just a rewrite in parts but a completely new book. The author's explanations of the basic principles are excellent and this book would prove useful to all studying electronics as well as basic radio. It is unfortunate that most of the work is based on valve theory and practice, however the radio principles are unaffected by this and there is a useful section on transistor theory and function and some transistor circuits are given and described in the text.

Sections 11 and 12 are concerned with "Disc Record Players and Radiograms" and "Hi-Fi Reproduction". Although these items may seem rather out of context under the title of this book they are both worthwhile sections describing the principles involved and giving block diagrams of the systems.

A selection of circuit symbols is given at the front of the book together with a brief description of each and lists of abbreviations and a wavelength/frequency conversion table are given at the back. Also included is an index of words and terms described in the text.

M.K.

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A	Simple battery record player	**Z.30**	Crystal P.U., 12V battery volume control	**£4.48**
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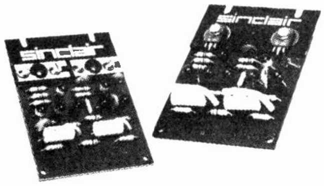
Sinclair Project 60

Z.30 & Z.50 power amplifiers



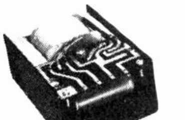
The Z.30 and Z.50 are of advanced design using silicon epitaxial planar transistors to achieve unsurpassed standards of performance. Total harmonic distortion is an incredibly low 0.02% at full output and all lower outputs. Whether you use Z.30 or Z.50 amplifiers in your Project 60 system will depend on personal preference, but they are the same size and may be used with other units in the Project 60 range equally well.

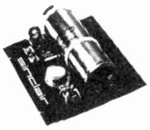
SPECIFICATIONS ***(Z50 units are interchangeable with Z.30s in all applications).***
Power Outputs
Z.30 15 watts R M.S. into 8 ohms using 35 volts: 20 watts R M S. into 3 ohms using 30 volts.
Z.50 40 watts R.M S into 3 ohms using 40 volts: 30 watts R.M S. into 8 ohms, using 50 volts.
Frequency response: 30 to 300 000 Hz ±1dB.
Distortion: 0 02% into 8 ohms.
Signal to noise ratio: better than 70dB unweighted.
Input sensitivity: 250mV into 100 Kohms.
For speakers from 3 to 15 ohms impedance.
Size $3\frac{1}{2} \times 2\frac{1}{4} \times \frac{1}{2}$ in.

Z.30
Built tested and guaranteed with circuits and instructions manual **£4.48**

Z.50
Built, tested and guaranteed with circuits and instructions manual. **£5.48**

Power Supplv Units





Designed specially for use with the Project 60 system of your choice.
Illustration shows PZ.5 to left and PZ.8 (for use with Z.50s) to the right. Use PZ.5 for normal Z.30 assemblies and PZ.6 where a stablised supply is essential.

PZ-5 *30 volts unstabilised* **£4.98**
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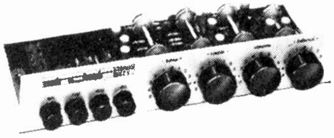
Guarantee

If within 3 months of purchasing Project 60 modules directly from us, you are dissatisfied with them, we will refund your money at once. Each module is guaranteed to work pe fectly and should any defect arise in normal use we will service it at once and without any cost to you whatsoever provided that it is returned to us within 2 years of the purchase date. There will be a small charge for service thereafter No charge for postage by surface mail. Air-mail charged at cost.

Stereo 60 pre-amp/control unit

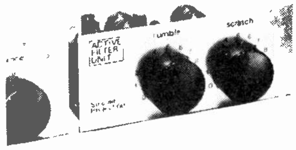


Designed for the Project 60 range but suitable for use with any high quality power amplifier. Again silicon epitaxial planar transistors are used throughout, achieving a really high signal-to-noise ratio and excellent tracking between channels. Input selection is by means of push buttons and accurate equalisation is provided for all the usual inputs.

SPECIFICATIONS
Input sensitivities: Radio-up to 3mV. Mag. p.u. 3mV: correct to R.I.A.A. curve ± 1dB:20 to 25,000 Hz. Ceramic p.u.–up to 3mV: Aux–up to 3mV.
Output: 250mV
Signal-to-noise ratio: better than 70dB.
Channel matching: within 1dB.
Tone controls: TREBLE + 15 to —15dB at 10KHz: BASS + 15 to—15dB at 100Hz.
Front panel: brushed aluminium with black knobs and controls.
Size: $8\frac{1}{4} \times 1\frac{1}{2} \times 4$ ins.

Built, tested and guaranteed. **£9.98**

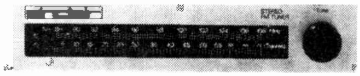
Active Filter Unit



For use between Stereo 60 unit and two Z.30s or Z.50s, and is easily mounted. It is unique in that the cut-off frequencies are continuously variable, and as attenuation in the rejected band is rapid (12dB/octave), there is less loss of the wanted signal than has previously been possible. Amplitude and phase distortion are negligible. The A.F.U. is suitable for use with any other amplifier system. Two stages of filtering are incorporated – rumble (high pass) and scratch (low pass). Supply voltage – 15 to 35V. Current – 3mA. H.F. cut-off (–3dB) variable from 28k Hz to 5kHz. L.F cut-off (–3dB) variable from 25Hz to 100Hz. Distortion at 1kHz (35V. supply) 0.02% at rated output.

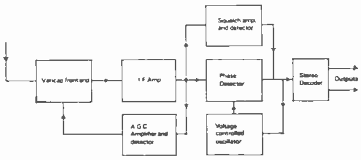
Built, tested and guaranteed **£5.98**

Stereo FM Tuner



first in the world to use the phase lock loop principle
Before production of this tuner, the phase lock loop principle was used for receiving signals from space craft because of its vastly improved signal to noise ratio over other systems. Now, for the first time, the principle has been applied to an FM tuner with fantastically good results. Other original features include varicap diode tuning, printed circuit coils, an I.C. in the specially designed stereo decoder and squelch circuit for silent tuning between stations. Sensitivity is such that good reception becomes possible in difficult areas. Foreign stations can be tuned in suitable conditions and often a few inches of wire are enough for an aerial. In terms of a high fidelity this tuner has a lower level of distortion than any other tuner we know. Stereo broadcasts are received automatically as the tuning control is rotated, a panel indicator lighting up as the stereo signal is tuned in. This tuner can also be used to advantage with any other high fidelity system.

SPECIFICATIONS:
Number of transistors: 16 plus 20 in I.C.
Tuning range: 87.5 to 108 MHz
Capture ratio: 1.5dB
Sensitivity: 2µV for 30dB quieting: 7µV for full limiting.
Squelch level: 20µV.
A.F.C. range: ±200 KHz
Signal to noise ratio: >65dB
Audio frequency response: 10Hz—15KHz (±1dB)
Total harmonic distortion: 0.15% for 30% modulation
Stereo decoder operating level: 2µV
Pilot tone suppression: 30dB
Cross talk: 40dB
I.F. frequency: 10.7 MHz
Output voltage: 2 x 150mV R.M.S.
Aerial Impedance: 75 Ohms
Indicators: Mains on: Stereo on; tuning indicator
Operating voltage: 25-30 VDC
Size: 3.6 x 1.6 x 8.15 inches: 91.5 x 40 x 207 mm



Price: £25 built and tested. Post free

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Volume and tone controls, mains operation, 3Ω output, new and boxed **£3·63** POST PAID

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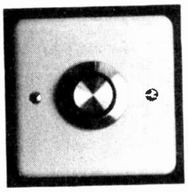

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