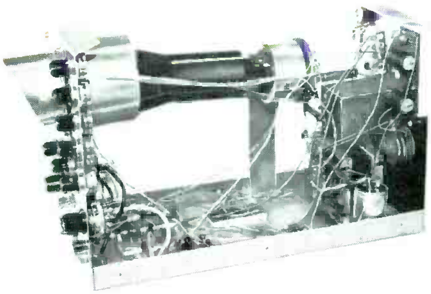
RADIO & ELECTRONICS CONSTRUCTOR

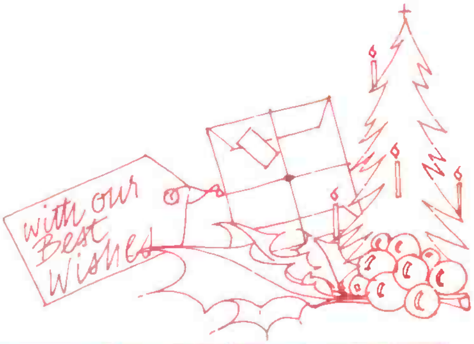
Vol. 26 No. 5 DECEMBER 1972 20p

SPECIAL FEATURE

TRANSISTORISED OSCILLOSCOPE

In this oscilloscope the only thermionic device is the cathode ray tube





ALSO FEATURED

HIGH-GAIN SILICON REFLEX RECEIVER

THIS IS THE FIRST PAGE OF THE GREAT BI-PAK SECTION

Cut these 3 pages out and keep for reference

BRAND NEW FULLY GUARANTEED DEVICES

AC 107	20p	AD 149	50p	BC 143	30p	BD 131	50p	BF 179	30p	C 444	35p	2G 301	19p
AC 113	20p	AD 161	33p	BC 145	45p	BD 132	60p	BF 180	30p	C 450	22p	2G 302	19p
AC 115	23p	AD 162	33p	BC 147	10p	BD 133	65p	BF 181	30p	MAT 100	19p	2G 303	19p
AC 117K	20p	AD 161 and		BC 148	10p	BD 135	40p	BF 182	40p	MAT 101	20p	2G 304	24p
AC 122	12p	AD 162(MP)	55p	BC 149	12p	BD 136	40p	BF 183	40p	MAT 120	19p	2G 306	40p
AC 125	17p	ADT 140	50p	BC 150	18p	BD 137	45p	BF 184	25p	MAT 121	20p	2G 308	35p
AC 126	17p	AF 114	24p	BC 151	20p	BD 138	50p	BF 185	30p	MPF 102	42p	2G 309	35p
AC 127	17p	AF 115	24p	BC 152	17p	BD 139	55p	BF 188	40p	MPF 104	37p	2G 339	20p
AC 128	17p	AF 116	24p	BC 153	28p	BD 140	60p	BF 194	12p	MPF 105	37p	2G 339A	16p
AC 132	14p	AF 117	24p	BC 154	30p	BD 155	80p	BF 195	12p	OC 19	35p	2G 344	18p
AC 134	14p	AF 118	35p	BC 157	18p	BD 175	60p	BF 196	14p	OC 20	63p	2G 345	16p
AC 137	14p	AF 124	30p	BC 158	12p	BD 176	60p	BF 197	14p	OC 22	38p	2G 371	16p
AC 141	14p	AF 125	25p	BC 159	12p	BD 177	65p	BF 200	45p	OC 23	42p	2G 371B	12p
AC 141K	17p	AF 126	28p	BC 160	45p	BD 178	65p	BF 222	95p	OC 24	56p	2G 373	17p
AC 142	14p	AF 127	28p	BC 161	50p	BD 179	70p	BF 257	45p	OC 25	38p	2G 374	17p
AC 142K	17p	AF 139	30p	BC 167	12p	BD 180	70p	BF 258	60p	OC 26	25p	2G 377	30p
AC 151	15p	AF 178	50p	BC 168	12p	BD 185	65p	BF 259	85p	OC 28	50p	2G 378	16p
AC 154	20p	AF 179	50p	BC 169	12p	BD 186	65p	BF 262	55p	OC 29	50p	2G 381	16p
AC 155	20p	AF 180	50p	BC 170	12p	BD 187	70p	BF 263	55p	OC 35	42p	2G 382	16p
AC 156	20p	AF 181	45p	BC 171	14p	BD 188	70p	BF 270	35p	OC 36	50p	2G 401	30p
AC 157	24p	AF 186	45p	BC 172	14p	BD 189	75p	BF 271	30p	OC 41	20p	2G 414	30p
AC 165	20p	AF 239	37p	BC 173	14p	BD 190	75p	BF 272	80p	OC 42	24p	2G 417	25p
AC 166	20p	AL 102	65p	BC 174	14p	BD 195	85p	BF 273	35p	OC 44	15p	2N 388	35p
AC 167	20p	AL 103	65p	BC 175	22p	BD 196	85p	BF 274	35p	OC 45	12p	2N 388A	55p
AC 168	24p	ASY 26	25p	BC 177	19p	BD 197	90p	BFW 10	60p	OC 70	10p	2N 404	20p
AC 169	14p	ASY 27	30p	BC 178	19p	BD 198	90p	BFX 29	27p	OC 71	10p	2N 404A	28p
AC 176	20p	ASY 28	25p	BC 179	19p	BD 199	95p	BFX 84	22p	OC 72	14p	2N 524	42p
AC 177	24p	ASY 29	25p	BC 180	24p	BD 200	95p	BFX 85	30p	OC 74	14p	2N 527	49p
AC 178	28p	ASY 50	25p	BC 181	24p	BD 205	80p	BFX 86	22p	OC 75	15p	2N 598	42p
AC 179	28p	ASY 51	25p	BC 182	10p	BD 206	80p	BFX 87	24p	OC 76	15p	2N 599	45p
AC 180	17p	ASY 52	25p	BC 182L	10p	BD 207	95p	BFX 88	22p	OC 77	25p	2N 696	12p
AC 180K	20p	ASY 54	25p	BC 183	10p	BD 208	95p	BFY 50	20p	OC 81	15p	2N 697	13p
AC 181	17p	ASY 55	25p	BC 183L	10p	BDY 20	£1.00	BFY 51	20p	OC 81D	15p	2N 698	24p
AC 181K	20p	ASY 56	25p	BC 184	12p	BF 115	24p	BFY 52	20p	OC 82	15p	2N 699	35p
AC 187	22p	ASY 57	25p	BC 184L	12p	BF 117	45p	BFY 53	17p	OC 82D	15p	2N 706	8p
AC 187K	20p	ASY 58	25p	BC 186	28p	BF 118	70p	BPX 25	85p	OC 83	20p	2N 706A	9p
AC 188	22p	ASZ 21	40p	BC 187	28p	BF 119	70p	BSX 19	15p	OC 84	20p	2N 708	12p
AC 188K	20p	BC 107	9p	BC 207	11p	BF 121	45p	BSX 20	15p	OC 139	20p	2N 711	30p
ACY 17	25p	BC 108	9p	BC 208	11p	BF 123	50p	BSY 25	15p	OC 140	20p	2N 717	35p
ACY 18	20p	BC 109	10p	BC 209	12p	BF 125	45p	BSY 26	15p	OC 169	25p	2N 718	24p
ACY 19	20p	BC 113	10p	BC 212L	11p	BF 127	50p	BSY 27	15p	OC 170	25p	2N 718A	50p
ACY 20	20p	BC 114	15p	BC 213L	11p	BF 152	55p	BSY 28	15p	OC 171	25p	2N 726	28p
ACY 21	20p	BC 115	15p	BC 214L	14p	BF 153	45p	BSY 29	15p	OC 200	25p	2N 727	28p
ACY 22	16p	BC 116	15p	BC 225	25p	BF 154	45p	BSY 38	18p	OC 201	28p	2N 743	20p
ACY 27	18p	BC 117	15p	BC 226	35p	BF 155	70p	BSY 39	18p	OC 202	28p	2N 744	20p
ACY 28	19p	BC 118	10p	BCY 30	24p	BF 156	48p	BSY 40	28p	OC 203	25p	2N 914	14p
ACY 29	35p	BC 119	30p	BCY 31	26p	BF 157	55p	BSY 41	28p	OC 204	25p	2N 918	30p
ACY 30	28p	BC 120	80p	BCY 32	30p	BF 158	55p	BSY 95	12p	OC 205	35p	2N 929	21p
ACY 31	28p	BC 125	12p	BCY 33	22p	BF 159	60p	BSY 95A	12p	OC 309	40p	2N 930	21p
ACY 34	21p	BC 126	18p	BCY 34	25p	BF 160	40p	Bu 105	£2.00	P 346A	20p	2N 1131	20p
ACY 35	21p	BC 132	12p	BCY 70	14p	BF 162	40p	C 111E	50p	P 397	42p	2N 1132	22p
ACY 36	28p	BC 134	18p	BCY 71	18p	BF 163	40p	C 400	30p	OCP 71	43p	2N 1307	14p
ACY 40	17p	BC 135	12p	BCY 72	14p	BF 164	40p	C 407	25p	ORP 12	43p	2N 1303	14p
ACY 41	18p	BC 136	15p	BCZ 10	20p	BF 165	40p	C 424	20p	ORP 60	40p	2N 1304	17p
ACY 44	35p	BC 137	15p	BCZ 11	25p	BF 167	22p	C 425	50p	ORP 61	40p	2N 1305	17p
AD 130	38p	BC 139	40p	BCZ 12	25p	BF 173	22p	C 426	35p	ST 140	12p	2N 1306	21p
AD 140	48p	BC 140	30p	BD 121	60p	BF 176	35p	C 428	20p	ST 141	17p	2N 1307	21p
AD 142	48p	BC 141	30p	BD 123	65p	BF 177	35p	C 441	30p	TIS 43	30p	2N 1308	23p
AD 143	38p	BC 142	30p	BD 124	60p	BF 178	30p	C 442	30p	UT 46	27p	2N 1309	23p

2N 1613	20p	2N 2926(R)	10p	2N 3906	27p
2N 1711	20p	2N 2926(B)	10p	2N 4058	12p
2N 1889	32p	2N 3010	70p	2N 4059	10p
2N 1890	45p	2N 3011	14p	2N 4060	12p
2N 1893	37p	2N 3053	17p	2N 4061	12p
2N 2147	72p	2N 3054	46p	2N 4062	12p
2N 2148	57p	2N 3055	50p	2N 4284	17p
2N 2160	60p	2N 3391	14p	2N 4285	17p
2N 2192	35p	2N 3391A	16p	2N 4286	17p
2N 2193	35p	2N 3392	14p	2N 4287	17p
2N 2194	35p	2N 3395	14p	2N 4288	17p
2N 2217	22p	2N 3394	14p	2N 4289	17p
2N 2218	20p	2N 3395	17p	2N 4290	17p
2N 2219	20p	2N 3402	21p	2N 4291	17p
2N 2220	22p	2N 3403	21p	2N 4292	17p
2N 2221	20p	2N 3404	28p	2N 4293	17p
2N 2222	20p	2N 3405	42p	2N 5172	12p
2N 2368	17p	2N 3414	15p	2N 5457	32p
2N 2369	14p	2N 3415	15p	2N 5458	32p
2N 2369A	14p	2N 3416	28p	2N 5459	40p
2N 2411	24p	2N 3417	28p	2S 301	50p
2N 2412	24p	2N 3525	75p	2S 302A	42p
2N 2646	47p	2N 3646	9p	2S 302	42p
2N 2711	21p	2N 3702	10p	2S 303	55p
2N 2712	21p	2N 3703	10p	2S 304	70p
2N 2714	21p	2N 3704	11p	2S 305	84p
2N 2904	17p	2N 3705	10p	2S 306	84p
2N 2904A	21p	2N 3706	9p	2S 307	84p
2N 2905	21p	2N 3707	11p	2S 321	56p
2N 2905A	21p	2N 3708	7p	2S 322	42p
2N 2906	15p	2N 3709	9p	2S 322A	42p
2N 2906A	18p	2N 3710	9p	2S 323	56p
2N 2907	20p	2N 3711	9p	2S 324	70p
2N 2907A	22p	2N 3819	28p	2S 325	70p
2N 2923	14p	2N 3820	50p	2S 326	70p
2N 2924	14p	2N 3821	35p	2S 327	70p
2N 2925	14p	2N 3823	28p	2S 701	42p
2N 2926(G)	12p	2N 3903	28p	40361	40p
2N 2926(Y)	11p	2N 3904	30p	40362	45p
2N 2926(O)	10p	2N 3905	28p		

DIODES & RECTIFIERS

AA 119	8p	BY 130	16p	OA 47	7p
AA 120	8p	BY 133	21p	OA 70	7p
AA 129	8p	BY 164	50p	OA 79	7p
AAY 30	9p	BYX 38 30	42p	OA 81	7p
AAZ 13	10p	BYZ 10	35p	OA 85	9p
BA 100	10p	BYZ 11	30p	OA 90	6p
BA 116	21p	BYZ 12	30p	OA 91	6p
BA 126	22p	BYZ 13	25p	OA 95	7p
BA 148	14p	BYZ 16	40p	OA 200	6p
BA 154	12p	BYZ 17	35p	OA 202	7p
BA 155	14p	BYZ 18	35p	SD 10	5p
BA 156	13p	BYZ 19	28p	SD 19	5p
BY 100	15p	CG 62		IN 34	7p
BY 101	12p	(Eq) OA 91	5p	IN 34A	7p
BY 105	17p	CG 651 (Eq)		IN 914	6p
BY 114	12p	OA 70–OA79	6p	IN 916	6p
BY 126	14p	OA 5	35p	IN 414B	6p
BY 127	15p	OA SSL	21p	IS 021	10p
BY 128	15p	OA 10	35p	IS 951	6p

NEW COMPONENT PAK BARGAINS

Pack No.	Qty.	Description	Price
C 1	250	Resistors mixed values approx. count by weight	0.50
C 2	200	Capacitors mixed values approx. count by weight	0.50
C 3	50	Precision Resistors .1%, .01% mixed values	0.50
C 4	75	¼th W Resistors mixed preferred values	0.50
C 5	5	Pieces assorted Ferrite Rods	0.50
C 6	2	Tuning Gangs, MW/LW VHF	0.50
C 7	1	Pack Wire 50 meters assorted colours	0.50
C 8	10	Reed Switches	0.50
C 9	3	Micro Switches	0.50
C10	15	Assorted Pots & Pre-Sets	0.50
C11	5	Jack Sockets 3—3.5m 2 — Standard Switch Types	0.50
C12	40	Paper Condensers preferred types mixed values	0.50
C13	20	Electrolytics Trans. types	0.50
C14	1	Pack assorted Hardware – Nuts/Bolts, Gromets, etc.	0.50
C15	4	Mains Toggle Switches, 2 Amp D/P	0.50
C16	20	Assorted Tag Strips & Panels	0.50
C17	10	Assorted Control Knobs	0.50
C18	4	Rotary Wave Change Switches	0.50
C19	3	Relays 6 – 24V Operating	0.50
C20	4	Sheets Copper Laminate approx. 10"×7"	0.50

Please add 10p post and packing on all component packs, plus a further 10p on pack Nos. C1, C2, C19, C20.
Component Lists for mail order available on request.

JUMBO COMPONENT PAKS

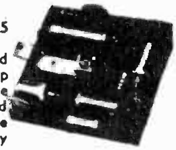
MIXED ELECTRONIC COMPONENTS
Exceptionally good value

Resistors, capacitors, pots, electrolytics and coils plus many other useful items. Approximately 3lbs in weight. Price incl. P. & P. **£1.50 only**

BRAND NEW POST OFFICE TYPE TELEPHONE DIALS

ONLY 35p each

THE NEW S.G.S. EA 1000 AUDIO AMP MODULE **Guar. 3 Watts RMS. Module Tested and Guaranteed.**
Qty. 1—9 **£2.63**; 10—25 **£2.28**. Price each.
Larger quantities quoted on request. Full hook-up diagrams and complete technical data supplied free with each module or available separately at 10p each.



SYSTEM 12 STEREO

Each kit contains two amplifier modules, 3 Watts RMS, two loudspeakers, 15 OHMS, The pre-amplifier, transformer, power supply module, front panel and other accessories as well as an illustrated stage-by-stage instruction booklet designed for the beginner. Further details available on request.

ONLY £16.95 FREE P & P

NOW-TURN OVER FOR MORE FANTASTIC OFFERS

-the lowest prices!

74 Series T.T.L. I.C'S

**Bi-Pak Still Lowest in Price.
Full Specification Guaranteed.
All Famous Manufacturers.**

	1	25	100+
SN7400	0.15	0.14	0.12
SN7401	0.15	0.14	0.12
SN7402	0.15	0.14	0.12
SN7403	0.15	0.14	0.12
SN7404	0.15	0.14	0.12
SN7405	0.15	0.14	0.12
SN7406	0.35	0.31	0.28
SN7407	0.35	0.31	0.28
SN7408	0.18	0.17	0.16
SN7409	0.18	0.17	0.16
SN7410	0.15	0.14	0.12
SN7411	0.25	0.24	0.23
SN7412	0.35	0.31	0.28
SN7413	0.29	0.26	0.24
SN7416	0.43	0.40	0.38
SN7417	0.43	0.40	0.38
SN7420	0.15	0.14	0.12
SN7422	0.50	0.48	0.45
SN7423	0.50	0.48	0.45
SN7425	0.50	0.48	0.45
SN7427	0.45	0.42	0.40
SN7428	0.70	0.65	0.60
SN7430	0.15	0.14	0.12
SN7432	0.45	0.42	0.40
SN7433	0.80	0.75	0.70
SN7437	0.64	0.62	0.60
SN7438	0.64	0.62	0.60
SN7440	0.15	0.14	0.12
SN7441	0.67	0.64	0.58
SN7442	0.67	0.64	0.58
SN7443	£1.30	£1.25	£1.20
SN7444	£1.30	£1.25	£1.20
SN7445	£1.80	£1.77	£1.75
SN7446	0.97	0.94	0.88
SN7447	£1.00	0.97	0.96
SN7448	£1.00	0.97	0.96
SN7450	0.15	0.14	0.12
SN7451	0.15	0.14	0.12
SN7453	0.15	0.14	0.12
SN7454	0.15	0.14	0.12
SN7460	0.15	0.14	0.12
SN7470	0.29	0.26	0.24
SN7472	0.29	0.26	0.24
SN7473	0.37	0.35	0.32
SN7474	0.37	0.35	0.32
SN7475	0.45	0.43	0.42
SN7476	0.40	0.39	0.38
SN7480	0.67	0.64	0.58
SN7481	£1.20	£1.15	£1.10
SN7482	0.87	0.86	0.85
SN7483	£1.10	£1.05	0.95
SN7484	£1.00	0.95	0.90
SN7485	£3.60	£3.50	£3.40
SN7486	0.32	0.31	0.30
SN7489	£5.50	£5.25	£5.00

	1	25	100+
SN7490	0.67	0.64	0.58
SN7491	£1.00	0.95	0.90
SN7492	0.67	0.64	0.58
SN7493	0.67	0.64	0.58
SN7494	0.77	0.74	0.68
SN7495	0.77	0.74	0.68
SN7496	0.87	0.64	0.78
SN74100	£1.65	£1.60	£1.55
SN74104	0.97	0.94	0.88
SN74105	0.97	0.94	0.88
SN74107	0.40	0.38	0.36
SN74110	0.55	0.53	0.50
SN74111	£1.25	£1.15	£1.10
SN74118	£1.00	0.95	0.90
SN74119	£1.35	£1.25	£1.10
SN74121	0.40	0.37	0.34
SN74112	£1.40	£1.30	£1.10
SN74123	£2.80	£2.70	£2.60
SN74141	0.67	0.64	0.58
SN74145	£1.50	£1.40	£1.30
SN74150	£3.00	£2.70	£2.50
SN74151	£1.00	0.95	0.90
SN74153	£1.20	£1.10	0.95
SN74154	£1.80	£1.70	£1.60
SN74155	£1.40	£1.30	£1.20
SN74156	£1.40	£1.30	£1.20
SN74157	£1.90	£1.80	£1.70
SN74160	£1.80	£1.70	£1.60
SN74161	£1.80	£1.70	£1.60
SN74162	£4.00	£3.75	£3.50
SN74163	£4.00	£3.75	£3.50
SN74164	£2.20	£2.15	£2.10
SN74165	£2.25	£2.20	£2.15
SN74166	£3.50	£3.25	£3.00
SN74174	£2.30	£2.20	£2.10
SN74175	£1.60	£1.50	£1.40
SN74176	£2.50	£2.40	£2.30
SN74177	£2.50	£2.40	£2.30
SN74180	£2.00	£1.60	£1.40
SN74181	£5.50	£5.00	£4.75
SN74182	£2.00	£1.80	£1.60
SN74184	£3.50	£3.25	£3.00
SN74190	£1.95	£1.90	£1.85
SN74191	£1.90	£1.85	£1.80
SN74192	£1.95	£1.90	£1.85
SN74193	£2.00	£1.80	£1.75
SN74194	£2.70	£2.60	£2.50
SN74195	£2.00	£1.90	£1.80
SN74196	£1.80	£1.70	£1.60
SN74197	£1.80	£1.70	£1.60
SN74198	£5.50	£5.00	£4.50
SN74199	£5.50	£5.00	£4.50

LINEAR I.C's— FULL SPEC.

Type No.	Price 1-24	25-99	100 up
BP 201C—SL201C	63p	55p	45p
BP 701C—SL701C	63p	50p	45p
BP 702C—SL702C	63p	50p	45p
BP 702—72702	53p	45p	40p
BP 709—72709	38p	34p	30p
BP 709P—μA709C	36p	34p	30p
BP 710—72710	44p	42p	40p
BP 711—μA711	45p	43p	40p
BP 741—72741	75p	60p	50p
μA 703C—μA703C	28p	26p	24p
TA A263	70p	60p	55p
TA A293	90p	75p	70p
TA A350	170p	158p	150p

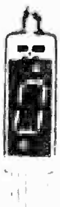
LOGIC DTL 930 SERIES I.C's

ROCK BOTTOM PRICES

Type No.	Price 1-24	25-99	100 up
BP930	12p	11p	10p
BP932	13p	12p	11p
BP933	13p	12p	11p
BP935	13p	12p	11p
BP936	13p	12p	11p
BP944	13p	12p	11p
BP945	25p	24p	22p
BP946	13p	11p	10p
BP948	25p	24p	22p
BP951	65p	60p	55p
BP962	12p	11p	10p
BP9093	40p	35p	30p
BP9094	40p	35p	30p
BP9097	40p	35p	30p
BP9099	40p	35p	30p

Devices may be mixed to qualify for quantity price. Larger quantity prices on application. (DTL 930 Series only).

NUMERICAL INDICATOR TUBES



MODEL	CD66	GR 116	3015F
Anode voltage (Vdc)	170 min	175 min	5
Cathode cur'nt (mA)	2.3	14	
Numeral h'ght (mm)	16	13	9
Tube height (mm)	47	32	22
Tube diameter (mm)	19	13	12
I.C. driver rec.	BP41 or 141	BP41 or 141	BP47
PRICE EACH	£1.70	£1.55	£1.90

All indicators 0.9 + Decimal point: All side viewing: Full data for all types available on request.

RTL MICROLOGIC CIRCUITS

Epoxy TO-5 case	Price each 1-24	25-99	100 up
μL900 Buffer	35p	33p	27p
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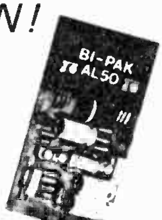

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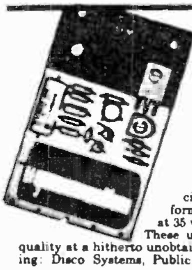

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Harmonic Distortion: better than 0.1%
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Input overload + 26dB; Supply + 35 volts @ 20mA
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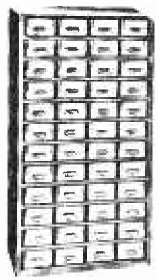

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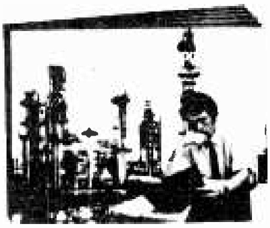

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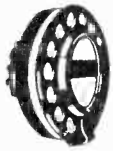

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USING THE F.E.T.

by
M. Harding

Some notes on the functioning of the field effect transistor, together with a typical circuit application in which it may be employed.

ONE OF THE FIRST THINGS THAT ONE LEARNS ABOUT the field effect transistor or f.e.t. is that it has properties more like those of the thermionic valve than those of the ordinary transistor.

The f.e.t. is a voltage controlled device unlike the conventional transistor, which is current operated. One of the most important properties of the f.e.t. lies in its very high input resistance, although there are some other useful features which will be briefly discussed.

The f.e.t. is by no means a new device, for if one goes back to 1933 reference can be found to a patent taken out by J. E. Lilienfeld concerning a field effect device from which, in 1952, W. E. Shockley was able to develop the first practical f.e.t.

INTERNAL CONSTRUCTION

In order to get to grips with any device it is necessary to briefly consider its internal construction together with its characteristic behaviour. In almost all accounts about the f.e.t. various terms turn up which tend to give the device a slight aura of mystery. Such terms are 'depletion layer' and 'enhancement mode'. A brief explanation of these aspects of the device will be given in order to enable the reader to make fullest use of the device.

Fundamentally there are two types of f.e.t. in common usage, these being

(a) the *jugfet* or junction gate f.e.t.
(b) the *igfet* or insulated gate f.e.t.

This latter device is more commonly called the *mosfet* or metal oxide silicon f.e.t., and therefore throughout the rest of this article 'mosfet' will be used to describe the insulated gate type of f.e.t. For the most part we will be concerned with the jugfet and will conclude with a practical design for an a.f. buffer stage which illustrates the way in which the f.e.t. characteristics may be exploited. However, comparisons will be made with the mosfet because of the importance of the latter device.

PRINCIPLES OF OPERATION

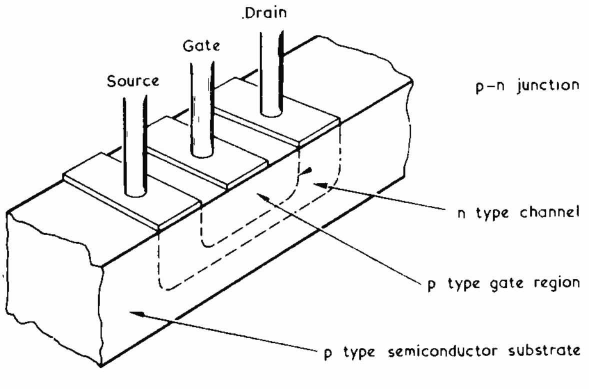
Fig. 1(a) illustrates the basic structure of the jugfet. Just like the ordinary transistor there are three electrodes, but this time they are called the gate, source and drain. The so-called channel is formed by the region of semiconductor material connecting the source and drain. In the diagram this is shown as being composed of n type silicon and the device would be referred to as an n channel f.e.t. In fact just as we have p.n.p. transistors to complement n.p.n. types, reverse polarity or p channel f.e.t.s also exist.

As shown in the diagram, with an n channel f.e.t. the gate region is p type silicon, and in this article only n channel devices are considered.

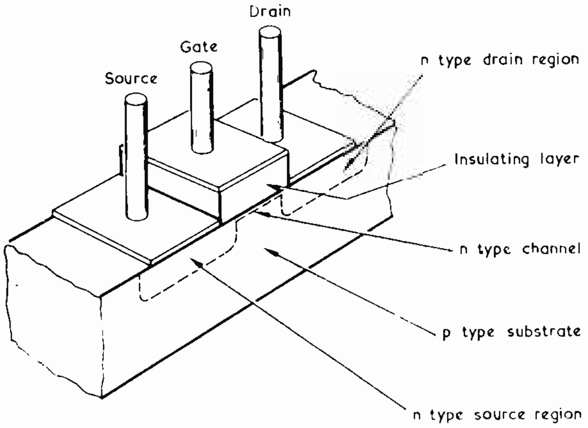
It should be noted that both drain and source contacts are non-rectifying or ohmic contacts and therefore the current flowing between them is proportional to the applied voltage across them.

As a useful guide it can be said that in general the source is the common electrode, the gate the input electrode and the drain the output electrode.

Like the thermionic valve the majority current carriers in an n channel f.e.t. are electrons and they



(a)



(b)

Fig. 1 (a). Basic construction of an n type channel junction gate f.e.t.
(b). The n channel depletion mosfet

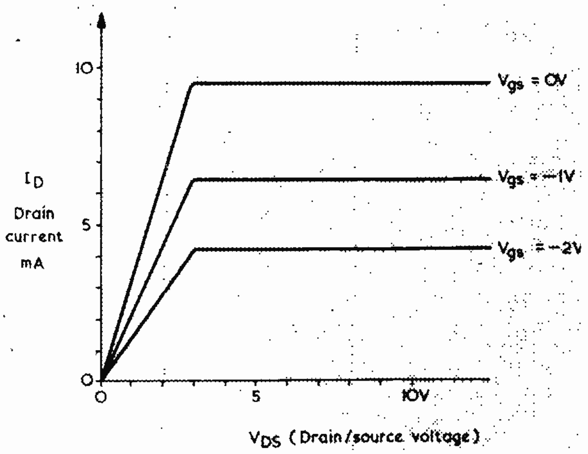


Fig. 2. Typical drain current-voltage characteristic curves for a jugfet

flow between source and drain - these electrodes being very aptly named. It is interesting to contrast this situation with the ordinary transistor which uses two types of current carrier, i.e. electrons and holes. In consequence the f.e.t. is often referred to as a unipolar device in order to distinguish it from the ordinary transistor which is then referred to as a bipolar device.

In normal operation the gate to source junction is reverse biased and therefore the input impedance can be very high indeed, some hundreds of megohms. With certain mosfets the figure can reach a million megohms. The basic structure of a mosfet is illustrated in Fig. 1(b).

To return to the jugfet we find that when the gate-source bias is increased the so-called depletion layer, in the region of the junction, extends into the channel and effectively reduces its width. (A short discussion on the depletion layer is included at the end of this article.) Accepting that this depletion layer is encroaching into the channel, the result is going to be a higher channel resistance and therefore a smaller channel current flow for a given potential between source and drain.

It is from this behaviour that the device gets its name, since changes in the transverse electric field of the junction region produces changes in the channel resistance. And so, we have a device which acts as a voltage controlled resistance. If we put a load resistance in series with the drain we have a direct current amplifier.

It is useful at this point to consider a graph showing the relationship between drain current Id and drain-to-source voltage Vds for three values of gate voltage. The result for a typical n channel f.e.t. is shown in Fig. 2. Valve men will at once see the similarity between the graph of Fig. 2 and the transfer characteristics of the pentode. The graph relating the drain current to gate-to-source voltage is shown in Fig. 3. For those with mathematical inclinations it can be shown that this characteristic has a square law relationship. This point

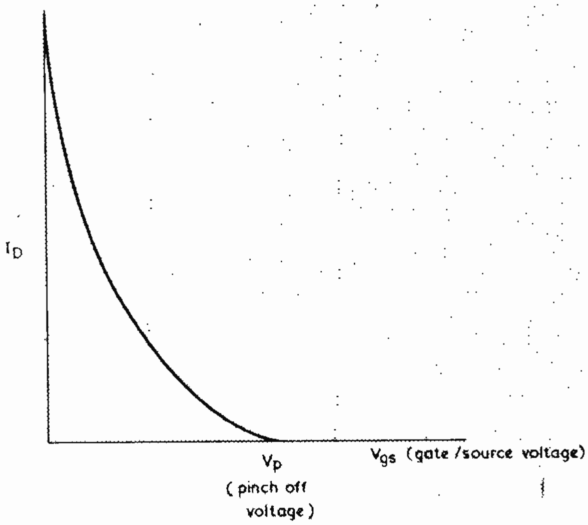


Fig. 3. Curve showing drain current against gate voltage

is of some importance when the f.e.t. is used as a mixer because it gives the device an excellent cross-modulation characteristic. This graph is also useful in showing the value of gate to source voltage required to completely cut off the source to drain current. This last parameter is called the pinch-off voltage Vp and varies, from device to device, from between as little as 3V to about 10V.

Of note is the fact that some jugfets are symmetrical, i.e. the drain and source are interchangeable, and the appropriate circuit symbol is shown in Fig. 4(a). However is should be noted that this symbol is sometimes used for a non-symmetrical jugfet and one should not take too much for granted in this respect. Fig. 4(b) shows the symbol which is normally used for a non-symmetrical jugfet. Both Fig. 4(a) and 4(b) show n channel devices. The arrow on the gate electrode is reversed for p channel devices. The symbol commonly used for the mosfet is shown in Fig. 4(c), a fourth lead being attached to the substrate. Fig. 4(d) shows the symbol used for the dual gate mosfet, which has particular application in r.f. stages.

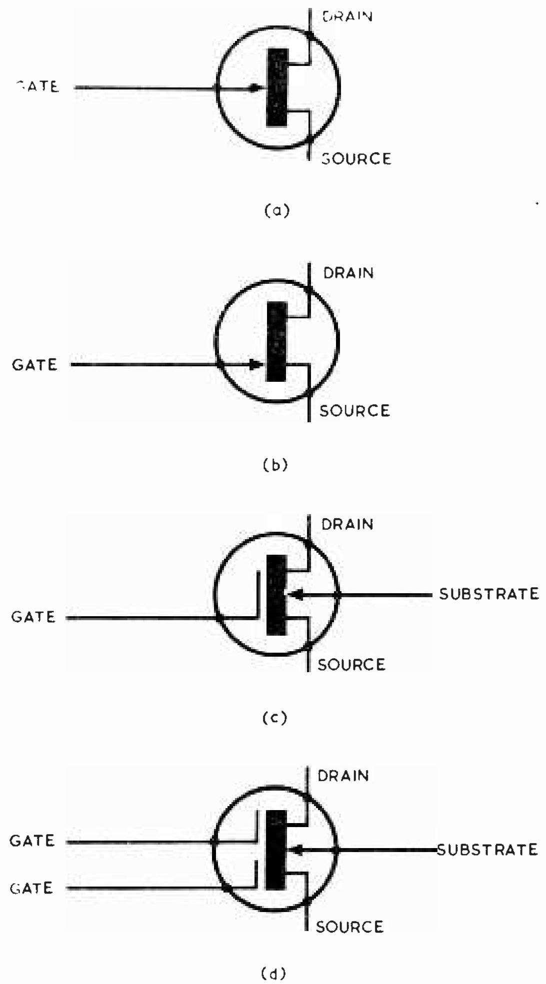


Fig. 4. Commonly employed circuit symbols. Those in (a) and (b) are for symmetrical and non-symmetrical jugfets respectively. A mosfet is shown in (c) and a 2-gate mosfet in (d). All devices are n type channel

It should be realised that up to now we have been discussing the depletion layer type of jugfet. The depletion mosfet functions in the same manner as the depletion jugfet. A thin channel of n material appears between source and drain, and is affected by gate potential in the same way. However, using the mosfet technology it is also possible to produce an f.e.t. in which the channel is not present between source and drain until the appropriate gate bias is applied. This type of f.e.t. is called an enhancement device and has the useful property that it is normally non-conducting, i.e. with zero gate voltage no source-to-drain current flows. In fact it has to be turned on by the application of suitable gate bias. The main field of application is in the realms of logic circuitry because of the switch-like characteristics coupled with the fact that in manufacture many hundreds of these devices may be crammed onto a single chip of silicon. This means that complex functions such as large shift registers, which are encountered in computer engineering, may be built in a single package. Medium Scale Integration (M.S.I.) using bipolar transistors is, of course, already well established but mosfets offer the possibility of producing nearly all the electronics of say a digital voltmeter in a single multilead package. This is called Large Scale Integration (L.S.I.) and it is in this field where the enhancement mosfet is really coming into its own, but that's another story.

The proper symbol for the enhancement mosfet is shown in Fig. 5(a) and a simplified version of the same thing, which is commonly encountered, is shown in Fig. 5(b).

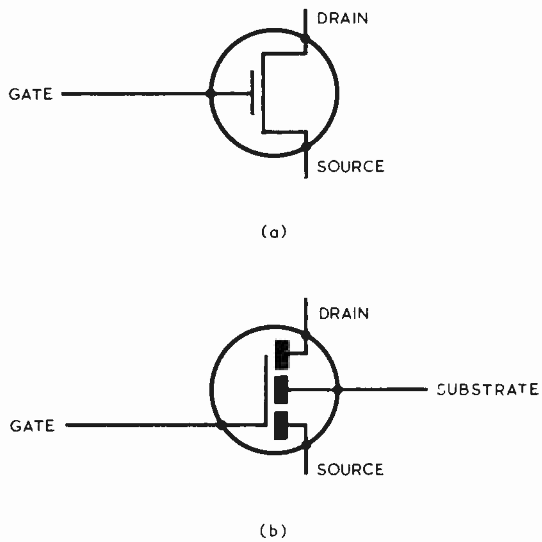


Fig 5 (a). Symbol for an enhancement mosfet (b). Another symbol employed for this type of f.e.t. An arrow may be added to the substrate connection to indicate channel polarity, as in Figs. 4 (c) and (d)

SOME COMPARISONS

A lengthy discussion of the various attributes of the two basic types of f.e.t. and ordinary bipolar devices would be out of place but some important points must be brought out.

It has already been pointed out that the f.e.t. has a high input impedance which can be anything from 100 to 100,000 MΩ shunted by 1 to 10 pF. The f.e.t. has an output impedance similar to that of the bipolar transistor but, of course, the input impedance of the latter device is more typically 1kΩ shunted by a higher capacitance. For a typical jugfet type MPF105, an input capacitance of 4.5pF would be representative.

Looking at the mosfet we note that the device is capable of handling large positive and negative input swings without degredation of the input impedance due to diode current loading—this is very useful when a.g.c. is involved. Indeed the mosfet can offer a useful low noise amplification up to 250MHz. A typical R.C.A. device type 40603 has a 24dB power gain at 100MHz. The reverse transfer capacitance for a mosfet is typically 0.02pF compared with the jugfet 1.5pF. Because of these features, together with the advent of the dual-gate mosfet which features two separate channels each having an independent control gate, the mosfet is an attractive r.f. amplifier and mixer. Indeed the dual-gate device has applications as product detectors, balanced modulators and in colour demodulation circuitry, and as a bonus no neutralisation is required.

On a practical note, static charges produced when handling the device can cause permanent damage to the mosfet gate insulation although most modern devices have protection diodes connected to the gate to prevent damage.

We can see that mosfets are an attractive proposition to the designer of v.h.f. front ends and the like. Why do we not see the jugfet in common usage as a Class A low level amplifier more often than we do? If we consider a widely used jugfet such as the 2N3819, then without selection of devices one would have to compensate for a 10 to 1 variation in drain current which, with a self-biasing stage, is a bit tricky.

If we turn back to the jugfet's high input impedance, however, we find a very useful feature indeed. In general, with very large values of source resistance the noise performance of an f.e.t. can be better than that of a transistor. From this it will be realised that with transducers such as the ceramic or crystal pick-up type, the f.e.t. could offer some useful advantages.

Armed with this information we will look at a practical circuit for a buffer amplifier for use with a ceramic cartridge.

PRACTICAL CIRCUIT

The simple circuit of Fig. 6 uses the jugfet in a source follower configuration which is similar in many ways to the emitter follower configuration given with bipolar transistors. The input impedance is substantially constant at 2MΩ from 15Hz to beyond 20KHz and the output impedance, with the 10μF coupling capacitor C2, is 500Ω at 1KHz. The voltage gain is just a little less than unity and the stage will handle signal swings of up to 2V peak to peak. The current consumption of the stage is some 1.5mA but will vary somewhat with individual f.e.t.'s dependent on manufacturing spreads.

The circuit is useful as a buffer stage between any high impedance transducer such as a crystal microphone

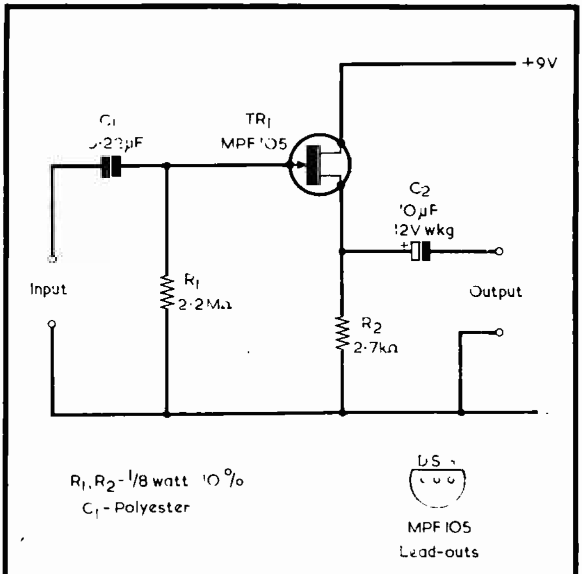
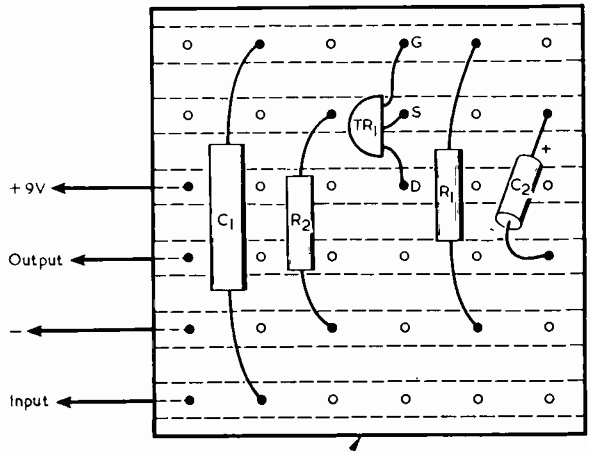


Fig. 6. Buffer amplifier for coupling a crystal microphone or a crystal or ceramic pick-up cartridge to an amplifier

or a ceramic cartridge. It is quite well known that these devices need to operate into a high impedance if the low frequency response is not to suffer. Because the circuit of Fig. 6 is so simple the entire array of components may be assembled in close proximity to the transducer; with a crystal microphone often within the case of the microphone itself. A simple Veroboard layout is shown in Fig. 7 and, as can be seen, using the 0.15 matrix board, the entire circuit less the battery only occupies a square inch or so.



Veroboard (0·15" matrix)

Fig. 7. The components for the buffer amplifier may be mounted on a piece of Veroboard about 1 in. square. This diagram shows the component side of the board

The output impedance is low, as already stated, and therefore the output signal may be passed along quite a long length of cable without hum problems.

On a practical point, it should be noted that the usual heat shunt was applied when soldering the f.e.t. into circuit and, as an added precaution, the iron was unplugged from the mains supply to ensure that high static voltages were not inadvertantly applied to the gate. This is a 'rather be safe than sorry' tactic and with jugfets is usually unnecessary.

DEPLETION LAYER

Before concluding, let us deal briefly with the all-important depletion layer, since this facet of transistor physics is not always fully understood.

What happens when p and n type materials are in close contact? If we take separate p and n type crystals and make their sufaces as flat as possible and then press them together the desired results expected of a p-n junction are not obtained. Instead both parts have to be grown in one crystal and opposite impurities introduced so as to form zones with a junction between them. With no external connections made to the zones, electrons in the n zone cross the junction into the p zone, which is almost void of electrons. Similarly holes in the p zone diffuse into the n zone. Both of these migrations form a conventional positive current flow from p to n. A so-called 'potential barrier' is formed and a balance is established when the barrier is just sufficient to counteract the tendency to diffuse. The important bit is that we now discover that the migrating charges uncover, as it were, fixed ions—the atoms of impurities in the crystal lattice which have an electron each too many or too few. Therefore, at the junction a thin layer with fewer mobile charges than elsewhere exists. In consequence in the neighbourhood of the junction there is a small surplus of fixed charges which constitutes the depletion layer. In a conventional bipolar transistor the layer is only thousandths of a millimetre thick but in the f.e.t. it is the growth of this layer into the channel which gives the device its fundamental properties. ■

SWITCH ABBREVIATIONS

There is, inevitably, a continual flow of newcomers to the hobby of radio construction, and it behoves the more experienced amongst us to do the courteous thing every now and again and explain points that to the initiated are obvious, but which are nevertheless very confusing for the novice.

One of the matters which perplex beginners has to do with the abbreviations employed for switches. These components are often referred to by the abbreviations 'd.p.s.t.' and the like, and for those who are not in the know these references can be mystifying, to say the least.

The four switch descriptions which are presented in abbreviated form are 's.p.s.t.', 's.p.d.t.', 'd.p.s.t.' and 'd.p.d.t.'. The letters 's.p.s.t.' stand for 'single-pole single-throw' and they refer to a switch which has two contacts only. On one position of the switch these contacts are open whilst on the other position of the switch they are closed. That simple on-off electric light switch on the wall is an s.p.s.t. switch.

The abbreviation 's.p.d.t.' means 'single-pole double-throw'. This applies to a switch whose arm (the moving contact) connects to one fixed contact in one position and to another fixed contact in the alternative position. A switch of this nature is also frequently described as a 'changeover' or 'c.o.' switch.

Some switches have two separate arms insulated from each other which move together as the switch is actuated, and these are the double-pole types. The contraction 'd.p.s.t.' stands for 'double-pole single-throw'. In one position the two arms connect to two separate fixed contacts whilst, in the other position, both sections of the switch are open. Finally, 'd.p.d.t.' refers to 'double-pole double-throw'. A d.p.d.t. switch is merely two s.p.d.t. switches ganged together, as it were.

These abbreviations are normally applied only to toggle and slide switches. They may occasionally be applied to simple 2-position rotary switches if these carry out the corresponding switching action. Normally, however, rotary switches offer more complex functions, and these are referred to by such terms as '3-pole 4-way' and so on. A 3-pole 4-way rotary switch has 3 moving arms and 4 positions.

A very popular type of switch is the miniature rotary model having 12 fixed contacts. These switches are mass-produced and individual versions have variations in the moving arm section and in the stop mechanism which limits spindle rotation. All versions of the switch have the 12 fixed contacts, whereupon the switches are made up to employ all these and are available as 1-pole 12-way, 2-pole 6-way, 3-pole 4-way and 4-pole 3-way. Because of their low price it is often economic to employ miniature rotary switches in circuits where not all the poles (or arms) are used. Thus, if one required a 2-pole 4-way switch, one could use a 3-pole 4-way miniature rotary switch and merely make connections to two of the poles and their fixed contacts only. The remaining pole and fixed contacts are simply ignored. ■

Trade News . . .

P.C.B. MARKING PENS

Decon Dalo P.C.B. Marking Pens, until now sold in dozens, and therefore restricted more to the larger electronics companies, are now available in half-dozens and single units, making them ideal for the smaller engineering department and laboratory engaged in small-scale and prototype p.c.b. production, and for the home amateur.

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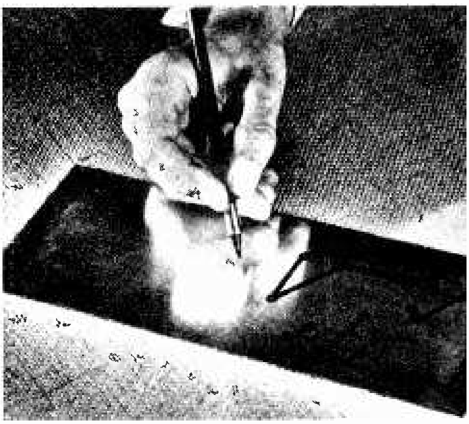

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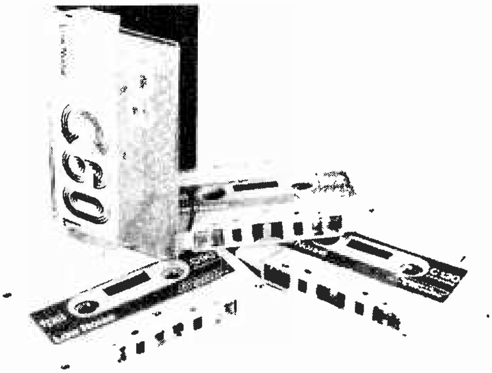

Fraser Peacock Associates Limited, the Wimbledon based audio-visual organisation have announced that demand for the range of compact cassettes which the company launched three months ago has "exceeded everyone's most optimistic forecasts".

The cassettes are available in 60, 90 and 120 minute versions.

David Tuckman, a director of Fraser Peacock Associates, said: "It was a logical development for us to go into our own brand compact cassettes since an increasing part of our business over the last few months has been in the tape duplicating field. Our cassettes do have a tremendous price advantage, and they are also fully guaranteed".

ELECTRONICS KIT FOR STUDENTS

Limrose Electronics have announced their new Electronics Kit which has been specially developed to meet the requirements of the Nuffield 'A' Level Physics course.

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All modules measure 124mm × 124 mm × 50mm and require 4mm patch leads fro making interconnections.

In addition to the Basic Unit, Lamp Indicator, Switch (contact-bounce free), AND Gate, Multivibrator, Bistable and Beam Splitter Modules required to make up the Nuffield Starting and Working Kits, a number of extension modules such as Digital Readout, Triple Lamp and Binary Counter are available.

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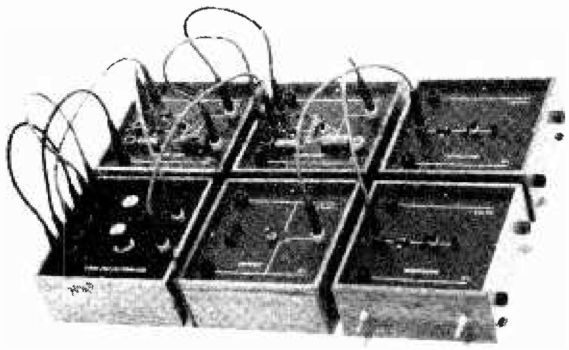
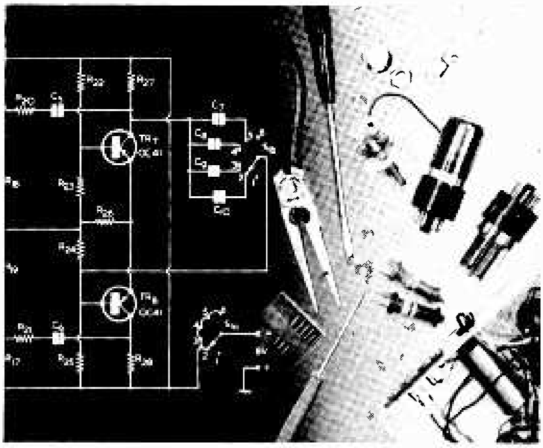
Further information from Limrose Electronics Limited, 8–10 Kingsway, Altrincham, Cheshire, WA14 1PJ.



D.C. VOLTMETER

by G. A. FRENCH



THE DEVICE WHICH FORMS THE subject of this month's 'Suggested Circuit' article is a d.c. voltmeter having a sensitivity of 200kΩ per volt. This is, of course, a much higher sensitivity than is provided by a standard testmeter, and it corresponds to a current, at full-scale deflection, of 5μA. A feature of the circuit is that it can be made up, in one version, with standard 5% resistors in the input section. It incorporates a readily obtainable integrated circuit operational amplifier.

CIRCUIT PRINCIPLE

To appreciate the basic manner in which the voltmeter functions it will be helpful to commence by examining Fig. 1(a). This diagram shows an operational amplifier, depicted by the triangle, with connections applied to it under theoretical conditions. The inverting input is identified by a minus sign and the non-inverting input by a plus sign, whilst the output appears at the right-hand apex of the triangle. R2 is a resistor applying negative feedback to the inverting input of the op-amp and R1 is a resistor in series between this inverting input and the input to the complete circuit. It is assumed that the source of input voltage has zero internal resistance. Under these conditions the voltage gain offered by the complete circuit is R2 divided by R1.

In Fig. 1(b) we use the circuit of Fig. 1(a) to function as a voltmeter. Across the output from the op-amp is connected a current reading meter in series with a pre-set variable resistor, the pre-set resistor being set up such that the meter reads full-scale deflection when the voltage at the op-amp output is 1 volt. R2 and R1 are given the values shown. Since both these resistors have the same value, R2 divided by R1 becomes equal to unity, and the voltage gain of the complete circuit is similarly unity. If, therefore,

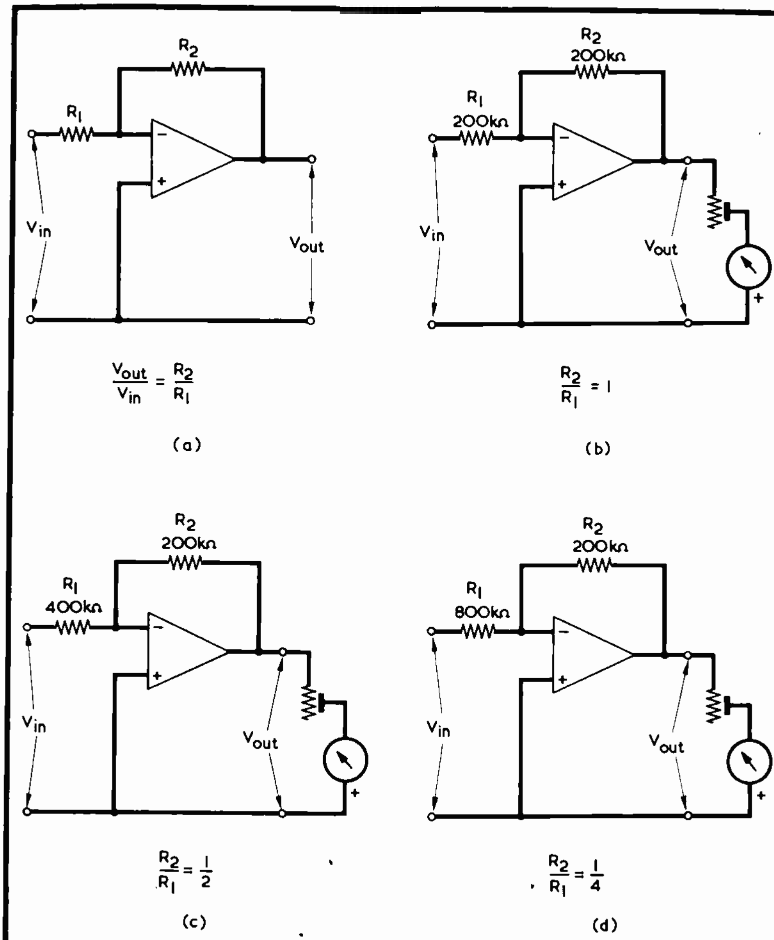


Fig. 1 (a). Basic operational amplifier circuit with feedback
(b). Amplifier circuit offering a voltage gain of unity
(c). An amplifier whose voltage gain is one-half
(d). Here, the voltage gain is one-quarter

we apply a voltage of 1 volt to the input, the output will also be 1 volt, and the meter will read full-scale deflection. The polarity of the input voltage is such that the upper input point is positive. Since this point is coupled to the inverting input of the op-amp, the op-amp output will be negative. This output polarity corresponds with the polarity ascribed to the meter in Fig. 1(b).

We turn next to Fig. 1(c), in which the conditions are the same as before, except that R1 has been increased to 400kΩ. R2 divided by R1 and, hence, the voltage gain of the circuit, is now one-half, and it follows that an input voltage of 2 volts will cause an f.s.d. reading to be given in the meter. In Fig. 1(d) R1 is increased to 800kΩ, whereupon the gain of the complete circuit becomes equal to one-quarter. The input voltage which produces f.s.d. in the meter is now 4 volts.

It will be obvious that we have, in Figs. 1(b), (c) and (d), an embryo voltmeter having a sensitivity of 200kΩ per volt. As has been demonstrated, the voltmeter is capable of giving an f.s.d. reading for any input voltage provided that the value of R1, in kilohms, is 200 times that voltage. A further point which may now be taken into consideration is that the inverting input of the op-amp is a 'virtual earth', since its potential varies by a negligible amount despite large shifts in the input voltage applied to the complete circuit. The circuit becomes, in consequence, a true voltmeter because the right hand end of R1 terminates in a point which is, to all intents and purposes, connected to the lower input terminal by zero resistance. The circuit responds, nevertheless, to the current which flows in R1, and this current is the applied voltage divided by R1.

It is assumed here that, for zero input and zero output voltage, the inverting input of the op-amp is at the same potential as the non-inverting input. In practice there is a small offset voltage but, with the integrated circuit which is employed in the practical version, this is of the order of a few millivolts only, and should not noticeably influence circuit operation.

Brief mention of a minor point of detail may be included here for the benefit of newcomers to voltmeters of this nature. It was said, when Fig. 1(d) was discussed, that an applied voltage of 4 volts results in an f.s.d. reading in the meter. An input voltage of 2 volts will result in a half f.s.d. reading, and an input voltage of 1 volt will give a reading of a quarter of f.s.d. Thus, the arrangement of Fig. 1(d) is capable of measuring all voltages up to 4 volts. Similarly, the arrangement of Fig. 1(c) can measure voltages up to 2 volts and that of Fig. 1(b) voltages up to 1 volt.

Returning to the main theme, we may next consider R2. At first sight it might appear that this needs to be a close tolerance component, but such is not the case and a standard 5% resistor will be quite suitable here. If the resistor employed happens to be, say, on the upper limit of its tolerance, at 210kΩ, all the gain figures shown in Figs. 1(b), (c) and (d) become multiplied by a factor of 210 divided by 200. This discrepancy is taken up, quite simply, by adjusting the variable resistor in series with the meter accordingly. The variable resistor now becomes a 'Calibrate' component. The circuit of Fig. 1(b) could then be used to set it up, a known voltage of 1 volt being applied to the input of the complete circuit and the variable resistor then adjusted to give an f.s.d. reading in the meter. The circuit will still, under these circumstances, give its 200kΩ per volt performance. It is possible, even, to dispense with close tolerance resistors in the R1 position, the variable resistor in series with the meter being again adjusted to take up any discrepancies introduced thereby. This point is discussed at the end of the article, when a second version of the input circuit is discussed.

A final design point is concerned with that fact that it has been assumed up to now that the device, functioning as a voltmeter, gives an f.s.d. reading in the meter when the output voltage from the op-amp is nominally 1 volt. This assists in the explanation because it enables simple figures to be employed. But it would be possible to adjust the variable resistor in series with the meter to a setting which gave an f.s.d. reading for 0.5 volt, 2 volts, 5 volts or any other voltage, within reason, at the output of the op-amp. The complete circuit would still be capable of functioning as a voltmeter although, of course, it would then be necessary to recalculate the value of R2 to obtain an input sensitivity figure of 200kΩ per volt. It so happens, however, that in addition to easing the description of circuit operation, the nominal 1 volt figure represents a satisfactory practical value to work to, and it also enables a simple meter protection circuit incorporating two silicon diodes to be employed.

WORKING CIRCUIT

The full working circuit of the voltmeter is given in Fig. 2. In this diagram R1 of Fig. 1 is replaced by whichever of R1 to R4 is switched in by the Range switch S1. R2 of Fig. 1 reappears in Fig. 2 as R7. The pre-set variable resistor and meter are now given by VR2, R8, R9 and M1. The two silicon diodes just mentioned are D1 and D2.

The integrated circuit is an ML741C and the numbers around its outline correspond to the 14 pin dual-in-line tag layout shown in the inset. Pin 4 of the i.c. is the inverting input and pin 5 the non-inverting input. Pin 11 is the connection for the positive supply and pin 6 is the connection for the negative supply. The similarity with Fig. 1 becomes very noticeable when it is remembered that the only major change introduced in Fig. 2 is the introduction of the battery supply which, of course, the i.c. must have in any case if it is to operate. The non-inverting input at pin 5 is not now returned to the 'zero line' as in Fig. 1, but to the potentiometer given by R5, VR1 and R6 connected across the supply lines. VR1 is the Set Zero control and it is adjusted for a zero reading in the meter when there is no input voltage at the test terminals, thereby causing the circuit to be balanced and taking up such things as differences in the voltages of the two batteries.

S1 provides four ranges, these being 0-1V, 0-2.5V, 0-10V and 0-25V. The corresponding series input resistors have values of 200kΩ, 500kΩ, 2MΩ and 5MΩ respectively. These values are each 200kΩ multiplied by the f.s.d. voltage figure of the corresponding range. Should it be desired to have ranges in the series 0-1V, 0-3V, 0-10V, etc., the series resistor for the 0-3V

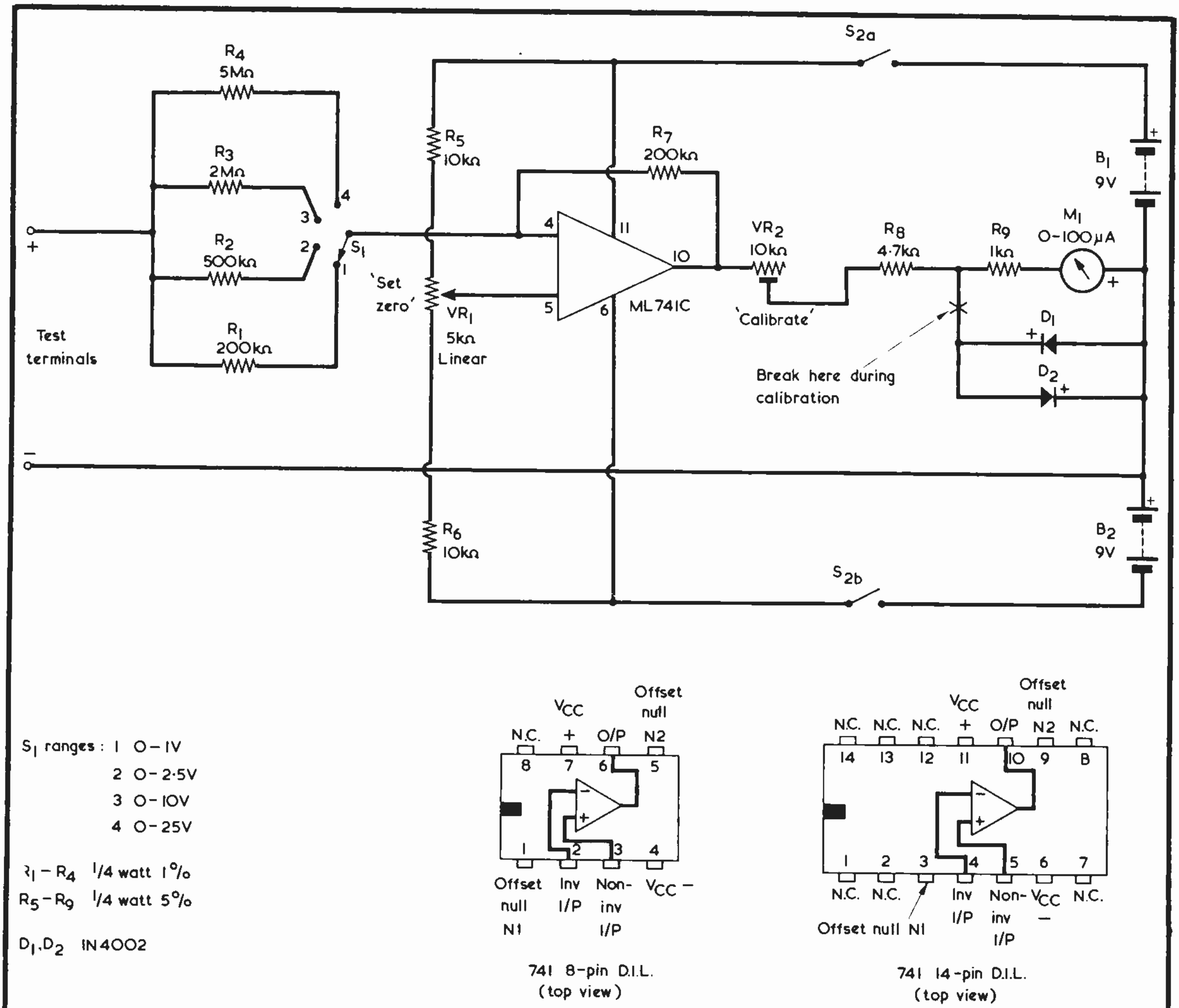


Fig. 2. Complete working circuit of the integrated circuit voltmeter

range would be 600kΩ. Any other ranges within reason can be incorporated by employing the appropriate multiplying factor for the series resistance required. In this version of the input switching circuit the series resistors should all have a tolerance of 1%.

In the meter section, diodes D1 and D2 provide protection when the voltage across the meter and R9 approaches the voltage at which forward conduction in the diodes takes place.

The ML741C integrated circuit was obtained from Henry's Radio, Ltd., by which firm it is advertised as a '741C (DIL)'. This i.c. has the 14 pin dual-in-line pin configuration shown, the rectangular identifying point between pins 1 and 14 being replaced by a paint dot. Other integrated circuits of the 741 type, such as SN72741, μA741, etc., could be employed instead, but it should be mentioned that the author has only checked the circuit with the i.c. obtained from Henry's Radio. Some versions of the 741 are available in 8 pin d.i.l. and the tag layout of this type is included in Fig. 2. Note that both tag layouts are top views, with the pins pointing away from the reader.

The 741 is a development from the earlier 709 op-amp, and is a particularly useful i.c. for amateur experimental and constructional projects since it has its own internal compensation and does not require any external capacitors to maintain stability. ('Compensation' defines the process where capacitance is employed to prevent instability in an i.c. due to excessive amplification at high frequencies). As will be seen from Fig. 2 it is necessary to make only five connections to the i.c. Also, the only components external to the i.c. are those which are directly involved in voltmeter operation. It is, incidentally, possible to obtain fine control of offset voltage by suitably connecting a potentiometer to the two 'offset null' pins, but this is not needed in the present design and no connections are made to these pins.

COMPONENTS AND CONSTRUCTION

Of the components, the series input resistors and the integrated circuit have already been discussed. VR1 is a panel-mounted potentiometer, whilst VR2 is a pre-set skeleton component. S2(a) (b) should be a double-pole toggle switch. The current drawn from each battery is 2mA only, and any small 9 volt batteries can be employed. They should be of the same type and both should be discarded at the same time when exhausted. The voltmeter should not be operated with one battery new and the other nearly exhausted. Diodes D1 and D2 can be any small silicon diodes or rectifiers. The author employed 1N4002's, which happened to be on hand.

All the components may be housed in a small case with VR1, S1, S2, M1 and the test terminals on the front panel. Wiring layout is not critical provided that R7 is fitted close to the i.c., and the i.c. output lead does not too closely approach the wiring to the two i.c. inputs. The connection between the junction of R8 and R9 and the junction of the positive lead-out of D1 and the negative lead-out of D2 should be of a temporary nature, as it is broken during the process of calibration. The author found it helpful to employ a d.i.l. holder for the i.c., wiring this up first and then inserting the i.c.

Calibration of the completed unit consists of checking it against another voltmeter, using the method shown in Fig. 3. In this diagram, the potentiometer should have a value which causes some 5 to 10mA to flow through its track. Thus, with a 12 volt battery the potentiometer could have a value of 2kΩ. Any suitable range is selected by S1 and the i.c. voltmeter is then switched on with VR1 slider at mid-track. VR1 is next adjusted for zero reading in the meter with the two test terminals short-circuited. The test terminals of the i.c. are then applied to the potentiometer shown in Fig. 3, after which that potentiometer is adjusted to give the f.s.d. value of the range selected, as indicated by the monitoring voltmeter. VR2 is then adjusted for f.s.d. in the i.c. voltmeter. After one range has been set up in this manner, all the other ranges will be correct.

Next, the i.c. voltmeter is switched off and D1 and D2 are disconnected from R9 and M1 as indicated in Fig. 2. The i.c. voltmeter is then switched on again. If the meter gives the same reading as before, all is well, and no further action is required other than the permanent connection of D1 and D2 into the circuit. If on the other hand, the meter gives a higher reading with D1 and D2 disconnected, the value of R9 will have to be reduced experimentally until D1 and D2 have no effect on meter reading. Each change in the value of R9 necessitates a re-setting of VR2. The check with D1 and D2 is desirable because a few 0-100μA meters have relatively high internal resistance, and the voltage dropped across the meter and R1 may conceivably just fall within the level at which some diodes commence to pass forward current. It is improbable that this effect will be present in most units made up to the circuit, but it is worthwhile carrying out the check nevertheless.

ALTERNATIVE INPUT CIRCUIT

As was mentioned earlier, it is possible to dispense with close tolerance resistors in the input circuit, as discrepancies from the nominal resistance can be taken up by adjustment of the Calibrate potentiometer, VR2. An alternative input circuit employing 5% fixed resistors is illustrated in Fig. 4. The three pre-set potentiometers in this circuit may all be skeleton types.

The circuit of Fig. 4 is set up by selecting Range 4 and connecting the unit to a source of voltage, monitored by another voltmeter as in Fig. 3, which is equal to f.s.d. value (i.e. 25V) on this range. VR2 is then set up for full-scale deflection in the meter. The test voltage is then reduced to the f.s.d. value for Range 3, Range 3 is selected, and the pre-set potentiometer in the Range 3 input circuit adjusted for an f.s.d. reading. The process is repeated with Range 2 and Range 1, after which the setting of the voltmeter is complete.

With the input circuit of Fig. 4, the input resistance of the i.c. voltmeter is not exactly 200kΩ per volt but only nominally so. If it should happen that the 5MΩ resistor is on the lower limit of its tolerance, at -5%, then the input resistance is 200kΩ -5% per volt.

If ranges other than those shown in Fig. 4 are to be used, the values shown in this diagram may be changed accordingly. The single fixed series resistor in the input circuit should be that which is selected on the highest voltage range, since this means that the pre-set potentiometers will then, assuming a reasonable choice of ranges, be required to have values of 1MΩ or less.

It should be mentioned that it may be a little difficult to obtain close tolerance 1% resistors having values higher than 1MΩ, whereupon some of the resistors in the input circuit of Fig. 2 will need to be made up of a number of single close tolerance resistors in series. The alternative input circuit of Fig. 4 may, in consequence, be more attractive than that of Fig. 2, even though it does require three pre-set potentiometers.

The experienced constructor with a good stock of resistors may be able to make up the lower range series resistors in Fig. 4 by experimental selection, if necessary 'trimming up' individual resistances by inserting small value resistors in series. This process dispenses with the pre-set potentiometers.

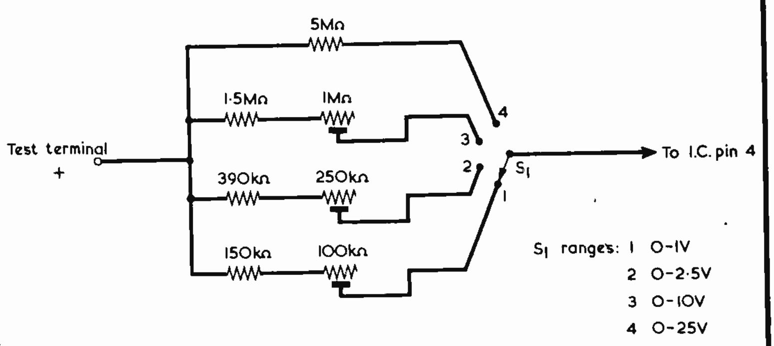


Fig. 4. An alternative input circuit which does not require close tolerance resistors

RESULTS WITH THE PROTOTYPE

The prototype circuit gave an acceptable performance with good linearity over each range. It was found that the Zero Set control did not have to be re-set frequently, this being particularly the case when the batteries had settled down to a steady voltage, as opposed to the high voltage given in the brand-new state. Although it is preferable to have the test terminals short-circuited when adjusting the Zero Set control, it was found that this was not essential and that the meter reading remained at zero after the short-circuit had been removed. This indicates a high level of basic stability in the circuit, a factor which is not always evident in what are sometimes described as 'electronic voltmeters'.

As was stated earlier, the current drawn from each battery was 2mA only. ■

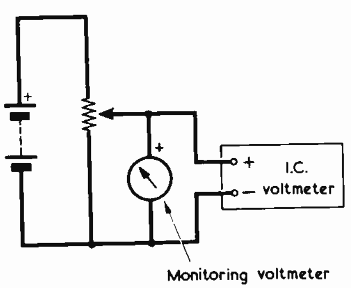


Fig. 3. The set-up required for calibration

NEWS . . . AND .

EMI LOCIC PROBE CHOSEN AS STANDARD TEST DEVICE FOR ROYAL NAVY USE

The LP 500/1 probe is pictured here in use during final testing of the data processing units at the division's Hayes, Middlesex, plant.

Following its introduction 18 months ago, EMI's 5 volt logic probe – the type LP.500/1 – has now entered service with the Royal Navy under NATO number 6625-99-119-2584. The probe has been specified as standard test equipment for use with data processing equipment fitted in RN ships.

Both the probes and data processing units are being manufactured by EMI Electronics' Radar & Equipment Division, Hayes, Middlesex, and form part of a special purpose range of equipment covered by contracts with EMI totalling over £1 million.

Designed for testing DTL and TTL circuitry, the LP.500/1 probe can detect seven different types of logic signal, including the important 'open circuit' condition, which are identified by the lighting sequence of the probe's opal lame. The 18cm long device enables rapid functional tests to be carried out without the need for expensive test equipment such as oscilloscopes. In many instances, the probe can be used to trace faults in less time than by employing an oscilloscope.

The EMI probe distinguishes between logic 1, logic 0, open circuit, +ve going pulses, –ve going pulses, square waves below 1MHz approx and pulse trains (including square waves) with a pulse recurrence frequency above 1MHz approx. It can be powered by the equipment under test, from a 4.5V battery or from a standard bench power supply.

To check that the probe is operating correctly, the 'open circuit' indication – a steady light for a.c. mode and a flashing light for d.c. – remains on until effective contact is made with the circuit under test. The device is protected against overload from input voltages up to ± 100V and no damage can result from supply polarity reversal.

NEW SOUND LEVEL METER

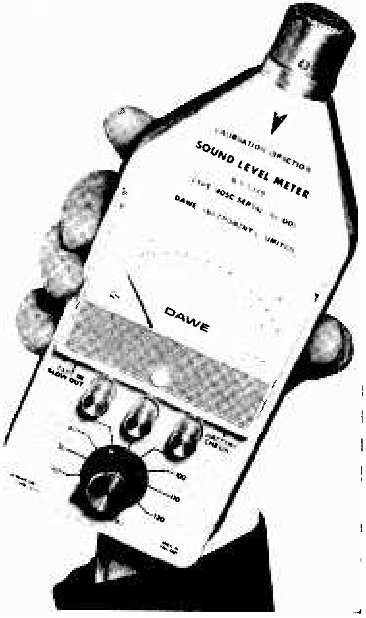
A Code of Practice for reducing the exposure of employed persons to noise has recently been announced by the Department of Employment.

To coincide with this important publication, which affects every noisy factory and office in the country, Dawe Instruments Limited, the leading British Manufacturer of noise measuring equipment, announce a new instrument, the Type 1405C Sound Level Meter, as a further addition to the already established and widely accepted Dawe range.

The Sound Level Meter Type 1405C provides a direct reading of sound level over the range 34dB to 130dB(A). The instrument consists of a ceramic microphone, weighting network, attenuators, high-gain amplifier, and an indicating meter. The highly stable and robust microphone is substantially non-directional; ageing and temperature effects are negligible.

The internationally standardised A-weighting frequency response is used because it provides measurements which correlate best with subjective noise ratings and is widely recommended for measurements relevant to hearing conservation and noise annoyance checks.

The instrument is battery powered, giving a typical operational life of 80 hours. The complete unit, with battery, weighs less than 2lb and may be easily held in one hand. A carrying case is available as an optional extra.



IEE TRAVELLING SCHOLARSHIP

An IEEE travelling scholarship of £300 is offered for visit(s) to foreign electrical or electronic research or manufacturing establishments by a postgraduate student.

The purpose is to promote an exchange of research and technological ideas and to foster a closer relationship between young engineers in different countries.

Candidates must submit a programme for their visit(s) by 31st December 1972, and the award will be made to the candidate whose programme is judged most likely to promote the objects of the scholarship.

The scholarship is financed by the UK and Republic of Ireland Section of the Institute of Electrical and Electronics Engineers, which is acting in collaboration with the Institution of Electrical Engineers and the Institution of Electronic and Radio Engineers. Entrants must be Student or Graduate Members of one of these three institutions.

Further information and entry forms from:

Prof. C. W. Turner
Dept. of Electrical & Electronic Engineering
King's College
Strand
London WC2R 2LS.

. . . COMMENT

ELECTROVALUE EXPANDS

David Longland started Electrovalue seven years ago, running his business from his home in Ascot. Before long he moved to comparatively larger premises, where in a partitioned off corner of somebody else's workshop, he took on staff and produced his first catalogue. Business increased and when a butcher's shop in Englefield Green became vacant, he moved in. More staff was taken on, and a teleprinter and a microfilm system were then installed. Now orders are individually microfilmed and the customer's original order returned with the goods for him to check for himself.

Electrovalue next installed an elaborately programmed full-size computer, programmed to provide stock control and processing information for instant stock position details and forcasting forward renewal requirements. Now with Electrovalue's latest catalogue packed with thousands of different items, the computer's services have become vital.

Electrovalue's latest 96 page catalogue, No. 6 already in its 3rd printing, is typical of the thoroughness with which the company operates. It includes I.C. circuit and connection diagrams, semi-conductor outlines and considerable technical information, it is a most useful handbook for the home constructor as well as full time electronics worker; the catalogue now includes a purchase refund voucher for the 25p it costs to buy. Everything is brand new and sold in accordance with manufacturers' specifications.

Today, Electrovalue service customers all over the world, and behind the facade of what appears to be a little village shop at 28 St. Judes Road, Englefield Green, Egham, TW20 0HB, is a complex specialist organisation geared, by use of some of today's most modern methods, to give good service to everyone.

UK 2M BAND PLAN

A special meeting of the RSGB VHF Committee was held on 11th October at which *The Short Wave Magazine* and the RSGB Raynet and Mobile committees were represented.

Subject to the approval of Council of RSGB, it was agreed to recommend that the following band plan be adopted:

(a) the existing UK 2M band plan as published should be retained i.e. with specified geographical Zones and Mode frequencies.

(b) the following FM channels should be added to the band plan:

Zone A	FM Working	144.40 MHz
Zone B	FM Working	144.80 MHz
Zone C	FM Working	145.20 MHz
Zone D	FM Working	145.60 MHz
FM Calling – National		144.48 MHz

It was agreed to leave open the question of repeater channels until the end of the one-year experimental period with GB3PI currently operating on 145.15/145.75 MHz in conformity with the Region1 Band Plan.

Those who have submitted views to the Committee are thanked for their valuable contributions. These were used as the basis of the discussion.

QUOTE

"The BBC is an institution – a great institution, which can still to-day both inspire deep loyalty and provoke strong criticism. It has moved a long way from 'the Reith Era', 'the Golden Age of Radio' and the days of 'Auntie'. It has even moved on from pastures 'greene' and is tackling new horizons in this immensely challenging age."—Sir John Eden

IN BRIEF

● A new "Guide to Enthoven Solders & Fluxes" is now available upon application, from Enthoven Solders Ltd., Dominion Buildings, South Place, London, EC2M 2RE. It is designed as a "Pocket Guide" for reseach and production engineers.

● Following full stability tests, the Post Office has accepted the Ferranti microwave telecommunications equipment linking the Isles of Scilly with the mainland.

● Levell Electronics Ltd of Moxon Street, Barnet, Herts, have added to their range of portable electronic instruments a D.C. Microvoltmeter type TM10.

● A.P.T. Electronic Industries Ltd, of Byfleet, Surrey, have produced a two-page leaflet on their new TRU range of d.c. power supplies.

● A new inexpensive magnetron announced by Mullard has been developed for use in low-cost, small-boat radar equipment. Type YJ1390, it operates with a low anode voltage of only 2kV.

No Sir, as far as I know there is no publication called Radio & Electronics Destructor

HIGH-GAIN SILICON REFLEX RECEIVER

by
G. W. Short

A sensitive 2-transistor receiver which requires few components and which can be adapted for a wide range of speaker impedances and battery voltages.

A FEW YEARS AGO THE 'RADIO CONSTRUCTOR' PUBLISHED the writer's design for a simple but effective reflex t.r.f. receiver using silicon planar transistors. This proved to be a reliable circuit with a good performance. Several modifications have appeared, including a low-consumption version for use with a crystal earpiece and a version with an f.e.t. input stage.*

The receiver described here is a new and improved version of the original circuit. Like the original, it has been kept very simple and straightforward. Nevertheless, it has proved possible to obtain a very useful increase in r.f. gain, and to provide enough audio output for low-volume loudspeaker listening indoors. The new circuit works from a 3 volt battery and is easily adapted to other voltages.

CIRCUIT DETAILS

Referring now to the circuit diagram, which is shown in Fig. 1, the heart of the receiver is a 2-stage amplifier with direct coupling between stages and d.c. negative voltage feedback to stabilize the operating conditions of the two transistors. Each transistor operates as a common-emitter amplifier to both a.f. and r.f. signals, giving very high overall gain.

R.F. signals picked up by the ferrite rod aerial L1 are stepped down and applied to the base of TR1 via L2, whose lower end, in the circuit diagram, is earthed to r.f. by C2. At the output of the 2-stage amplifier the r.f. signals are picked out and stepped up in voltage by an r.f. transformer (L3, L4) and applied to the detector D1, this being a point-contact germanium diode. The audio signals which appear across the detector load R4 (which is also the volume control) are fed back to TR1 and are then amplified by both transistors before application to the directly driven 75Ω loudspeaker.

A d.c. bias is applied to the diode by R5, which bleeds a little of the emitter current of TR2. Negative feedback at d.c. is taken via R4 from the emitter of TR2 to the base of TR1.

CONSTRUCTION

There is nothing special about the ferrite rod aerial and tuning capacitor C1. The prototype employed a 300pF Jackson Bros. 'Dilemin' tuning capacitor. This covers the medium wave band when L1 consists of about 70 turns of 5/46 litz wire close-wound on a paper former at the centre of a 4in. by ⅜in. ferrite rod. The secondary winding has 4 turns of insulated wire wound over the earthy end of L1. The precise gauge of wire is not important. (A suitable rod is available from Amatronix Ltd., 396 Selsdon Road, S. Croydon, Surrey, CR2 0DE. The same company also stocks wound rods to suit a 300pF tuning capacitance, but the secondary has too many turns for this receiver and six turns should be removed.)

The r.f. transformer L3, L4 is made by winding 50 turns of 32 s.w.g. enamelled, silk or cotton insulated wire on top of the existing winding of a 2.5mH r.f. choke,

* G. W. Short, "Silicon Transistor Reflex T.R.F.", *The Radio Constructor*, January 1968; G. W. Short, "Milli-watt' Silicon Reflex T.R.F. Receiver", *The Radio Constructor*, September 1969; A. W. Whittington, "F.E.T. Reflex Receiver", *The Radio Constructor*, August 1971.

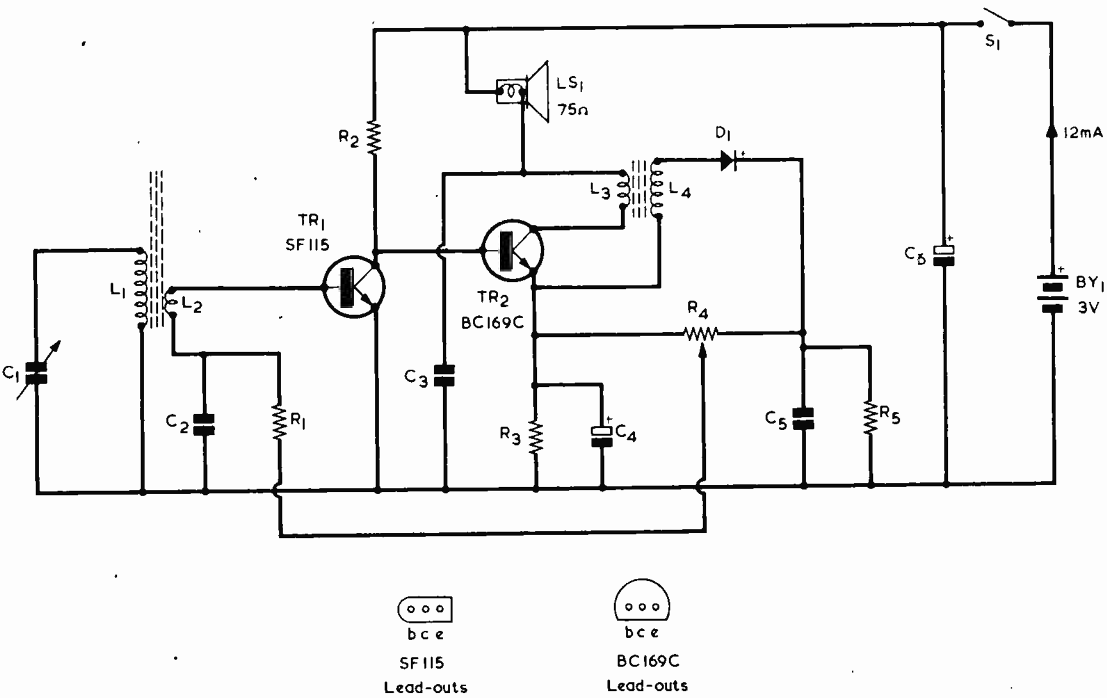


Fig. 1. The circuit of the high-gain silicon reflex receiver

COMPONENTS

Resistors
(All fixed values $\frac{1}{10}$ watt 10%)

R1	3.3kΩ
R2	1.2kΩ
R3	68Ω
R4	10kΩ potentiometer, log track
R5	22kΩ

Inductors

L1, L2	Windings on 4in. × ⅜in. ferrite rod (see text)
L3	Overwind on L4 (see text)
L4	R.F. choke type CH1 (Repanco)

Semiconductors

TR1	SF115
TR2	BC169C
D1	OA90

Capacitors

C1	Tuning capacitor, to suit L1 (see text)
C2	0.1μF
C3	0.1μF (see text)
C4	320μF electrolytic, 2.5 V.Wkg.
C5	0.01μF
C6	125μF electrolytic, 4 V.Wkg. (see text)

Switch

S1	s.p.s.t. switch (may be ganged with R4)

Loudspeaker

LS1	75Ω approx. (see text)

Battery

BY1	3 volt battery

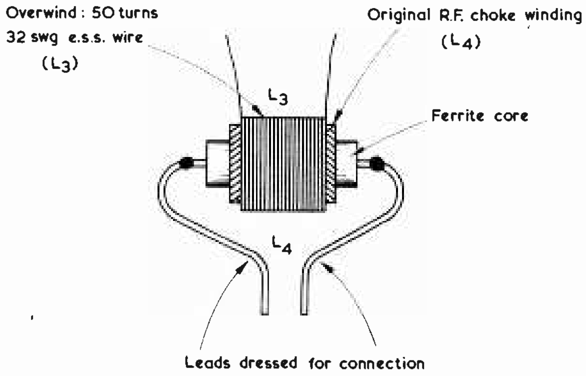


Fig. 2. Making up the r.f. transformer L3, L4

Repanco type CH1. See Fig. 2. Do not use a different kind of choke – it may not be suitable for the present purpose. The gauge of wire used for the added 50-turn winding is not important and any moderately fine insulated wire may be used. The winding may be 'scramble-wound'.

A wiring diagram is given in Fig. 3. Apart from L1, L2, all the components may be fitted to a small piece of insulating material fitted with a front panel, on which are mounted C1, R4 and S1. The components may be anchored to metal pins or tags at the positions indicated. For clarity, the transistors are omitted. The layout of the circuit should follow the circuit diagram and it is most important, in view of the high r.f. gain, to keep the output clear of the input or else screen the relevant portions.

A convenient means of providing the 3 volt supply consists of employing an Eagle battery holder type BH2, in which are fitted two U7 cells.

OVERCOMING INSTABILITY

The receiver is wide open to two quite distinct forms of instability, fortunately both easily cured. First, there is a chance that a.f. will break through the r.f. transformer and set up a continuous howl. This is cured, if it occurs, by reversing the connections to L3. Secondly, it is inevitable, unless the r.f. transformer is put into a screening box, that it will couple with the ferrite aerial. This may cause positive feedback and instability or negative feedback and loss of sensitivity, depending on the winding directions. To minimise such undesirable interactions, the transformer should be kept as far away from the rod as possible, and it should be so oriented that the ferrite core of the CH1 choke is pointing broadside off to L1 (like the down stroke of a capital T). Before connecting up L3, L4, dress the leads of the r.f. choke as shown in Fig. 2, so that the two ends of the leads can be soldered into circuit close together. This enables the choke to be twisted so as to re-orient it with respect to the ferrite aerial rod. In this way a position can be found where the coupling is zero or perhaps just slightly positive so that a useful improvement is obtained in selectivity. Varying the position of the ferrite aerial can also be helpful.

No other setting up adjustments are required. It will be found however that a sort of false instability occurs when the receiver is tuned in to a strong station with the volume too high. This is merely an overloading effect and the remedy is obvious – turn down the volume.

A simple test that the d.c. conditions are correct can be made by measuring the voltage drop across R3. This should be in the range 0.65 to 0.75V.

If desired, the on-off switch, S1, may be ganged to the volume control.

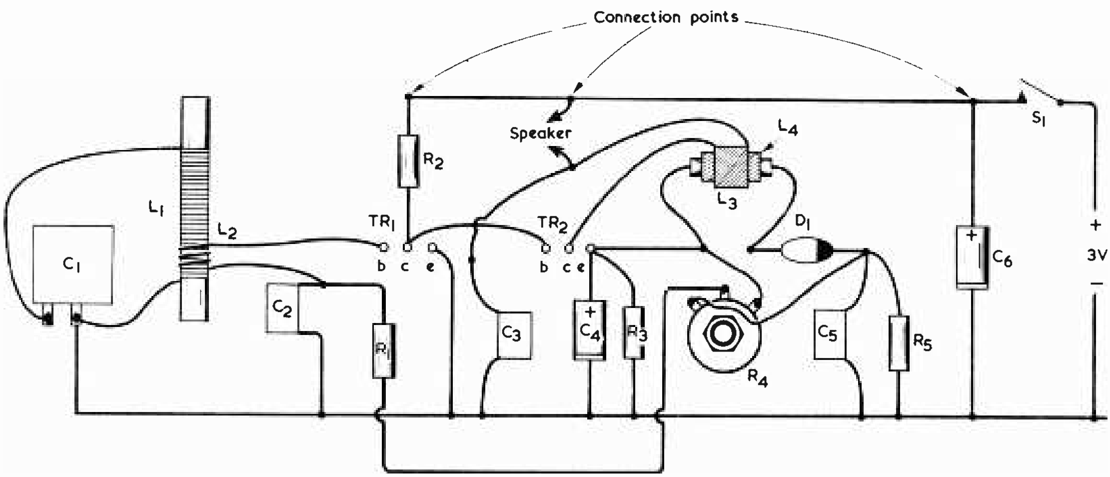


Fig. 3. A suitable component layout

LONG WAVE RECEPTION

The circuit will work on long waves given a suitable ferrite rod with long wave windings. (There is not room on a 4in. rod for both medium wave and long wave windings.) Alternatively, a single long wave station could be received by switching a suitable fixed capacitor across L1 and using C1 for fine tuning, as shown in Fig. 4. For reception of the Radio 2 transmission on 200kHz the added capacitor should be 2,200pF. A polystyrene film or silvered mica capacitor should be used.

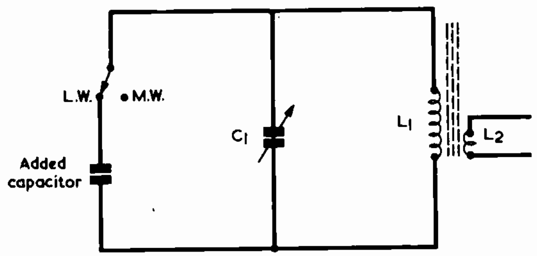


Fig. 4. Reception of a single long wave transmission is possible by switching an added capacitor across C1

OTHER SUPPLY VOLTAGES AND LOADS

In this direct-drive circuit it is essential to use a high impedance loudspeaker. The preferred impedance is 70 to 80Ω but speakers of somewhat different impedance may work: it depends upon how sensitive they are. A transformer may be used to match speakers of low impedance.

The voltage across R3 is stabilized at about 0.7 volt irrespective of the battery voltage. This makes it easy to set TR2 to take some particular collector current. At present, with R3 at 68Ω, TR2 takes a little over 10mA. If it were required to set the current at 1mA to suit an earphone of around 500Ω impedance in place of the speaker, R3 would be 680Ω.

With a 75Ω speaker, some increase in volume is obtainable by using the present resistor values but increasing the supply voltage to 4.5 volts. The circuit will go on working quite happily at higher voltages, up to 9 volts, but 75Ω is not then the optimum speaker impedance. (This rises to about 800Ω at 9 volts.)

Some constructors will want to use 3Ω speakers, which must be matched with a transformer. It is then useful to tailor the current in TR2 and the supply voltage to suit the load and transformer ratio. Allowing 1 volt for the drop across R3 plus the d.c. drop across the transformer primary, we are left with 1 volt less than the battery voltage across TR2. This voltage, divided by the transformed speaker impedance, should equal the collector current. Suppose we have a 3Ω speaker and a 10:1 transformer, giving a load impedance of 300Ω. With a 3 volt supply, the optimum current in TR2 is then 2 volts divided by 300Ω, which is 6.7mA. The required value of R3 is 0.7 volt divided by 6.7mA, or 106Ω, and we could use 100Ω, the nearest standard value.

Again, if we have a 20:1 transformer and a 5Ω speaker, the transformed speaker impedance is then $400 \times 5 = 2{,}000\Omega$. With a 3 volt supply the optimum current is 1mA, but since the power input to TR2 would then only be 2mW the audio power output cannot exceed 1mW, which may well be inadequate. The remedy is to use a higher battery voltage. With a 9 volt supply, the optimum current becomes 8 volts divided by 2,000Ω, or 4mA, and the d.c. input power to TR2 32mW, giving a possible 16mW of audio output (and a likely 8mW, assuming 50% transformer efficiency). The value of R2 for 4mA is 0.7 volt divided by 4mA, or 175Ω, so the appropriate standard resistor in this case is 180Ω.

When a high load impedance is used it may be necessary to reduce the value of the r.f. bypass capacitor C3, to avoid cutting the treble. Values down to 0.01μF may be used.

When working with supply voltages much above 3 volts it may be helpful, in the interests of battery economy, to reduce the current in TR1. This is done by increasing the value of R2. The voltage drop in R2 is held, by the d.c. feedback, at 1.4 volts less than the battery voltage, and a current in it of 1 to 2mA is adequate.

The working voltage of C6 must be increased for supply voltages greater than 3 volts. Constructors who intend experimenting with different supply voltages will find it useful to initially fit a capacitor here of 10 V.Wkg.

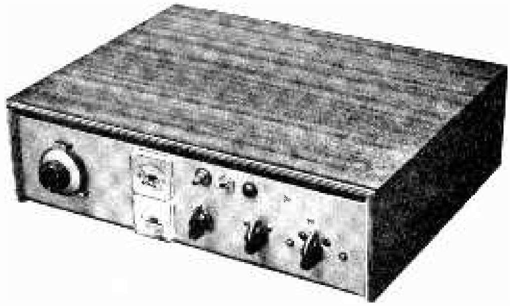
SEMICONDUCTORS

It is essential to use silicon planar transistors. The types specified have been carefully selected to give a good performance. (The SF115 transistor can be obtained from Amatronix Ltd., as can the other semiconductors and components.) Other transistor types will probably work, but less well. The input transistor must be an r.f. type with a low feedback capacitance and the SF115 specified has the added advantage of low a.f. noise as well. It should be possible to substitute BF115, which is the same transistor in a metal case. The BF167 will also work in this position.

The requirement for TR2 is rather different. This transistor may have to handle peak currents of 20mA or more, which rules out some r.f. types. It should have a low input capacitance and a fairly low feedback capacitance as well, to avoid putting too great a stray capacitance across R2 and so reducing the r.f. gain. Fortunately the BC169C has these features, and also the added one of very high hfe: some other high-gain audio types are much worse in the matter of capacitances.

In principle any point-contact diode will be satisfactory for D1, but here again some are better than others, and the OA90 is very suitable. ■

The 'WYVERN' 160 Metre Solid State Transmitter — Part 2.



by

John R. Green, B.sc., G3WVR

The second article in our 3-part series which describes the construction of a comprehensive transmitter design incorporating semiconductors throughout.

IN LAST MONTH'S ISSUE THE OVERALL DESIGN OF THE transmitter was described as also, in detail, were the v.f.o., the wideband driver section and the doubler and driver stage. This month's article covers the power amplifier stage and the power supply. The concluding article, to be published next month, will deal with the modulator, VU meter driver and general assembly and testing.

POWER AMPLIFIER

The circuit diagram for the p.a. stage is given in Fig. 11. This diagram also includes the power switching around S1(a) to S1(e).

The heart of the stage is the BD123 transistor, which has been chosen for three reasons:

(a) the frequency response cut-off fT, of 85mHz gives a more than adequate performance at 2mHz,

(b) the power dissipation capacity of 45W gives a safeguard against overheating and damage,

(c) the VCE (collector-emitter maximum voltage) of 60 volts gives a reasonable safety margin since on modulation peaks the collector to emitter instantaneous voltage (peak) can be as much as four times the normal supply voltage, i.e. 48 volts.

The drive to the base of the BD123 is controlled by RV1, which is mounted on the front panel of the transmitter. TR7 is pulsed on by positive-going r.f. half-cycles. The consequent pulses of collector current passing through the 2 turn winding of L4 are shaped by the 20 turn tuning winding before radiation. Both windings are close-wound, direct on the rod using 20 to 24 s.w.g. enamelled wire.

Loading and tuning adjustments for the p.a. are as for a conventional valve transmitter, with the exception that the loading setting is far less critical, particularly if the aerial is not quarter wave resonant, and final loading adjustments are carried out by means of the drive potentiometer.

It is important to note that all drive components, i.e. RV1, L2 tuning and L3 tuning, are normally set for maximum p.a. current; whereas the p.a. tuning is adjusted for minimum p.a. current.

Always begin tuning operations with RV1 turned up only sufficiently to draw, say, 500mA of current through the p.a. meter, and then perform initial tuning and loading. Gradually increase the drive given by RV1 until the legal maximum (830mA at 12 volts) is achieved, then make final fine tuning adjustments. Failure to follow this procedure could cost an output transistor (about £1).

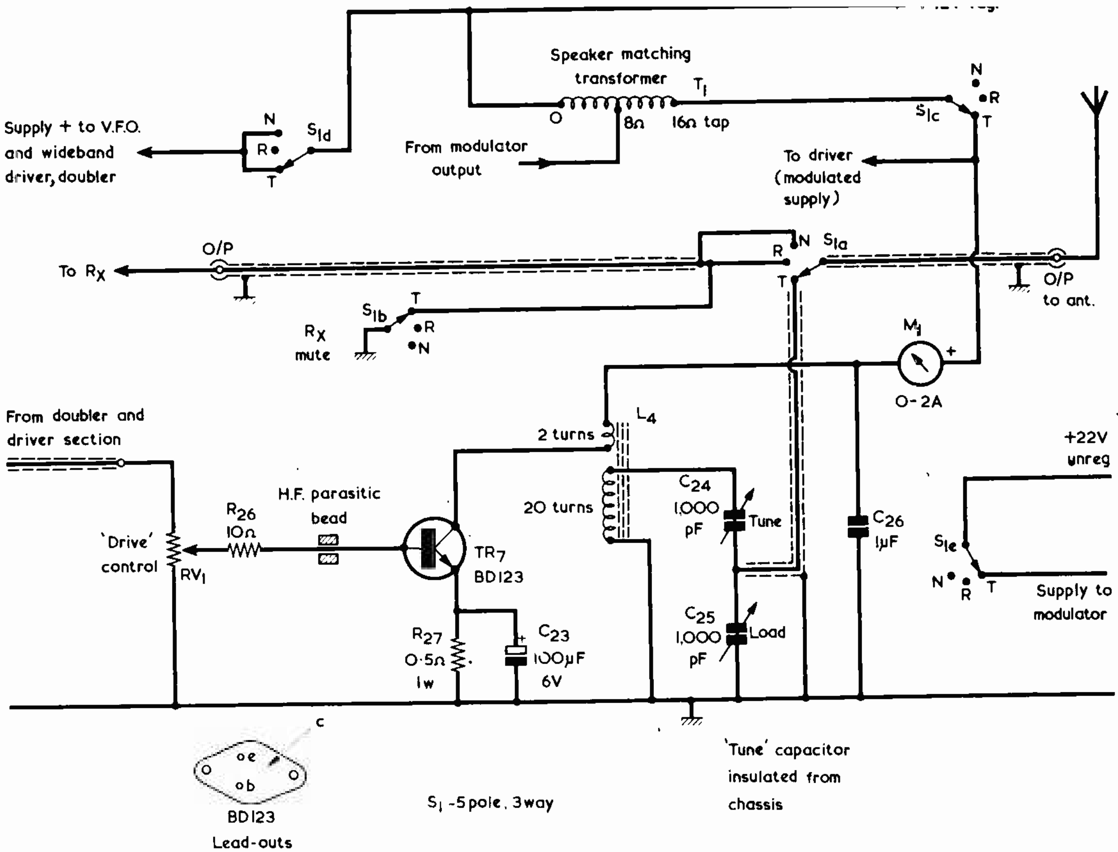


Fig. 11. The p.a. stage. Shown also are the Net, Receive and Transmit switching circuits and the modulation transformer, T1

COMPONENTS

Resistors
(All fixed values ½ watt 10%, unless otherwise stated)

R26	10Ω
R27	0.5Ω 1 watt
R28	1kΩ
R29	22kΩ
R30	1kΩ
R31	1kΩ
R32	220Ω
R33	0.25Ω 1 watt, see text
RV1	500Ω potentiometer, wire-wound

Capacitors

C23	100μF electrolytic, 6 V.Wkg.
C24	1,000pF variable
C25	1,000pF variable
C26	1μF plastic foil
C27	1,000μF electrolytic, 25 V.Wkg.
C28	2,000μF electrolytic, 25 V.Wkg.
C29	100μF electrolytic, 25 V.Wkg.

Inductors

T1	Speaker matching transformer, 8Ω and 16Ω or 8Ω and 15Ω, minimum rating 10 watts
T2	Mains transformer, secondary 0–12–15–20–24–30 volts at 2 amps, Douglas type MT3AT
L4	P.A. output coil, wound on ferrite rod 6ins. by ½in. diameter

Semiconductors

TR7	BD123
TR8	BFY50/2N3053
TR9	2N3053
TR10	2N3250/2N3905/2N3702
TR11	2N3055
D1–D4	Silicon rectifiers, 2A 100 P.I.V.
ZD2, 3	6.8V 200mW zener diodes

Switches

S1	5-pole 3-way, wafer
S2	s.p.s.t. toggle

Meter

M1	0–2A meter

Neon

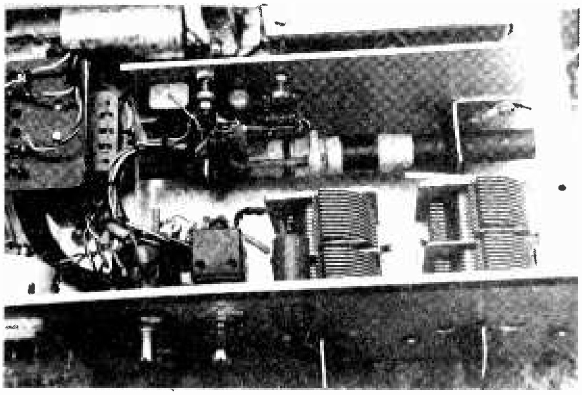
NE1	Panel-mounting neon assembly with integral series resistor

Fuses

F1–3	2 amp anti-surge, with holders

Miscellaneous
Ferrite lead
2 coaxial sockets
4-way tagstrip
3 pointer knobs
Printed circuit board
16 s.w.g. aluminium
Coaxial cable

The ferrite rod, on which is wound the output coil, is clearly visible here. The component to the left of the rod is the modulation transformer



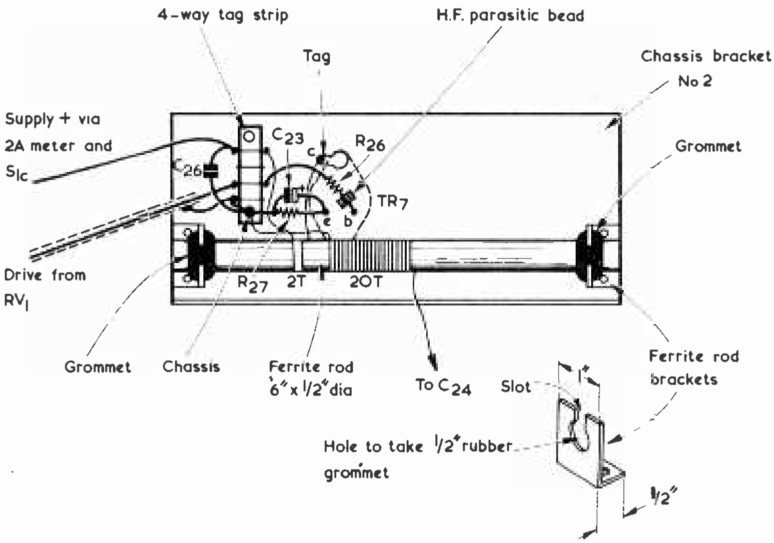


Fig. 12. Physical layout of the p.a. stage. The parts are mounted on Chassis Bracket No 2

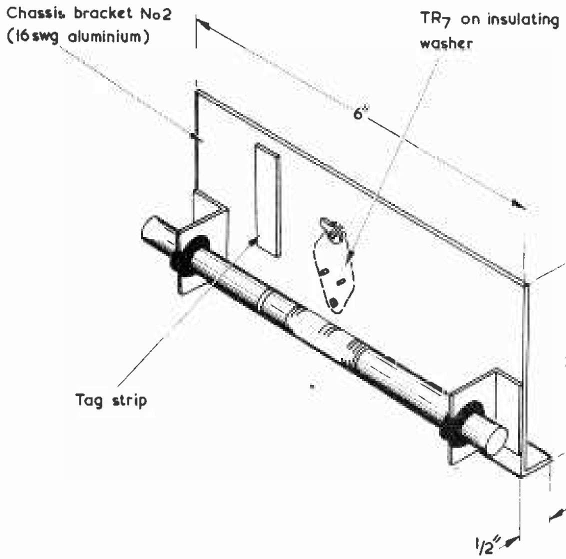


Fig. 13. Details of the Chassis Bracket No 2

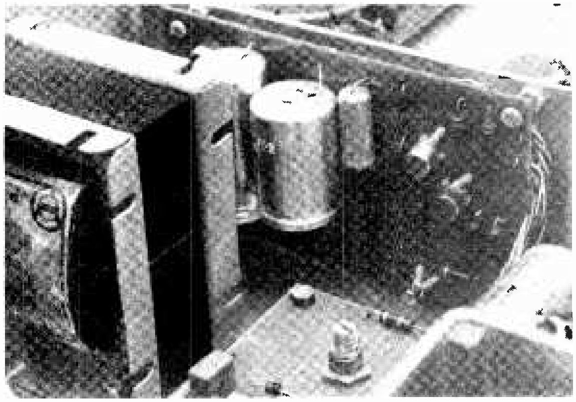
Do not attempt to increase the p.a. efficiency (which is about 60%) by increasing the number of turns on the collector winding of L4, as this will cause 'jump tuning' and poor output waveform, resulting in TVI.

Also, do not use a smaller ferrite rod for L4 or saturation of the ferrite may result, destroying the transformer action. If desired, use a larger ferrite rod but *do* ensure that it is suitable for operation at 2MHz, as many ferrite grades are not. The rod used by the author is 6ins. long by ½in. diameter, and was obtained from G. W. Smith & Co. (Radio) Ltd., 3 Lisle St., London, W.C.2.

The construction of the p.a. stage is shown in Fig. 12. The output transistor is fitted to Chassis Bracket No. 2, the dimensions of which are given in Fig. 13. The transistor is insulated from the bracket by means of the usual mica washer and insulated mounting bushes, and its body is on the opposite side of the bracket to the ferrite rod. The latter is secured by two brackets with slots in the holes through which the rod passes. The slots prevent shorted-turn action. The earthy end of the 20 turn winding is that which is closer to the collector winding. A 4-way tagstrip is also mounted on the bracket.

Fig. 11 also shows the switching carried out by S1(a) to (e). This is quite simple and straightforward and the circuits controlled at each switch position can be readily traced through. The modulation transformer T1 is a speaker matching transformer having taps at 8Ω and 16Ω. A transformer having taps at 8Ω and 15Ω could alternatively be employed if this should prove easier to obtain. Whatever transformer is employed *must* have a power capability of at least 10 watts audio handling.

As will be illustrated in greater detail in next month's article, in which the general assembly will be dealt



A view of the power supply board. This is partly obscured by the mains transformer

with, switch S1, driver potentiometer RV1 and meter M1 are all mounted on the front panel of the transmitter. So also are C24 and C25, the 'Tune' and 'Load' capacitors. The frame of the 'Tune' capacitor is insulated from the chassis by mounting it on a sheet of Paxolin. The frame of the 'Load' capacitor is bolted direct to the panel. In practice both capacitors consist of 2-gang 500 + 500 pF components with the two sections in parallel.

The modulation transformer, T1, is positioned between the v.f.o. box and Chassis Bracket No. 2.

POWER SUPPLY

The circuit diagram of the power supply is shown in Fig. 14. The design incorporates the simplest form of regulation for the 12 volt supply, using zener diodes

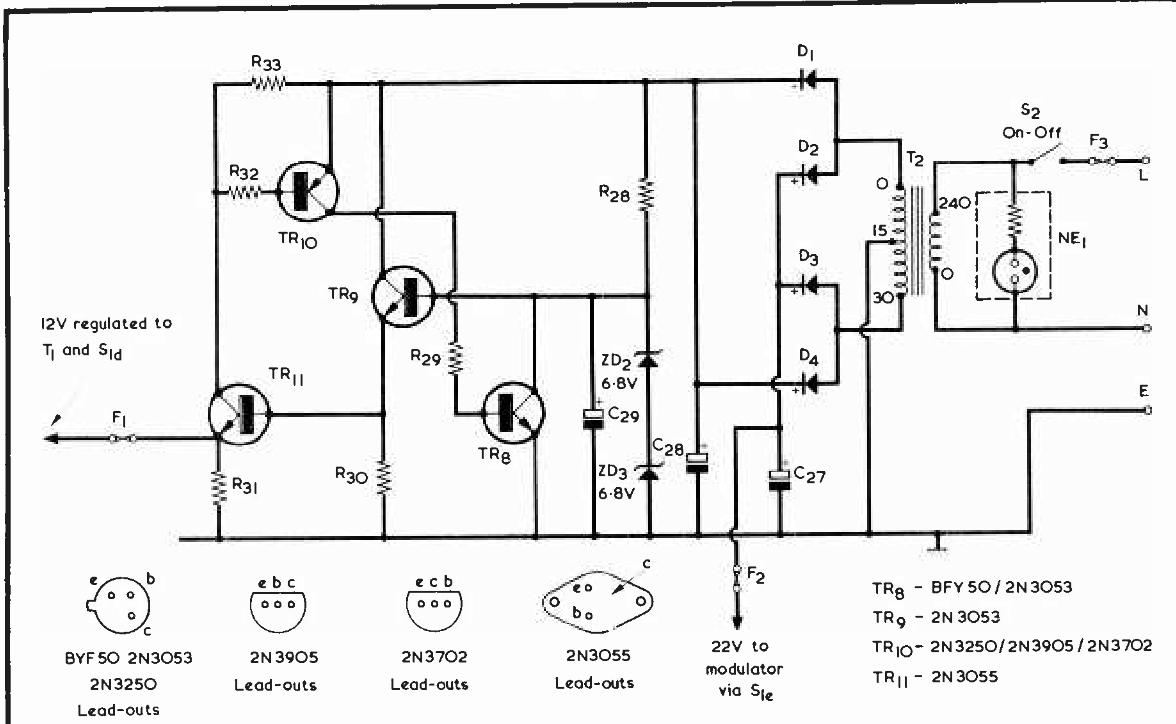


Fig. 14. The circuit of the power supply. This offers both regulated and unregulated outputs

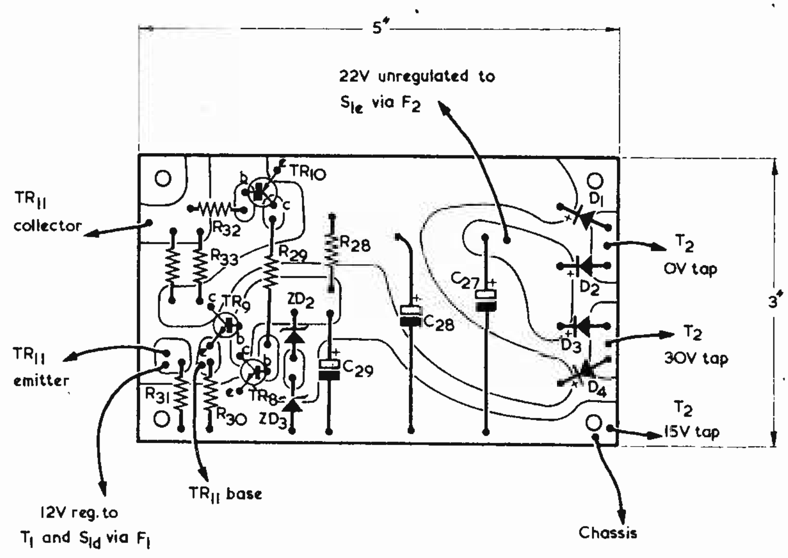


Fig. 15. The power supply printed circuit board, as seen from the component side.

ZD2 and ZD3 and the emitter followers TR9 and TR11. Overload protection is given by TR10 and TR8. If the current drawn through R33 causes a voltage to appear across it which is sufficiently high to allow base current to flow in TR10, this transistor becomes conductive. Its collector current flows in the base circuit of TR8, whereupon TR8 causes a reduction in the voltage across ZD2 and ZD3 and, in consequence, in the regulated output. The current limit is 2.5 amps.

A 22 volt unregulated supply is also provided for the Class B modulator.

The mains tranformer, T2, has a number of secondary tappings, of which only the 0, 15 and 30 volt tappings are employed here. The 15 volt tapping becomes the earthed centre-tap in this arrangement.

The use of fuses in the mains input and regulated and unregulated output circuits is recommended, and they can be located in any available space in the transmitter. A neon mains indicator lamp with integral series resistor may be fitted, if desired.

The printed circuit board for the power supply is reproduced, full size, in Fig. 15. The view is from the component side of the board. In the prototype R33 is made up of two ½ watt 0.5Ω resistors in parallel and two resistors are shown, in Fig. 15, in the R33 position. The board is mounted, with spacing stand-off washers to Chassis Bracket No. 3, which is illustrated in Fig. 16. The bracket also acts as a heat sink for TR11, the body of which is on the opposite side of the bracket to the board. TR11 is insulated from the bracket by a mica washer and insulated mounting bushes.

The whole power supply (both 12 and 22 volt outputs) may be replaced by a car battery or other 12 volt accumulator (but *not* by dry batteries, which cannot supply the current required). The author's transmitter incorporates additional sockets and switching to achieve this. It should be pointed out, however, that when running from a 12 volt supply the modulator will not supply the output required for 100% modulation. Incidentally, the 22 volt output from the mains power supply will, of course, drop in voltage under load but this is not detrimental to the modulation quality unless excessive bass frequencies are present.

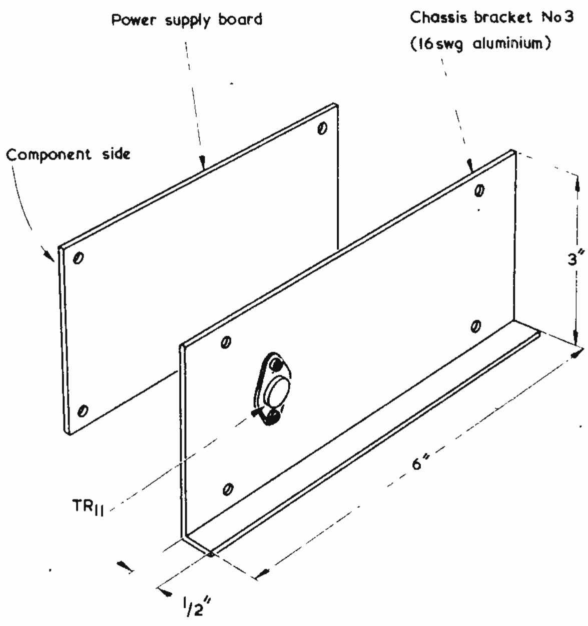


Fig. 16. Fitting the power supply board to Chassis Bracket No 3

(To be concluded)

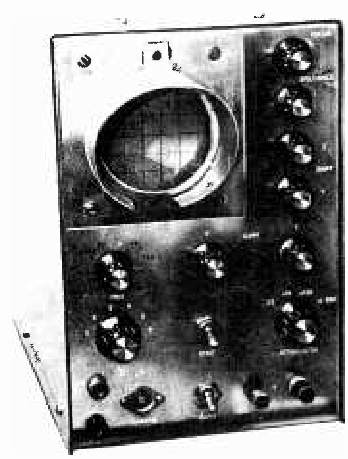
TRANSISTORISED OSCILLOSCOPE

Part 1
by R. A. Penfold

In this oscilloscope the only thermionic device is the cathode ray tube. The present article describes the mechanical construction of the instrument, the power supply and display section, and the X amplifier module. The remainder of the circuit will be covered in a concluding article, which will be published next month.

An oscilloscope is probably the most useful piece of test equipment an electronics enthusiast can possess (with the exception perhaps of the multi-range meter), even if it is only a very simple instrument. Unfortunately, an oscilloscope is also one of the most expensive pieces of equipment to buy. The instrument which is the subject of this article is quite inexpensive when compared with the cheapest commercially manufactured oscilloscopes, but it has to be pointed out that quite a considerable amount of work is involved in building it.

It is suitable for most applications, except very specialised ones such as television servicing, where a very wide bandwith is required. As the instrument was designed mainly for audio work, a high sensitivity was considered to be more desirable than a wide bandwidth, although as shown in the specification table, the useful bandwidth of the oscilloscope stretches to beyond 2MHz.



The unit is housed in a home-made case, the outside dimensions of which are 14 ins. deep by 6 ins. wide by 9 ins. high. The accompanying photographs will assist in demonstrating how the parts of the case are assembled together. Construction of the case should commence with the front and rear panels, details of which are given in Fig. 1. The material is aluminium and the exact gauge is not critical, although a fairly thick gauge should be used for all parts of the case. The aluminium employed for the front and rear panels of the prototype was 20 s.w.g.

For those without the proper equipment for bending the metal, it will be found easier if a slightly thinner gauge of aluminium is used, although this will mean sacrificing some of the stiffness of the case.

On the front panel the holes for the control bushes should have diameters of ⅜ in. with the exception of the holes for S4 and S1, which are toggle switches. The hole marked 'T/B' is for a flush-mounting coaxial socket, and the two pairs of holes marked 'X' and 'Y' take 3mm. insulated sockets. Note that VR8 is fitted on the rear panel and that this also requires a ⅜in. hole. The rear panel mains lead hole should be fitted with a rubber or p.v.c. grommet to prevent damage to the lead. The method of mounting the other parts fitted to the rear panel will become clear when these are discussed.

In Fig. 1 the front panel is seen from the front and the rear panel from the rear. In both cases the 1in. sections at top and bottom are bent down away from the reader. The ½in. side sections shown in dotted outline are optional and, as is explained shortly, are only incorporated if a cover different to that used by the author is employed. They should also be bent down, away from the reader.

The bottom of the case is made next, and this is shown in Fig. 2. The two 1in. flanges are bent up, towards the reader. Fig. 2 also shows the positioning of components and circuits which will later be fitted to the bottom. The lower flanges of the front and rear panels pass under the case bottom and are secured by 4BA bolts and nuts fitted at the holes marked 'X' in Fig. 2.

To ease assembly the corresponding holes in the front and rear panel flanges are best marked out from those in the bottom after all the bending has been carried out. The holes in the top flanges of the front and rear panel can be ½in. from the flange edge and 1½ins. from each side. They are drilled to take self-tapping screws for securing the cover. If the side flanges on the front and rear panels are incorporated, they may also have holes drilled to take self-tapping screws. Four rubber feet

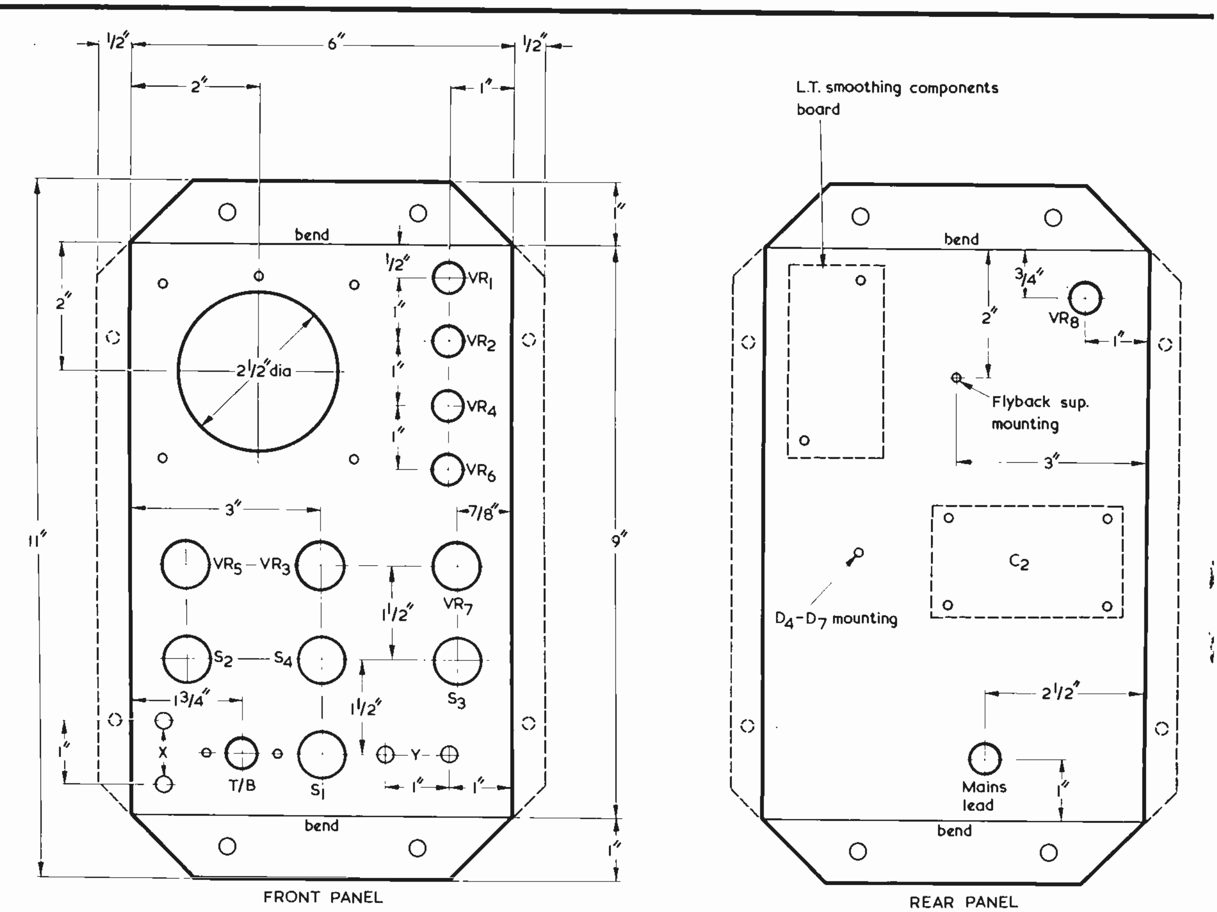


Fig. 1. Constructional details of the front and rear panels

C.R.T. MOUNTING

are fitted to the bolts at the holes marked 'X'.

An outer casing is very desirable to prevent dust from entering the unit and to improve appearance. With the prototype, the casing was made from a single sheet of aluminium suitably bent, but this was found to introduce a magnetic field to the c.r.t. from the mains transformer, resulting in a wider trace than was otherwise obtained. If the tube were fitted with a magnetic screen this effect would no doubt disappear. On the prototype it was eliminated by glueing thin pieces of steel sheet at strategic points on the inside of the case.

Alternatively the outer casing could be constructed from a non-metallic substance such as Perspex or Formica. It would be necessary to use three separate pieces, and this would require the addition of the two extra flanges on the front and rear panels shown in dotted line in Fig. 1.

For the best appearance the cover should overlap the front and rear panels by about ⅛ to ¼in. The outer casing is fastened in place by ten self-tapping screws (eighteen if it is made of three separate pieces). With the outer casing added the unit will have greatly increased stiffness.

The c.r.t. mounting comprises three sections, a metal tube fastened to the front panel into which the front of the c.r.t. is passed, a bracket which fits around the tube base, and an L-shaped bracket fixed to the bottom of the chassis to which the second bracket is coupled. All parts are made from 22 s.w.g. aluminium.

The metal tube holding the front of the c.r.t. is illustrated in Fig. 3. A piece of aluminium measuring 12 by 2ins. is bent round to form a tube with an internal diameter of 3½ins. To prevent the metal from opening up once it has been bent to shape, two ¼in. 6BA countersunk bolts, with the heads on the inside, are passed through the holes illustrated. A small angle bracket, made from a piece of aluminium 1in. by ½in., is mounted on one of these bolts, and a second by means of a countersunk 6BA bolt at a hole on the opposite side of the tube. The holes in Fig. 3 are not dimensioned as it will probably be found best to mark them out with the aid of the actual parts. The hole in each half of the angle brackets is central. The tube is fitted to the front panel at two holes, which are next drilled for it. These are two of the holes diagonally opposite each other which are shown outside the 2½in. hole in Fig. 1. When these holes have been drilled, the remaining two diagonally opposed holes may be marked up to balance them and drilled out also.

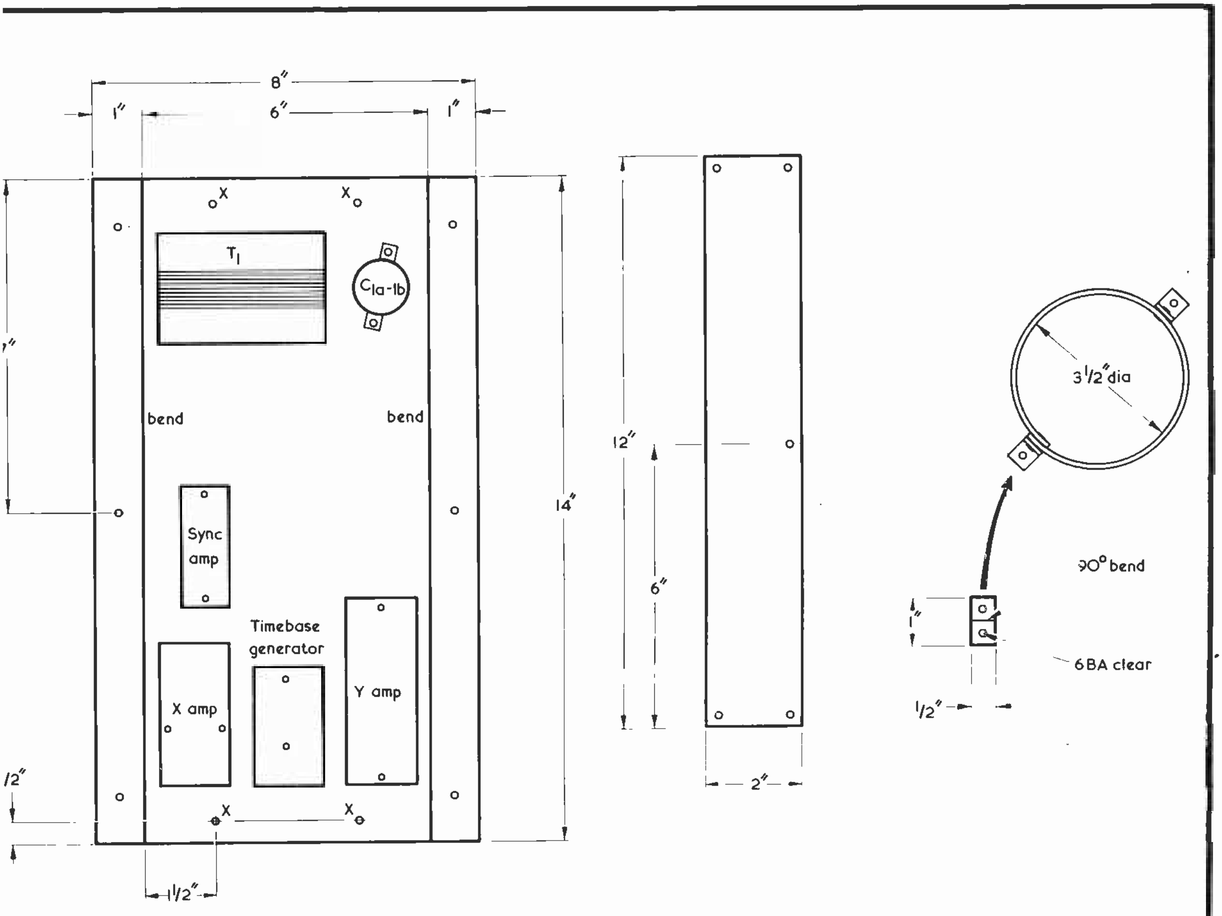


Fig. 2. Details and layout of parts on the chassis

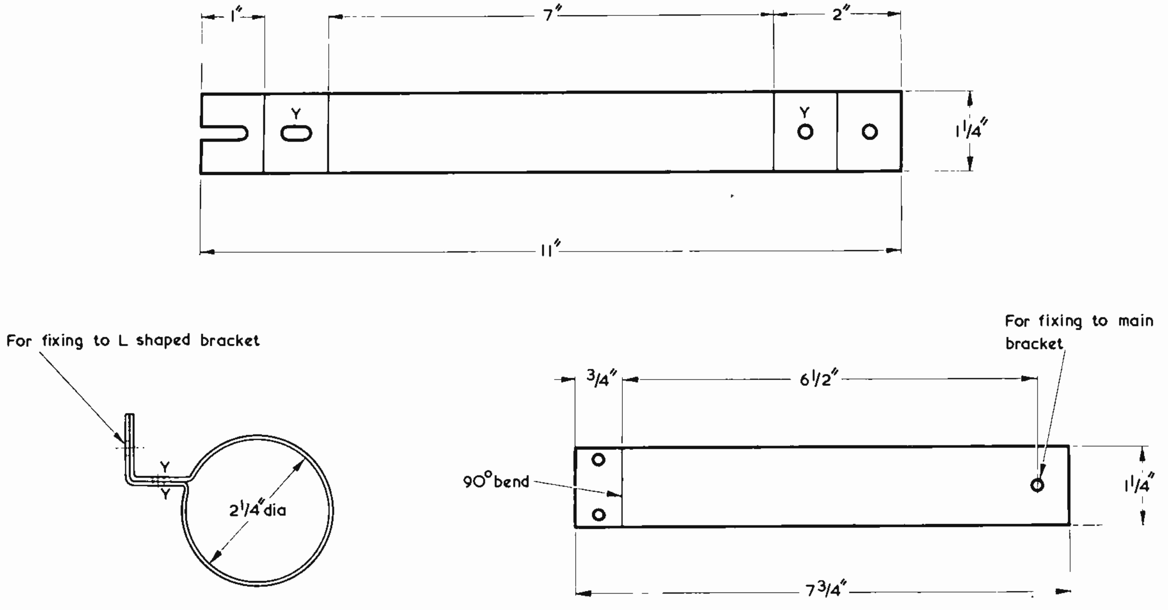


Fig. 4. The sections which form the rear mounting for the c.r.t.

Fig. 4 gives details of the mounting arrangement at the rear of the tube. A piece of aluminium, 11 by $1\frac{1}{4}$ins. is drilled as shown and bent to shape. The L-shaped bracket is next made, from a piece of aluminium measuring $7\frac{3}{4}$ by $1\frac{1}{4}$ins. The first bracket is fitted around the c.r.t. base and loosely bolted to the L-shaped bracket. A 2in. 6BA bolt is passed through the holes marked 'Y' and is tightened until the bracket holds the c.r.t. base firmly. It is advisable to wrap a couple of bands of sticky-backed foam rubber or foam plastic strip (sold as draught-excluder) side by side around the c.r.t. base, as this will assist in causing the base to be held firmly by the bracket. Care must be taken not to overtighten the 2in. 6BA bolt, as this could damage the c.r.t. The L-shaped bracket is bolted to the chassis by two 6BA screws at the point which allows the c.r.t. to take up a correct position. The tube should be orientated such that its pins 8 and 9 are uppermost.

To prevent the c.r.t. from being damaged through vibration, several layers of the foam rubber strip should be wound around the front of the c.r.t. on the area between the phosphor and graphite coatings. A couple of layers should also be wound around the inside of the metal tube at the extreme front.

When the c.r.t. is mounted finally, the two brackets of Fig. 4 are bolted securely together. Obviously, great care must be taken when handling the c.r.t. during these operations. It should be removed from its mounting after the positioning of the mounting parts has been satisfactorily established, and placed on one side, since further drilling operations have to be carried out on the chassis.

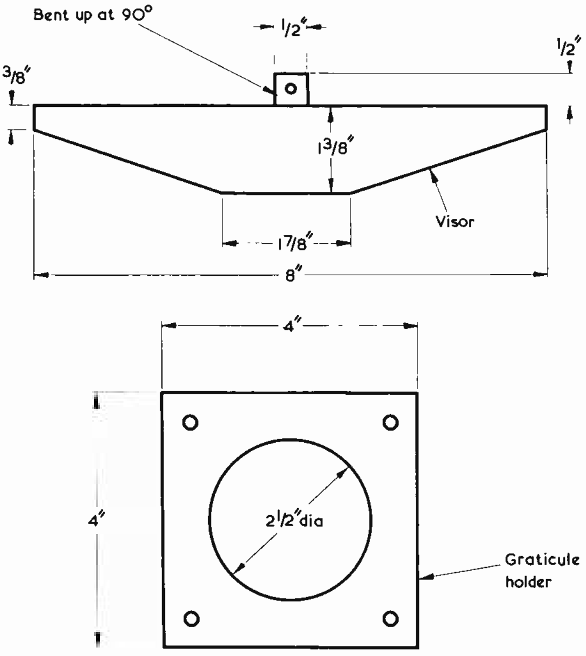


Fig. 5. The visor, before bending, and the graticule holder

VISOR AND GRATICULE

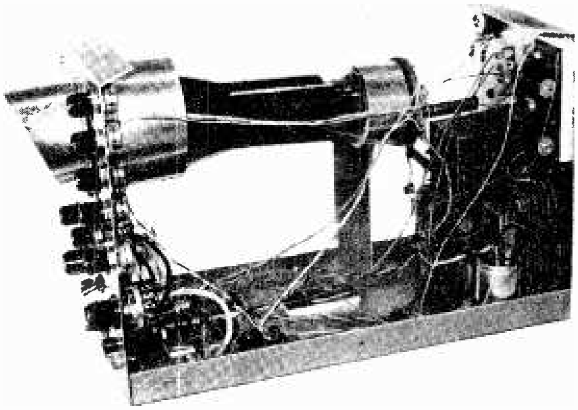
In strong lighting conditions, a visor to shield the screen from external light is a decided asset. A suitable visor is quite easy to construct and may be made from a piece of aluminium having the dimensions shown in Fig. 5. After cutting out, this is bent round to have a diameter slightly greater than the $2\frac{1}{2}$ins. hole in the front panel. It is secured to the front panel by a single 6BA bolt in a hole which is marked out from the visor itself.

On the prototype, the visor was left with a natural finish, but it can be made more efficient by being painted matt black. The visor is fitted after the escutcheon which holds the graticule (next to be described) has been mounted.

When using the oscilloscope to measure signal voltages a graticule is required. This is merely a piece of transparent material such as Perspex which is marked with the X and Y centre axes. Graticules also have lines parallel with these axes, and these are usually marked off at 1mm. intervals with heavier lines at 1cm. intervals.

A suitable graticule can be constructed by cutting a piece of Perspex $2\frac{7}{8}$ins. square. This is then marked as required by scribing it as deeply as possible with a sharp pointed instrument. To calibrate X and Y axes at 1mm. intervals by hand is extremely difficult, and it is very much easier if 2 or 2.5mm. divisions are used.

The graticule is held in place by an aluminium escutcheon, details of which are given in Fig. 5. This is bolted to the front panel by four 6BA bolts, two of which are already present as part of the tube mounting. The graticule is trapped between the escutcheon and the front panel. The four mounting holes for the escutcheon correspond with the four holes already drilled in the panel. A fifth hole, not shown in Fig. 5, takes the bolt which holds the visor in position.



A view inside the oscilloscope. Most of the components are wired up on small printed circuit modules

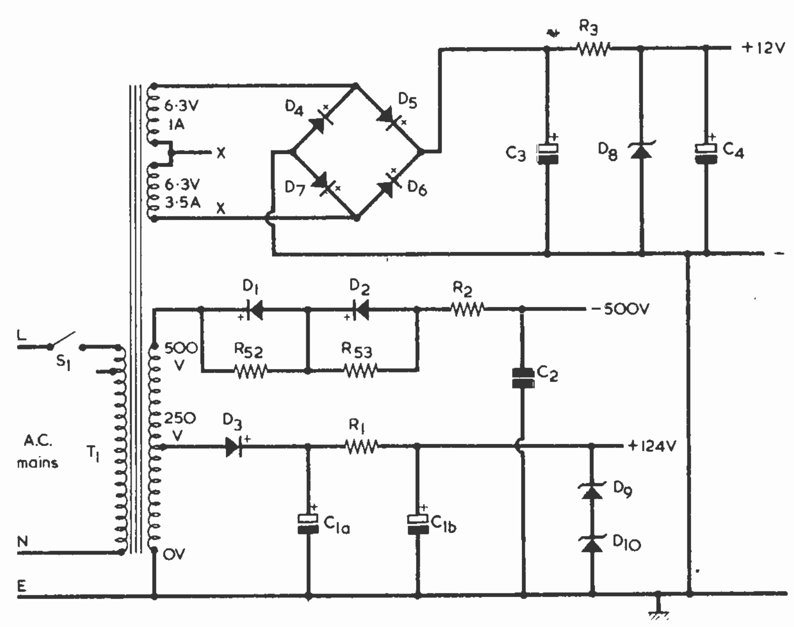
POWER SUPPLY

The circuit of the power supply section is shown in Fig. 6. This circuit provides four voltages, these being approximately 500 volts e.h.t., 124 volts stabilized, 12 volts stabilized, and 6.3 volts a.c. for the tube heater.

The 250-0-250 volt secondary of the mains transformer has the chassis connection made to one end, causing it to provide 500 volts. This is of course 500 volts r.m.s., and the peak voltage is in the region of 700 volts. In consequence, despite losses in the half-wave rectifier and smoothing circuit given by D1, D2, R2 and C2, 500 volts is still available at the output. It should be noted that this output is negative with respect to chassis, whereas the other two d.c. outputs are positive with respect to chassis. Capacitor C2 was a 4μF 500 V.Wkg. paper component in the prototype. A component with a slightly higher working voltage could be employed here and it is noted that Home Radio advertise a 4μF 600 V.Wkg. capacitor under Cat. No. 2EG55.

A second half-wave smoothing circuit is used for the 124 volt h.t. supply. The power is taken from the centre tap of the h.t. secondary of T1, which now offers 250 volts, and is rectified by D3. C1(a) and C1(b) are the reservoir and smoothing capacitors, whilst R1 and the zener diodes D9 and D10 reduce the output voltage to a nominal 124 volts. The ZL100 specified for D10 is a 100 volt 5% zener diode rated at 1 watt, and it is available from Henry's Radio. Other series combinations of zener voltages may be used to obtain the 124 volt figure, and typical instances are given by two 62 volt diodes or a 56 volt and a 68 volt diode in series. Each diode should be rated at 1 watt.

Fig. 6. The power supply section of the oscilloscope



The two 6.3 volt secondaries of the transformer are connected in series to provide the 12 volt output, the alternating voltage being rectified by the bridge selenium rectifier, D4 to D7. This rectifier should be rated at 12 volt 0.5 amp or more. Zener diode D8 stabilizes the supply at 12 volts. The cathode ray tube heater requires 6.3 volts at 1 amp and this is taken from the 6.3 volt 3.5 amp winding of the transformer at the points marked 'X'. The only disadvantage with this method of supplying the c.r.t. heater is that it causes a high voltage to appear between the tube cathode and the heater, and there is a consequent risk of breakdown in the cathode-heater insulation. No trouble was experienced on this score with the prototype, but constructors who would prefer to avoid the risk of damage to the c.r.t. are advised to supply its heater from a separate small 6.3 volt transformer, which can be mounted at the rear of the chassis.

The power supply section is mainly wired up using point-to-point wiring. The positioning of T1 and C1(a) (b) is shown in Fig. 2. C2 and the bridge rectifier D4-D7 are mounted on the rear panel, as illustrated in Fig. 1. D1, D2, R52, R53 and R2 may be wired between the transformer and C2 in any convenient manner, such as would be given by using a small tagstrip bolted to one of the slots in the transformer frame. R3, C3, C4 and D8 are mounted on a Paxolin board measuring 3⅜ by 1½ins. The layout on this board runs along very much the same lines as the circuit diagram. The board is mounted to the rear panel, as in Fig. 1, and it must be spaced away from the panel by stand-off washers. Alternatively, a piece of polystyrene tile, cut to the same dimensions as the board, may be sandwiched between the board and the panel.

After throughly checking the completed power supply wiring for mistakes, the unit should be switched on and the various output voltages checked. The 124 and 12 volt outputs should have voltages that are within 5% of their nominal values since they are controlled by zener diodes. The e.h.t. should be somewhat higher, at 600 volts or more, as it is not under load conditions as it stands.

DISPLAY UNIT

Fig. 7 shows the circuit diagram of the display unit. This is very straightforward, and uses standard circuitry. The astigmatism control is required to ensure that the beam is properly focused, whatever part of the screen it is aimed at.

No special insulation was used on the brilliance and focus controls as is sometimes done due to the high voltages involved, and this was found to be quite satisfactory. Point-to-Point wiring is used. R7 can be conveniently mounted between pin 3 and pin 6 of the c.r.t. base, as there is no internal connection to pin 6.

The 3BP1 c.r.t. employed is available from a number of suppliers, including Henry's Radio. Although this tube is intended to operate from a 1,500 volt supply, it gives perfectly satisfactory results at the lower voltages employed here. The only effect of using a lower voltage is a slight loss of trace brightness and an increase in deflection sensitivity.

To test that the display unit is functioning correctly, the X and Y plates should be temporarily earthed to chassis. The unit should then be switched on, and after a brief warm-up period for the c.r.t., a spot should appear on the screen. It should be possible to adjust the intensity of the spot with the brilliance control, while adjustment of the focus control should enable the spot to be reduced to about 1mm. diameter.

For the time being the astigmatism control should be set at its mid-point. This control can be given the correct adjustment later, after the X and Y deflection amplifiers have been installed.

When these are installed, the astigmatism control should be tried at various settings, with the focus control being re-adjusted for each new setting. The X and Y shift controls are then employed to move the spot to the extremities of the screen and thereby check how well the spot remains focused.

The control is left finally at a setting which gives a properly focused spot at any part of the screen.

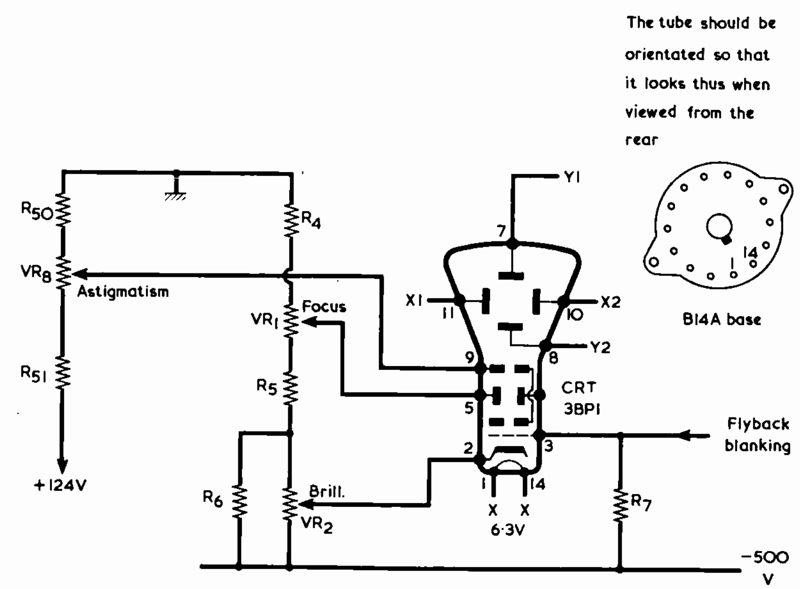


Fig. 7. The display section

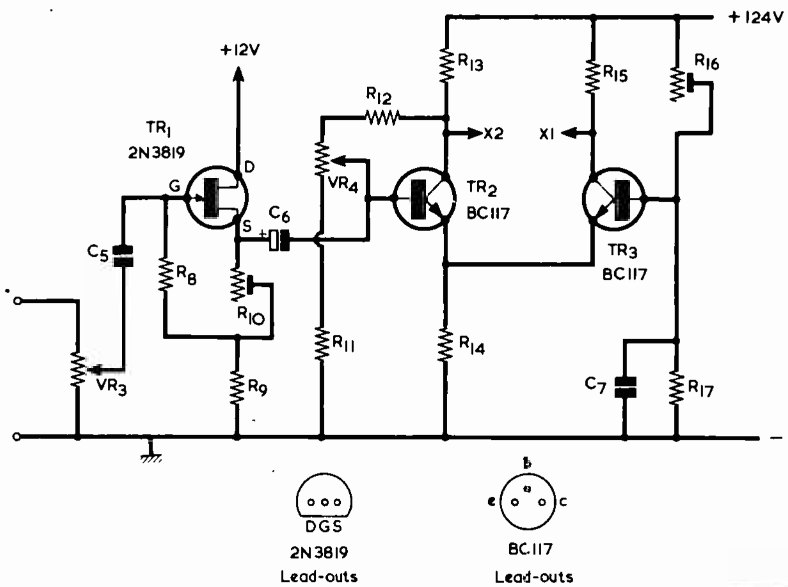


Fig. 8. The circuit of the X amplifier

X AMPLIFIER

The X amplifier uses a very simple circuit incorporating only three transistors, including an f.e.t. input stage. The circuit diagram is given in Fig. 8.

TR1 is a 2N3819 field effect transistor operated in the source follower mode (the f.e.t. equivalent of the emitter or cathode follower circuits). Pre-set resistor R10 is adjusted to give approximately half the supply potential at TR1 source. The 6.8MΩ gate biasing resistor, R8, is given a certain amount of bootstrapping by being taken to a tap in the source load resistance. Because of the high input impedance of the f.e.t. and the very high effective resistance offered by R8 the circuit achieves an extremely high input resistance, but this is shunted by the gain control, VR3. A source follower gives a very low input capacitance (a few picafarads) and the actual input capacitance of this section of the oscilloscope will depend largely upon the stray capacitance in the input wiring.

TR2 and TR3 are operated as a paraphase amplifier. This is a form of phase splitter. The easiest way to consider the operation of this circuit is to regard TR2 as a common emitter amplifier, and TR3 as a common base amplifier. Signals at TR2 base will appear amplified, but 180° out of phase, at TR2 collector. These signals will also appear, at a low impedance and in phase, at TR2 emitter.

TR3 is operated as a common base amplifier. In such a circuit the input is taken to the emitter of the transistor, and so the signals at TR2 emitter are coupled to the emitter of TR3. Here they are amplified, appearing at TR3 collector and again having undergone no phase change. Out-of-phase signals therefore appear at TR2 and TR3 collectors.

The output of the amplifier is directly coupled to the c.r.t. X deflection plates.

Capacitor C7 is used to give high frequency boost to the amplifier by bypassing R17 at high frequencies, at which it has a low reactance. VR4 is the X Shift control. Pre-set resistor R16 is adjusted to enable the X shift control to deflect the spot equally either side of centre. A shift of approximately 2 cm. either side of centre should be possible.

The X amplifier is constructed on a printed circuit board measuring 3 by 1½in. A diagram giving etching details of the board is shown in Fig. 9, and a second diagram of the board showing the component layout is given in Fig. 10. In common with all the other printed circuit board etching diagrams in this article, Fig. 9 is reproduced full size and may be traced.

The X amplifier board is mounted to the chassis in the position indicated in Fig. 2, being insulated from it by stand-off washers or by sandwiching a piece of polystyrene tile cut to the same dimensions between it and the metal. The input to the X amplifier is at the two sockets on the front panel marked 'X' in Fig. 1, and also at the coaxial socket, which is connected in parallel.

All leads at the input of the X amplifier must be screened. The capacitance to earth of the lead coupling the slider of VR3 to C5 should be kept low. The mains lead to the on-off switch on the front panel must be kept well clear of the f.e.t. and the input wiring, to prevent pick-up of mains hum.

When completed and checked for mistakes, the unit should be turned on, having first set R16 for maximum resistance (turned fully anti-clockwise). R10 should be

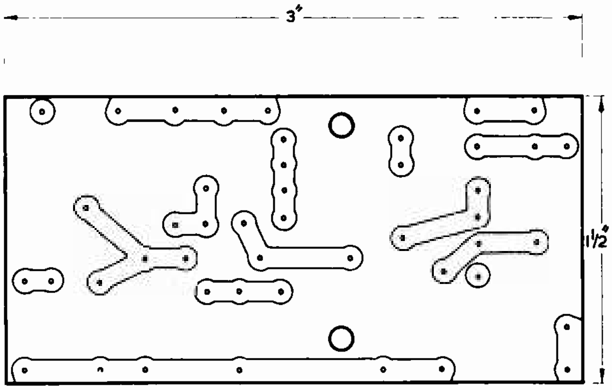


Fig. 9. The copper side of the X amplifier printed circuit board

This is reproduced full size and may be traced

COMPONENTS

Resistors

(All fixed values ¼ watt 10% unless otherwise stated)

R1	15kΩ 5 watt	
R2	33kΩ 2 watt	
R3	56Ω 1 watt	
R4	220kΩ	R.R.Y.
R5	39kΩ	O.W.O.
R6	12kΩ	BR.R.O.
R7	1MΩ	BR.B.G.
R8	6.8MΩ	B..
R9	4.7kΩ	
R10	1kΩ vertical skeleton pre-set	
R11	82kΩ	
R12	3.9MΩ	
R13	39kΩ	
R14	470Ω	
R15	39kΩ	
R16	100kΩ horizontal skeleton pre-set	
R17	1.2kΩ	
R18	270kΩ	
R19	3.3kΩ	
R20	15kΩ	
R21	680Ω	
R22	82Ω	
R23	12kΩ	
R24	10MΩ	
R25	10MΩ	
R26	15kΩ	
R27	5.6kΩ	
R28	1kΩ vertical skeleton pre-set	
R29	27kΩ	
R30	27kΩ	
R31	2.2kΩ	
R32	1.2MΩ	
R33	56kΩ	
R34	10MΩ 5%	
R35	1MΩ 2%	
R36	100kΩ 2%	
R37	11kΩ 2%	
R38	110Ω	
R39	47kΩ horizontal skeleton pre-set	
R40	1.5MΩ	
R41	3.9MΩ	
R42	120kΩ	
R43	2.2kΩ	
R44	2.2kΩ	
R45	47kΩ	
R46	47kΩ	
R47	10kΩ 2%	
R48	10kΩ 2%	
R49	8.2kΩ	
R50	15kΩ	
R51	15kΩ	
R52	1.5MΩ	
R53	1.5MΩ	
VR1	100kΩ potentiometer, linear	
VR2	25kΩ potentiometer, linear	
VR3	2MΩ potentiometer, linear	
VR4	500kΩ potentiometer, linear	
VR5	500kΩ potentiometer, linear	
VR6	100kΩ potentiometer, linear	
VR7	2MΩ potentiometer, linear	
VR8	100kΩ potentiometer, linear	

Capacitors

C1(a) (b)	32 + 32μF electrolytic, 350 V.Wkg.
C2	4μF paper, 500 V.Wkg. (see text)
C3	1,000μF electrolytic, 16 V.Wkg.
C4	1,000μF electrolytic, 16 V.Wkg.
C5	0.047μF plastic foil
C6	100μF electrolytic, 16 V.Wkg.
C7	5,000pF plastic foil
C8	1μF plastic foil
C9	0.1μF plastic foil
C10	0.01μF plastic foil
C11	1,000pF silvered mica
C12	100pF silvered mica
C13	200μF electrolytic, 10 V.Wkg.
C14	0.15μF plastic foil
C15	10μF electrolytic, 16 V.Wkg.
C16	2,000pF plastic foil or silvered mica (see text)
C17	120pF silvered mica (see text)
C18	10μF electrolytic, 16 V.Wkg.
C19	0.22μF plastic foil
C20	2,000pF paper, 500 V.Wkg.
C21	0.1μF disc ceramic
C22	0.1μF disc ceramic
C23	0.5μF electrolytic, 12 V.Wkg.

Transformer

T1 Mains transformer. Secondaries. 250-0-250V at 80mA, 6.3V at 3.5A, 6.3V at 1A, Douglas type MT1

Semiconductors

TR1	2N3819	TR9	BC117
TR2	BC117	TR10	BC169C
TR3	BC117	TR11	BC117
TR4	TIS43	TR12	XB113
TR5	BC169C	TR13	XB113
TR6	BC169C	D1	1N4007
TR7	BC109	D2	1N4007
TR8	BC117	D3	1N4006

D4-D7 Selenium bridge rectifier. 12V 0.5A

D8	12V 3 watt zener
D9	BZY88C24
D10	ZL100
D11	BAY31 or similar
D12	BAY31 or similar

Tube

Cathode ray tube type 3BP1

Switches

S1	s.p.s.t. toggle
S2	2-pole 6-way rotary
S3	3-pole 4-way rotary
S4	s.p.s.t. toggle

Miscellaneous

10 control knobs
B14A c.r.t. base
Flush-mounting coaxial socket
4 3mm. insulated sockets
5-way tagstrip, centre tag earthed
Capacitor clip (for C1)
Printed circuit board
Aluminium for case, chassis and c.r.t. mounting
Veroboard panel
Perspex for graticule
Screened lead
4 rubber feet

Table I
Specification

Cathode Ray Tube. 3BP1, giving 2½in. viewing area.
Timebase. 6-position switch plus fine frequency control. Ranges: 1, timebase off; 2, 5-50Hz; 3, 50-500Hz; 4, 500Hz-5kHz; 5, 5-50kHz; 6, 50-500kHz.
X Amplifier. Input impedance, 1.8MΩ. Sensitivity, 15mV/cm. Bandwidth, less than 5Hz to 250kHz at —3dB. X input provided.
Y Amplifier. Input impedance, 1.5MΩ. Sensitivity, 10mV/cm. Bandwidth, less than 5Hz to approx. 1MHz at —3dB. Useful response to beyond 2MHz. Four position attenuator, X1, X10, X100, X1000.
Sync. Internal sync.

Table II
Control Functions

S1	Mains on-off
S2	Timebase range
S3	Y attenuator
S4	Sync. on-off
VR1	Focus
VR2	Brilliance
VR3	X amplifier gain
VR4	X shift
VR5	Timebase fine frequency
VR6	Y shift
VR7	Y input gain
VR8	Astigmatism

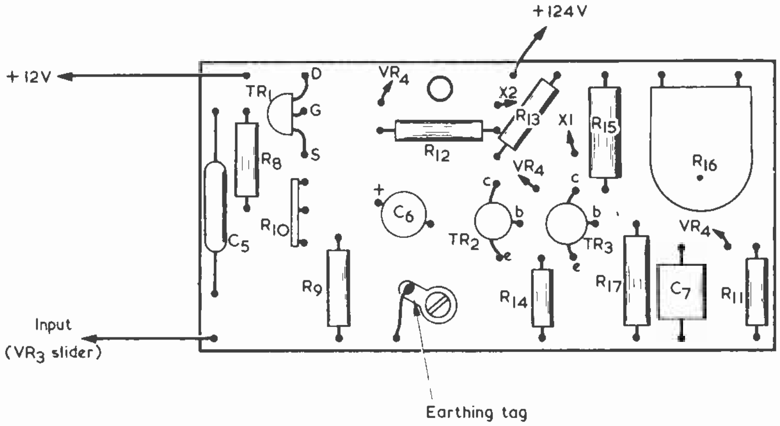
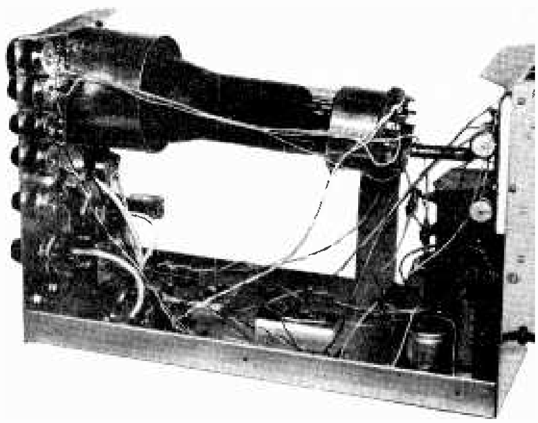


Fig. 10. The component layout on the X amplifier board



Another view inside the oscilloscope. The use of circuit modules represents an attractive constructional approach

adjusted for half resistance at the outset, and then adjusted to give 6 volts (plus or minus 1 volt) at TR1 source.

After the tube has had time to warm up, it should be possible to bring the spot on the screen by adjusting the X shift control. R16 should now be reduced in resistance until the X shift control can move the spot an equal distance on either side of centre.

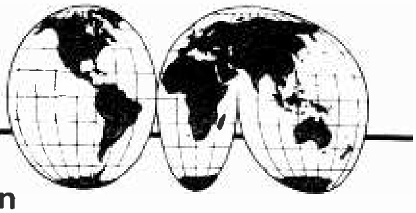
The circuit is very sensitive, and if it is working properly, touching the positive X input terminal will produce a line across the screen, the length of which can be controlled by the X gain control.

NEXT MONTH

The remainder of the constructional details of the oscilloscope will be discussed in the concluding article, to be published next month. The Components List accompanying the present article includes all the parts that are required. Some of the components will, in consequence, be referred to next month.

(To be concluded)

SHORT WAVE NEWS



FOR DX LISTENERS

By Frank A. Baldwin

Times = GMT

Frequencies = kHz

After some time spent searching for a clear 49 metre band outlet, Lakeland Radio, Blantyre, Malawi is reported by BADX (British Association of Dxers) operating on **9510** (31.55 metres) and signing-off at 2200. The schedule is from 0330 to 0430 (latter time is subject to some variation) and from 1845 to 2100 sign-off, also apparently liable to alteration. All programmes are in English from this 100kW transmitter.

AROUND THE DIAL

● LEBANON
Beirut has been heard signing-on with the National Anthem, station identification in English and a newscast in the same language at 1800 on **15170** (19.78m).

● AUSTRALIA
The best time to hear transmissions from this country is, of course, in the early mornings around 0700 but it can be logged during the afternoons on occasions. We logged Radio Australia at 1520 on **7235** (41.47m) when a programme in English to S.E. Asia "Politics in Australia" was being radiated.

● SOUTH AFRICA
Radio South Africa from Johannesburg may be heard during the evenings at 1900 on **15175** (19.77m) when radiating station identification and a newscast in the English programme.

For a more difficult exercise in the reception of South Africa, try the Internal English Service on **4965** (60.42m) from around 1930 onwards. Logged recently at 2010 with a programme of dance music records.

● ECUADOR
If you are interested in Dx, why not listen to "DX Party Line" broadcast every Tuesday in the English programme which commences at 1930 from HCJB Quito on **17755** (16.90m) amd in parallel on **15155** (19.80m) and **11715** (25.61m). The programme is mainly supported by listener reports from the USA but is nevertheless of interest to SWL's in the UK.

● CUBA
Havana can be heard, in English, from 2015 on **15140** (19.81m) but do not be surprised if you later hear Hanoi, Vietnam on the same channel in English – it is merely a relay.

● EGYPT
The Arab Republic of Egypt can be heard every evening with station identification and the news in English at 2200 on **9805** (30.59m) in the European Service. Address your reports to – European Service, P.O. Box 566, Cairo.

● YUGOSLAVIA
Radio Belgrade may be heard with identification and a newscast in English at 2200 on **9620** (31.18m).

● U.S.A.
WINB Red Lion is currently signing-on in English at 2100 on **15185** (19.75m).

● INDIA
All India Radio, Delhi, can be logged if conditions are right on **4860** (61.72m). We heard it at 2200 with the news in English until 2210, a talk on Indian affairs until 2215 when, after station identification, local songs and music were radiated. Also logged on another occasion at 1930 with a programme of local music.

AIR Bombay has also been logged at 1840 on **15080** (19.89m) with programme of Indian music. Station identification and news in English at 1945.

● ITALY
The news in English from Rome can be head, after identification, at 1930 on **11800** (25.42m), but see below.

● SRI LANKA
The **11800** channel also carries a programme of local music and songs from Colombo which may be heard around 1530, recently logged by us from 1520 through to 1550.

● ROUMANIA
Bucharest radiates the news in English at 1930 and can be heard on **11775** (25.47m).

● MALAYSIA
The BBC transmitter at Tebrau may be heard with the news in English at 2200 on **9570**.

● PAKISTAN
Radio Pakistan, Karachi, may be heard with the local news in English from 1915 to 1920 on **9460** (31.71m).

● CHINA
Some loggings of Radio Peking in recent weeks have been – **4865** (61.66m) at 2210, talks in a local dialect; **4905** (61.16m) at 2220, female in Chinese dialect; **7256** (41.34m) at 1435, dialogue in Chinese; **9020** (33.25m) at 2020, in Chinese; **9365** (32.03m) at 1500, sign-on with "East is Red" then into Russian – soon jammed; **11770** (25.48m) at 1542, female still talking; and on **15030** (19.96m) at 2005, programme in English about Chinese achievements.

● BRAZIL
If the LF bands are reasonably 'open', ZYX2 Radio Brasil Central, Goiania, on **4995** (60.06m) can be heard from around 2100 or so. Logged here recently at 2120 with Latin American music and announcements in

Portuguese.

Another Brazilian station to look for is ZYR56 Radio Excelsior, Sao Paulo, on **9585** (31.29m) around 2200. We logged it at 2210 with a sports commentary.

● **BOTSWANA**

Radio Botswana, Gaberones, can sometimes be heard in the U.K., conditions permitting, on **4845** (61.91m) around 1830. We logged it recently at 1850 when African drums and native musical instruments were blended in a rythmic sequence which went on, and on, and on!

● **ANGOLA**

Radio Clube do Huambo has a 10kW signal that is worth searching for on **5060** (59.28m) around 2230, programming is in Portuguese. Our last two loggings of this station however were marred by a continuous heterodyne on the channel – but we live in hope!

● **CAMEROON**

Radio Garoua on **5010** (59.88m) is more often than not blotted out by teletype transmissions but we did manage to hear the station at 2220 recently on a clear channel for a change. African chants by a chorus (!) of young ladies delighted our ears. Local 'pops' presumably!

GMT	*Freq.*	*Stn.*	*Rcvd.*
1435	7256	R. Peking	
1500	9365	R. Peking	
1520	7235	R. Australia	
1520	11800	Colombo	
1542	11770	R. Peking	
1800	15170	R. Beirut	
1830	15485	R. Libre	
1840	15080	Bombay	
1845	9510	Lakeland Radio	
1850	4845	R. Botswana	
1900	15175	Johannesburg	
1915	9460	R. Pakistan	
1925	4926	EAJ206 Bata	
1930	4965	Johannesburg	
1930	11715	HCJB Quito	
1930	15155	HCJB Quito	
1930	17755	HCJB Quito	
1930	4860	Delhi	
1930	11800	Rome	
1930	11775	Bucharest	
1945	15080	Bombay	
2005	15030	R. Peking	
2015	15140	R. Havana	
2020	9020	R. Peking	
2100	15185	WINB Red Lion	
2115	15105	R. Grenada	
2120	4995	ZYX2 R. Brasil	
2200	9585	ZYR56 R. Excelsoir	
2200	9805	Cairo	
2200	9620	R. Belgrade	
2200	4860	Delhi	
2200	9570	Tebrau	
2210	4865	R. Botswana	
2220	4905	R. Peking	
2220	5010	R. Garoua	
2230	5060	R.C. do Huambo	

● **CLANDESTINE**

Radio Libre, with identification and talk in Portuguese, was recently logged by us on **15485** (19.37m) at 1830.

● **WINDWARD ISLANDS**

Radio Grenada operates on **15105** (19.86m), where we recently heard a programme in English at 2115 about tourism in the West Indies.

● **EQUATORIAL GUINEA**

EAJ206 Bata, Rio Muni, may be heard on **4926** (60.90m) during the evenings here in the U.K. Programming is mainly in Spanish and we logged it at 1925.

TIME-CHECK

The transmissions featured in *AROUND THE DIAL* are listed here on a time-check basis for the convenience of readers.

NOW HEAR THESE

● **INDONESIA**

"The Voice of Indonesia", Jakarta, currently radiates a programme in English, directed to the U.K., Europe and New Zealand, from 1900 to 2000 on **11715** (25.60m).

● **SRI LANKA**

The English Service from Colombo may be heard from 1230 to 1730 on **7190** (41.72m), **9720** (30.85m) and on **15120** (19.84m).

● **BRAZIL**

The Brasilia International Service beams an English programme to Europe from 2200 to 2300 on **11720** (25.59m) and on **15447** (19.42m). but, according to reports, the time schedule is subject to variation.

● **IRAN**

Radio Iran is now back (at the time of writing) on **9030** (33.22m) and has vacated the **12180** channel.

● **FINLAND**

Broadcasts in English to Europe daily from Finland may be heard from 1400 to 1430 and from 1800 to 1830 on **15185** (19.75m) and from 2030 to 2100 on **9550** (31.41m).

● **KUWAIT**

The English programme from Radio Kuwait has been logged at 1710 on **15415** (19.46m). Current schedule in English is from 1630 to 1900, also in parallel on **9750** (30.76m).

● **CONGO REPUBLIC**

Brazzaville may be heard in the evenings on **15190** (19.74m) we logged it at 1950 when a programme of typical African music was being broadcast, identification in French at 2100. "The Voice of the Revolution" carries the local domestic service and is on the air from 0600 to 1300 and from 1500 to 2130.

● **INDIA**

AIR Delhi can be heard with a programme in English from 2100 on **11620** (25.81m). We logged it at 2110 and learned about the 5-year village improvment scheme.

CYCLOPS

PART SIX

by L. C. Galitz

This is the sixth and concluding article in the series concerning robots and cybernetic devices, and it describes the circuit operation and construction of the conditioned reflex circuits. Also dealt with is the battery charger unit.

In last month's issue the basic operation of the conditioned reflex circuitry was described, after which the circuit for the conditioned reflex unit was published, as Fig. 27, together with the Components List. Fig. 27 should now be consulted, since its operation will next be discussed in detail.

CIRCUIT OPERATION

In Fig. 27, the area enclosed by the dotted line is built on the new Veroboard panel, and above and below the dotted line are existing components such as RLA/4, RLB/1, RLC/1 and their contacts. There are also new components such as X2, the magnetic sensor, S4 and S3. The operation of the circuit is fairly straightforward, apart from a few details which are somewhat unusual – these are explained below.

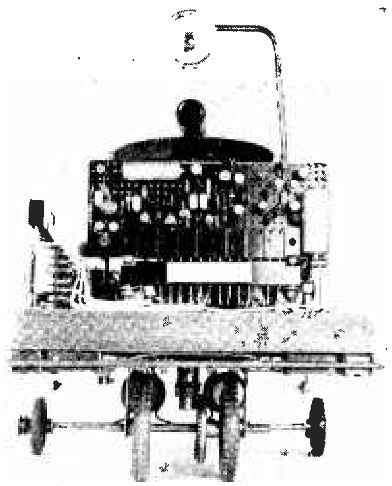
The output from the inhibit Ss gate triggers the differential monostable via R26 and C6. The two monostables in this circuit have a diode in the collector of the transistor which is normally turned off. This is to ensure that if there is a momentary reduction in the supply rail voltage, these diodes will be reverse biased, and the potential on the collectors of TR17 and TR22 will be held up by the charge across C7 and C9 respectively. This prevents spurious triggering of the monostables.

The extension monostable is fired directly by X2, a reed switch acting as a magnetic sensor, via C8. R37 holds the X2 end of C8 negative until the switch is triggered. The output of this monostable passes to the base of TR20, whilst the output of the differential monostable passes to TR19. These two transistors, along with R30, form the coincidence And-gate, using the current sinking logic principle. In other words, the emitters of the transistors are kept near the earth potential unless *both* transistors cut off, and this only happens when both bases are negative, which in turn only occurs when both monostables have fired at the same time. At all other times, the current through R30 is sunk to earth via either or both transistors. The output of the gate passes via D5 and R31 to the summing capacitor. D5 prevents the capacitor discharging through the gate when it is closed, and R31 allows the capacitor to charge up only by a certain amount every time the gate opens. S4 is wired across the summing capacitor and is labelled 'Forget' – it is used when one wishes to erase Cyclops' memory of previous experiences and start afresh on a new experiment.

TR23 in the common collector mode acts as a current amplifier for the summing capacitor. In the emitter circuit of this transistor is wired a potentiometer which sets the threshold level of the Schmitt trigger formed by TR24, TR25 and associated components. It so happens that all three outputs from the Schmitt trigger require the inverted function rather than the normal one, and therefore the output is taken from the first collector.

It will be noticed that the time-constant resistor for the extension monostable is split into two halves, R34 and R35. The junction between the resistors is connected via D7 to the output of the Schmitt trigger. When the Schmitt trigger is in its unfired state the cathode of D7 is negative and the diode conducts, reducing the effective overall time-constant resistance. When the Schmitt trigger fires, this diode is reverse biased, and both resistors come into normal operation. In the prototype, the two monostable quasi-stable periods were seven and ten seconds respectively.

The first output And-gate, the inhibit En gate, consists of TR26, and TR27 and R44. This gate operates in similar fashion to the coincidence And-gate. The output of this gate passes directly to TR28, the relay driver, and it has the usual diode to prevent relay transients damaging the driving transistor. The bases of the transistors forming the And-gate couple directly to the Schmitt trigger output and the monostable output respectively. This is possible because the transistors operate in the common collector mode and therefore have a high input impedance.



On the other hand, the transistors forming the 'instigate conditioned response' gate, TR29 and TR30, are in the common emitter mode, and they connect to the Schmitt trigger output and the Sn input via resistors. As with the previously mentioned gate there is a relay driver, TR31, wired directly to the output of the gate, again with the usual protection diode. From the output of this gate passes a wire to S3(c), and from this switch to the base of TR15 in the inhibit Ss gate, so that the automatic reinforcement feedback loop is inhibited when the switch is set to the 'magnetism means light' mode.

The other two sections of S3, which is the mode selector switch, occur in the input switching of Ss, and in the output switching of Es, in the 'touch' mode, Ss is connected via S3(a) to the make contact of RLA2, of which the common contact and the break contact are already in the basic reflex circuitry. (See Fig. 14, published in Part 3). At this point it should be noted that the positive lines of both the learn circuitry and the basic reflex circuitry are joined together. In the 'light' mode, Ss connects to the make contact of RLC1; the common contact connects to the earth line via RLA2. (This is just for convenience when wiring – it could connect straight to the earth line).

When switched to the 'touch' mode the Es output passes to pin 6 of the basic reflex circuitry socket via S3(b), i.e. to the base of TR1, which operates RLA/4; and, when switched to the 'light' mode, the Es output passes directly to RLC/1 coil. The output from En always goes to RLB/1 so that, when En is activated, Cyclops' motors cut off until the extension monostable reverts to its normal state.

It can now be appreciated why relays RLB/1 and RLC/1 were specified as having dual coils – in each case, one relay coil appears in the basic reflex circuitry and the other coil appears in the conditioned reflex circuitry. The isolation of the two coils helps keep the two sets of circuits separate.

The arm of S3(a) connects to the base of TR16, one of the two transistors in the 'inhibit Ss' gate. Resistor R23 keeps this transistor cut on until the appearance of the pulse from either RLA2 or RLC1.

COMPONENTS

All resistors and capacitors are standard components as specified in the Components List, which was published last month. The diodes are all silicon, and D5 should be chosen to have a high back resistance to limit discharging of the summer capacitor. Transistors TR19 and TR20 are n.p.n. silicon planar, with the leads having the e-c-b sequence. TR26 and TR27 are normal n.p.n. transistors, whilst all the others are p.n.p. transistors. The monostable transistors may have to be selected, as some cause spurious triggering of the circuit – in other words, some transistors have a property of being more susceptible to noise than others. The writer encountered this problem with some of the transistors he had on hand, but quite a number worked quite satisfactorily, giving no trouble at all. It is possible that the risk of spurious triggering could be reduced by adding a bypass capacitor, of around 0.047μF, across the supply rails, although this was not found necessary by the writer, who had little difficulty in finding suitable transistors.

TR23 should be selected for low leakage – a transistor with too high a leakage would cause C10 to discharge too quickly. This capacitor may also have to be selected for low leakage, and although capacitors working well below their rated voltage have in general a lower leakage figure, the author found no trouble with the several samples tried, which were working at half rated voltage in the circuit.

COMPONENTS

Resistors

R1	2.2kΩ ½ watt
R2	27Ω ½ watt (see text)
R3	330Ω 1 watt
R4	2.2kΩ ½ watt
R5	27Ω ½ watt (see text)
VR1	15Ω potentiometer, wirewound, preset

Capacitor

C1	1,000μF electrolytic, 20 V. Wkg.

Transformer

T1	Mains transformer, secondary 12V at 0.5A. Douglas type MT111AT

Semiconductors

TR1	AC127
TR2	AD161
TR3	AC127
D1–D6	Silicon diodes (see text)
W1	Bridge rectifier 24–36V, 1A

Switches

S1-S4	s.p.s.t. toggle

Neon

NE1	Neon bulb assembly with integral series resistor.

Miscellaneous

Mica washer and insulating bushes (for TR2)
Multi-way cable
Chassis, tagboard, etc., (see text)

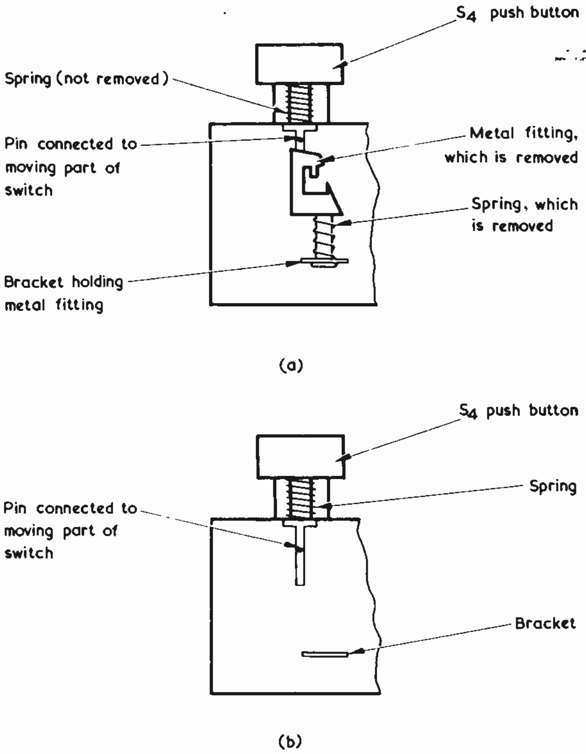


Fig. 28 (a). Switch S4 before modification
(b). How the switch appears after modification

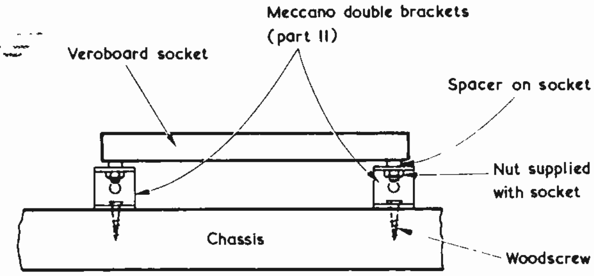


Fig. 29. Mounting the 15-way Veroboard socket. This is a view from the front of Cyclops

X2 is an R.S. Components reed switch, and the Veroboard connector used by the author was a Painton 15-way component. If difficulty is experienced in obtaining this connector a 16-way edge connector (Home Radio Cat. No. BTS45) could be employed with a 16-way piece of Veroboard, as was suggested for the board that is already fitted to Cyclops. The 16th way would, of course, be ignored when wiring up. Details of the relays RLB/1 and RLC/1, and of S3 and S4, were given in Part 3 of this series. However, although S3 is of the press-to-changeover, press-to-changeback, as on the switch-bank obtained, S4 is of the press-to-changeover, release-to-changeback variety, and was modified by removing a small metal fitting and a spring on the back of the switch. Details of this modification are shown in Fig. 28. Alternatively, separate switches can be obtained and mounted on the main control panel.

Battery BY3 is exactly the same as BY1, a Deac 6V 225mA/H rechargeable battery, but, as mentioned in Part 3, could be an Ever Ready PP1.

CONSTRUCTION

If the reader has obtained the Painton 15-way connector, this is mounted on the baseboard using a pair of Meccano double brackets as shown in Fig. 29. If the alternative 16-way connector is employed, this may be fitted in the same way as was the connector for the first board. The reed switch is next mounted using a Meccano rod, and rod and strip connector. Details of

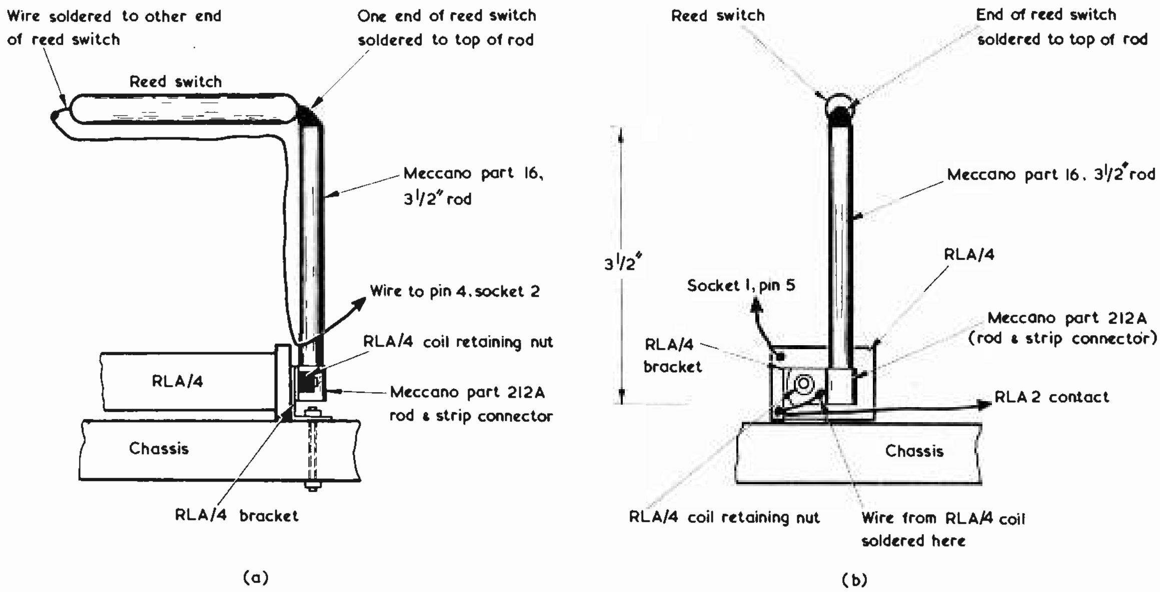


Fig. 30 (a). View from rear, showing the method of mounting the reed switch
(b). Another view, from the right side, of the reed switch mounting

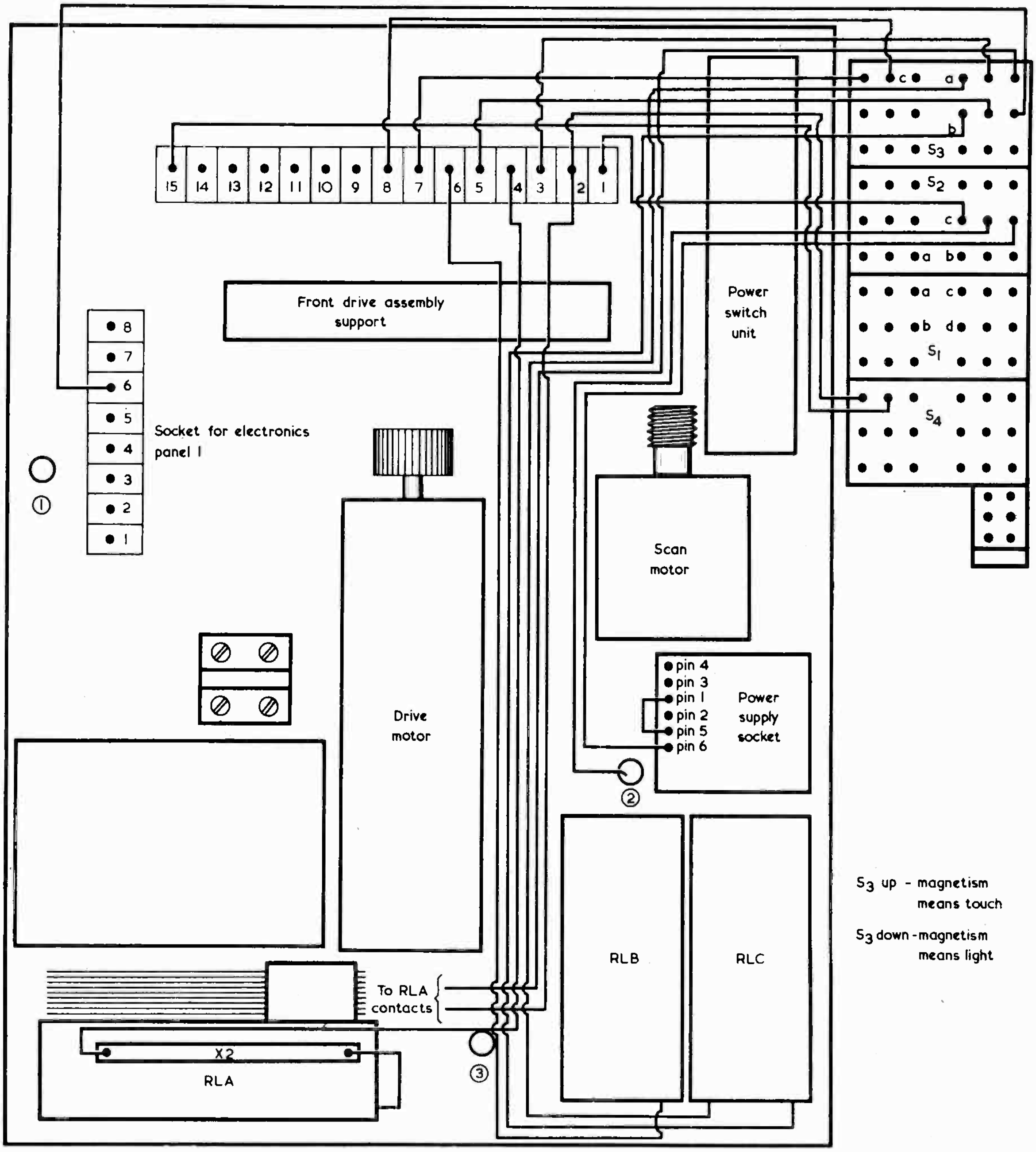


Fig. 31. The additional wiring on the main baseboard. As it is difficult to interpet diagrams in which the wires run closely together, as here, it is advisable to check against the circuit of Fig. 27 during wiring

how this assembly is built, and how it is mounted on the coil retaining nut of RLA/4 are given in Figs. 30(a) and (b).

The additional wiring can be carried out according to Fig. 31. Fig. 32 gives details of the wiring to the pins of the relays, which is not shown in sufficient detail in Fig. 31. It should be noted that the centre contact of RLC1 must be connected to the electronics earth, and the make contact of RLC1 should be connected to S3 (a). If the reverse is done, the circuit will not function correctly.

At this stage the Veroboard panel may be dealt with. This measures 2 by 5in. and has 13 strips, each with 33 holes. If the Painton 15-way connector is to be used, the area bounded by the holes K7, M7, K27 and M27 must be cut out, after which the connector can be mounted by enlarging the holes L6 and L28. These holes are illustrated in Fig. 33 and 34, which show the component and copper sides of the board respectively.

Next, cut the strips as indicated in Fig. 34. In wiring the board several points need to be observed. One of the lead-outs of R46 passes through the hole F17 (at which

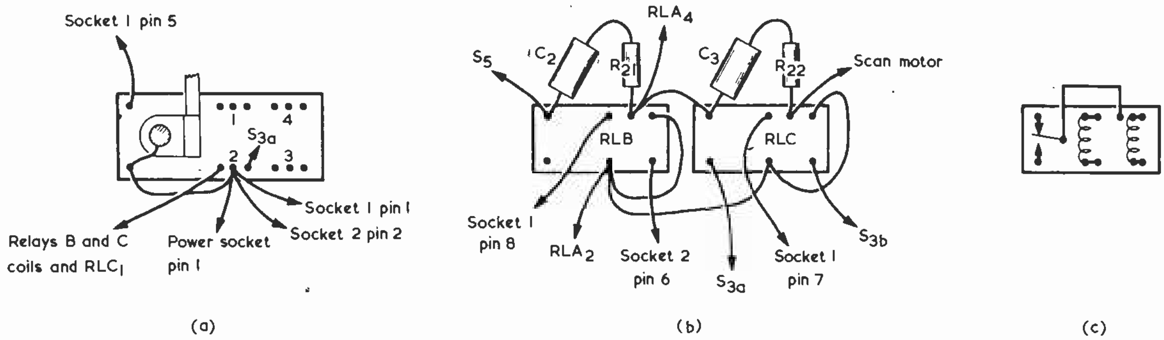


Fig. 32 (a). Wiring at RLA2. The additional connections are to S3 (a) and RLC1
(b). Connections to relays RLB and RLC. This includes existing wiring. RLB and RLC are wired in the mode shown here so that fields from separate coils assist each other. (It may be necessary to alter the existing wiring to the coils to achieve this)
(c). Pin designation for relays RLB and RLC

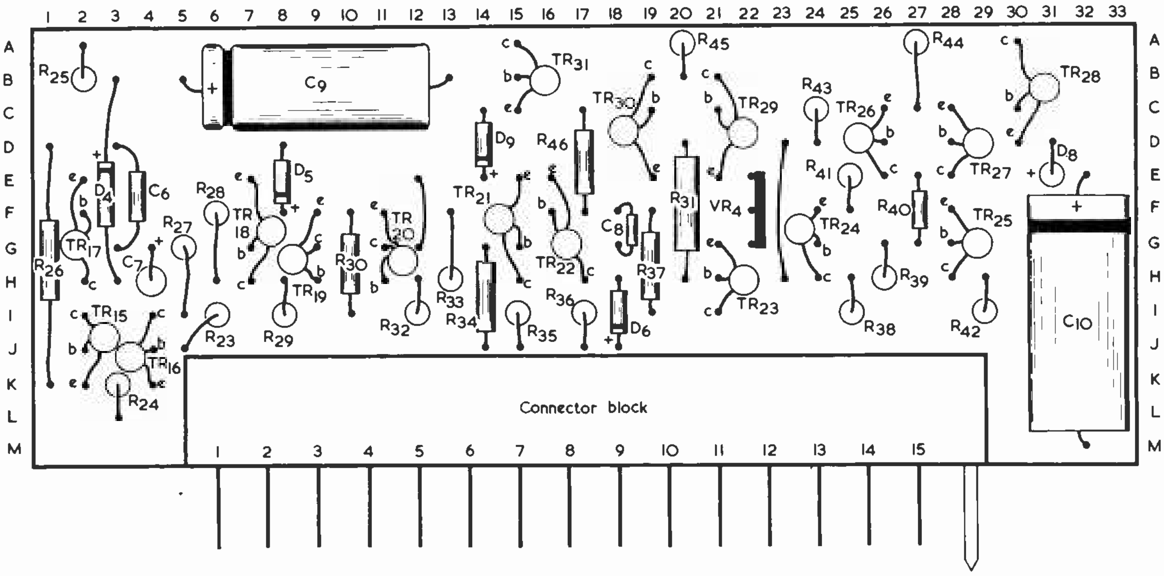


Fig. 33. Components side of Veroboard panel No. 2

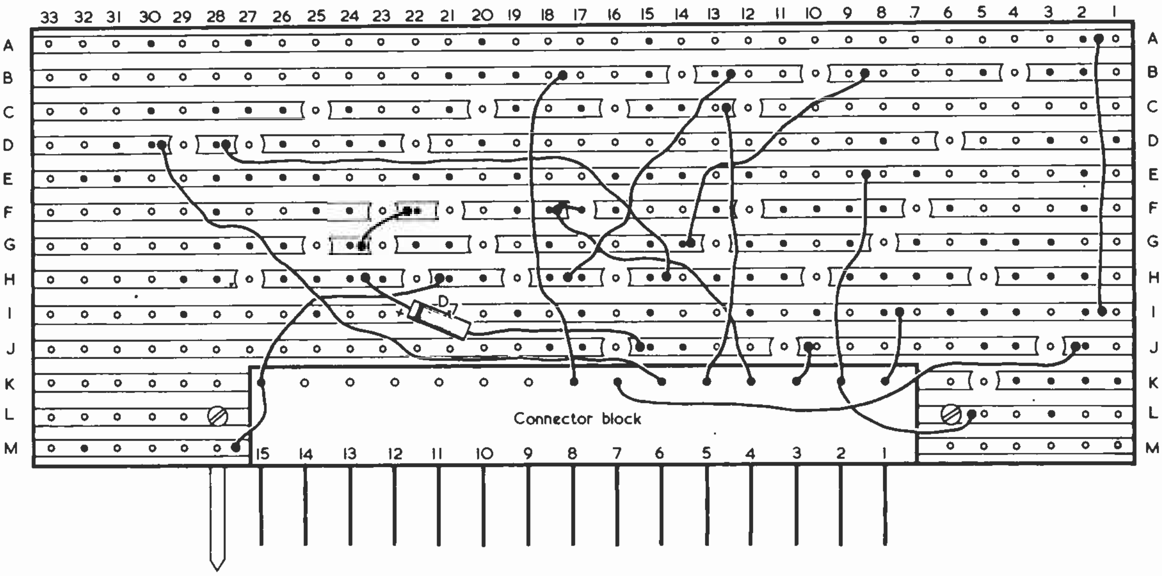


Fig. 34. The copper side of the Veroboard panel

the copper strip has been cut) and connects to the copper strip adjacent to F18. Diode D7 is mounted on the copper side of the board. There are, also, a number of links on the copper side of the board, these consisting of insulated wires soldered direct to the copper strips. Where possible, component lead-outs adjacent to the link connection points should be soldered before the links are fitted.

It is recommended that the circuit be built in stages; firstly the two monostables, then the coincidence gate and the inhibit Ss gate. Following this, the summer, Schmitt trigger, and finally, the output gates should be built. As each stage is completed the circuit can be tested. Any errors can be checked easily, because any faults that develop must be in the stage after the one previously tested. The polarities of the capacitors, diodes and transistors should be carefully checked before testing. When the circuit has been fully built and tested, the final setting up can take place.

SETTING UP

It may be found that minor difficulties occur during testing, and these may crop up due to tolerance spreads in the components used. There is only one resistor specified in the Components List which may need its value slightly changed, and that is R26. If this value is too small, Ss will not inhibit; if the value is too large, Ss will not trigger reliably. The author found that it was easiest to start with the resistor too small in value. Connect TR15 base to the negative rail via a 1kΩ resistor, and trigger the Ss input, increasing the value of R26 until the differential monostable does not fire. If, then, TR15 base is connected to the positive rail by a 10kΩ resistor, the differential monostable should trigger reliably every time Ss input is applied.

The monostable resistors governing the time-constant in the prototype were 6.8kΩ for the differential monostable, and two 15kΩ in series for the extension monostable. These give monostable quasi-stable periods of 0.6 seconds calculated, against 0.8 seconds in actual fact, for the differential monostable; and 8.6 seconds calculated, against 10 seconds in fact, for the extension monostable with the Schmitt trigger fired. With the Schmitt trigger in the normal unfired state, the monostable period is 7 seconds.

In the prototype, with R31 at 1kΩ, the summer needs six coincidences to give an output of 4 volts, at which potential the threshold of the Schmitt trigger is set. However, this figure is based on measurements obtained with coincidences made one immediately after the other. In normal operation, approximately ten coincidences are required before the Schmitt trigger fires. Constructors may wish to vary the value of R31 to make the number of coincidences required more or less. VR4 sets the Schmitt trigger threshold, and in the prototype this potentiometer was set to operate the trigger upon receiving an output of 4 volts from the summer.

Now the conditioned reflex unit should be complete, and Cyclops should behave in a more intelligent manner, modifying his actions to suit his environment, and he should be enjoying himself more than he did during his uneducated days.

CHARGING UNIT

In one of the photographs accompanying Part 1 of this series, Cyclops was shown having his batteries charged by a special charging unit coupled up to the 6-way power socket. Although any suitabe method of charging the batteries may be employed, readers may prefer to use the charging unit employed by the author.

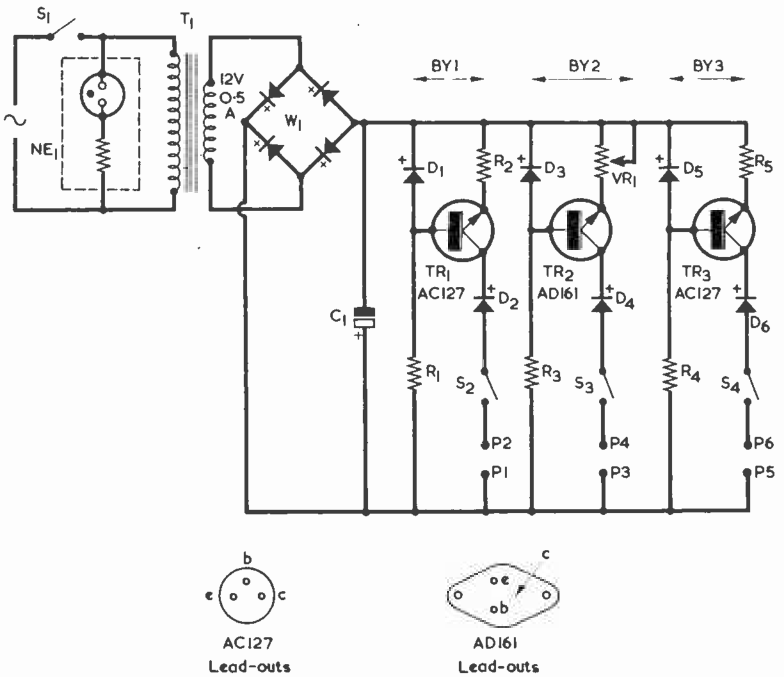


Fig. 35. The circuit of the battery charging unit

Brief details of this unit will now be given.

The circuit of the unit appears in Fig. 35. The a.c. mains input to T1 primary is switched by S1. The secondary output of 12 volts is rectified by W1 and smoothed by C1. The rest of the circuit consists of three constant current devices, one for each battery to be charged.

Considering the first constant current device, TR1 is germanium; therefore D1, a silicon diode with a voltage of about 0.7 volt across it, is sufficient to provide a constant voltage to TR1 base, TR1 being wired in the common base mode. R1 supplies sufficient current through the diode to swamp the current taken by TR1 base even when TR1 is passing the full constant current. As TR1 is in the common base mode, the constant current is set by the emitter resistor R2. S2 allows the charging current to be switched on and off. Diode D2 is in circuit to isolate the battery should the unit be disconnected from the mains. When this occurs D2 becomes reverse biased.

The same circuit description applies to the two other constant current devices.

The sections charging the Deac batteries BY1 and BY3 are set to give 27mA by adjusting the resistors R2 and R5. In the prototype the value required for these two resistors happened to be 27Ω exactly. The transistors used are AC127's. The section charging BY2 is set to 200mA by adjusting VR1. This section uses an AD161 power transistor.

The charging unit is built in a 6 by 4in. aluminium chassis, with S1 to S4 and the neon indicator mounted on the front panel. The electronics is built on a 2 × 10-way tagboard. The AD161 is bolted direct to the chassis, employing a mica washer and two insulating bushes for insulation of its collector in the usual manner. Each AC127 (which has an isolated envelope) is secured to chassis with the aid of a heat clip, which also functions as a bracket. The preset variable resistor, VR1, is mounted inside the chassis so that, once set, it cannot be accidentally disturbed. This component should be adjusted to insert maximum resistance before it is initially set up. Its resistance is then reduced until the desired 200mA charging current is achieved. A multi-way cable from the unit connects to a 6-way plug matching the power socket on Cyclops.

The mains transformer T1 is a Douglas MT 111AT offering 12 volts at 0.5amp. This is available from G. W. Smith & Co. Ltd., 3 Lisle St., London, W.C.2. Diodes D1 to D6 are any silicon diodes, but it must be remembered that D4 has to be able to pass 200mA.

The reason for including switches S2, S3 and S4 is simple. Sometimes the Cyclops electronics are run to test them without the motors, or the learn circuitry is not switched on. In either case, one battery has not been used and is still fully charged from the last time it was plugged into the charging unit. That battery is not then charged during the next charging period, it being switched out of the charging circuit by the appropriate switch.

The accompanying Components List shows the parts required for the charging unit.

CONCLUSION

The present series of articles on Cyclops is now concluded. However, further work has been carried out since these were written, and modifications are available which teach Cyclops how to earn his living and how to give him fits of neurotic depression when encountering hard times! These modifications will be described in a few months' time and it is suggested that readers retain the copies of *Radio & Electronics Constructor* in which the present series has appeared since reference will be made to the diagrams in these. ■

QUIZ DETECTOR

by

M. Jennings

A reliable device which indicates, by electronic means, which of a number of switching circuits has been closed first.

THIS CIRCUIT INDICATES WHICH OF TWO PUSH-BUTTONS has been pressed first and can, in consequence, be used in a game where two contestants match their reflexes in response to a stimulus, or in a quiz in which, after a question has been posed, the first team to press its button has the first option of answering. Circuits carrying out this second function are commonly used in B.B.C. sound radio quiz programmes. There are more serious applications also, since the circuit can determine which of a pair of contacts has closed first, and can thereby evaluate the comparative performance of two relays or similar switching devices. As will be explained later, the system can be extended to any number of push-buttons or external contact sets.

USE OF THYRISTORS

The circuit employs two thyristors (or silicon controlled rectifiers). It will be recalled that a thyristor is non-conductive until a positive pulse, relative to cathode, is applied to its gate. The thyristor then 'fires' and allows conventional current (from positive to negative) to flow through it from the anode to the cathode. Under this condition, about 0.6 volt is dropped across the thyristor. The thyristor remains conductive both in the presence or absence of a positive supply at its gate, and may only be made non-conductive again by switching off the source of anode-cathode current, or by short-circuiting the anode and cathode together.

In Fig. 1, two small thyristors type CRS1/05 are connected as shown. All the diodes in the circuit are silicon types. A 6 volt supply, which can be provided by a battery, is applied to the circuit. Let us assume that on-off switch S3 is now closed. Neither thyristor will conduct as there is no positive supply fed to either gate. Let us next say that push-buttons S1 and S2 are both pressed, with S1 closing momentarily before S2. As soon as S1 closes, a positive supply is fed to the gate of TH1 via R1, S1, R2 and the two forward biased diodes D2 and D3. A current flows in the gate-cathode circuit of the thyristor and it immediately fires, causing pilot lamp PL1 to be illuminated and the potential on the anode of the thyristor to fall to about 0.6 volt positive of the negative supply rail. Diode D1 now conducts, bringing point 'X', at the junction of R1, D1 and D4, to a level which is positive of the negative supply rail by about 1.2 volts, this being the sum of the forward voltage drops across TH1 and D1. Diode D4 is reverse biased and no current flows through it.

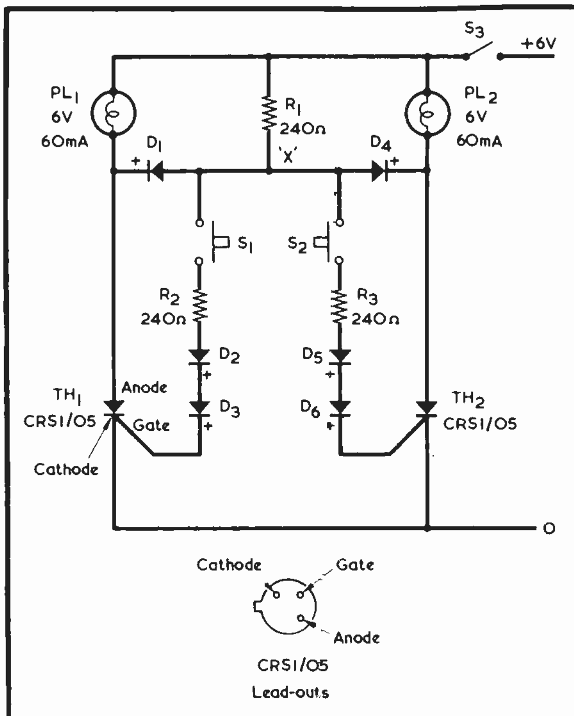


Fig. 1. The precedence detector circuit. The pilot lamps indicate which of the two push-buttons has been pressed first

With point 'X' at about 1.2 volts positive of the negative supply rail, it becomes impossible for push-button S2 to trigger TH2, because diodes D5 and D6, being silicon types, are unable to pass any significant forward current to TH2 gate. Thus, even if S2 is closed only a split-second after S1, it will only be lamp PL1 which will become illuminated, whilst PL2 will remain extinguished. If, on the other hand, S2 is closed a split-second before S1, it is TH2 which will fire, whilst TH1 will remain non-conductive. PL2 will then light up to indicate that it is S2 which, on this occasion, has been pressed first.

To bring the circuit back, to its original condition with both lamps extinguished it is necessary to open on-off switch S1 and then close it again.

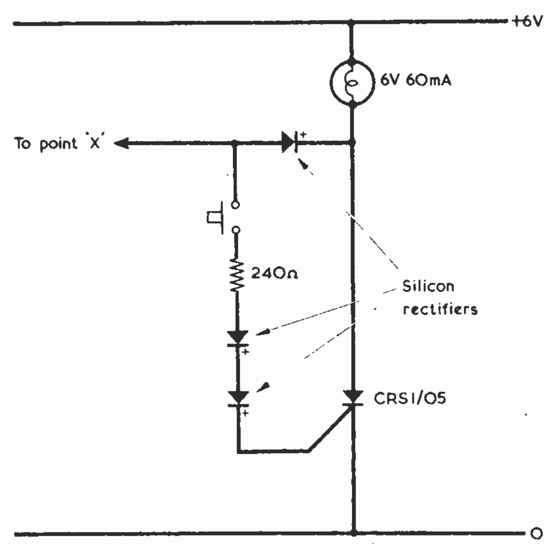


Fig. 2. The principle can be extended to any number of push-buttons and pilot lamps. Each additional push-button and pilot lamp employs the circuitry shown here

COMPONENTS

In the author's circuit S1 and S2 were push-buttons, as shown. Alternatively, two pairs of terminals can be provided for connection to external contact sets whose performance is to be evaluated. Diodes D1 to D6 can be any silicon rectifier diodes. The author used rectifiers type 1N4002, which happened to be on hand. The resistors are ½ watt 10% types.

The author employed low-consumpton m.e.s. pilot lamps rated at 6 volts 60mA (Home Radio Cat. No. PL7) in order to keep battery drain reasonably low. Lamps drawing a slightly larger current may be substituted, if desired, but care should be taken to ensure that their cold resistance (which can be many times greater than their hot resistance) is not so low as to cause an initial current in excess of 1 amp to flow in the associated thyristor at the instant of firing. The cold resistance of the bulbs to be used should be measured with an ohmmeter, and if it is less than 6Ω (which, of course, allows 1 amp to flow at 6 volts), a fixed resistor should be inserted in series with each bulb to bring the total resistance up to, or slightly greater than, this figure. The voltage dropped across the series resistor will be low when the bulb is lit and has attained its hot resistance value. Series resistors are not required with the 6 volt 60mA bulbs.

The circuit is not limited to merely two push-buttons and can, if desired, be expanded to accommodate any number of push-buttons (or external contact sets). Fig. 2 shows the circuit required for each additional push-button. This is identical to the existing individual push-button circuits in Fig. 1 and is connected across the same positive and negative supply rails. The diode in the anode circuit of the additional thyristor connects to point 'X' of Fig. 1. Circuit operation is the same as before. Whichever push-button is pressed first causes its associated thyristor to fire and its pilot lamp to light up, whilst at the same time bringing point 'X' down to about 1.2 volts positive of the negative supply rail and thereby disabling all the other gate circuits.

BOOK REVIEW

★ ★ ★

RADIO DATA REFERENCE BOOK, Third Edition. Compiled by G. R. Jessop, C.Eng., M.I.E.R.E., G6JP. 150 pages, 5½ × 8¾ins. Published by Radio Society of Great Britain. Price £1.00.

Intended mainly for the amateur transmitter and short-wave listener, this book nevertheless contains information that is of value to the constructor and experimenter. Its function is to provide equations, curves, abacs, tables and circuits for assistance in the design and use of equipment, together with short descriptions where applicable.

Typical of the topics dealt with are transmission line resonators, Yagi aerial design curves, folded dipole calculations, self-resonant frequencies of capacitors, coil winding turns, great circle calculations, meteorological data, SI units and the fundamental frequencies of FT241 crystals. However, these are just a few of the matters covered, which range from logarithm tables to the SINFO signal-reporting code.

"Radio Data Reference Book" provides a comprehensive and compact source of technical facts, and will be a useful addition to the shelves of any serious experimenter, especially if the major field of interest lies in short-wave transmission and reception. The author was assisted in his compilation of the book by G. C. Fox G3AEX, R. F. Stevens G2BVN, G.M.C. Stone G3FZL and H. L. Gibson G8CGA.

★ ★ ★

Radio Topics

By Recorder

★ ★ ★ ★ ★ ★ ★

I SEE THAT THESE NOTES WILL APPEAR in the December issue, at a time when most people are turning their thoughts to the choosing of Christmas presents. If anyone were to ask me what would probably be the most useful present for the radio construction enthusiast these days my answer would be immediate – a magnifying glass!

It's true, too. Transistors and all the other semiconductor devices are getting smaller and smaller as the years go by. The type markings on some of the tinier plastic devices are nowadays so microscopic that I'm sure that even the keenest sighted have difficulty in deciphering them. It may not be long before we follow in the footsteps of the watch makers and work with an eyeglass permanently in position.

MINIATURISATION

All this miniaturisation is of course a good thing, since there isn't much point in making devices that are larger than they need be. In the very early days of transisitors, when the common types were the OC70 and OC71, I well remember reading in a journal for the deaf a plea for the manufacture of smaller transistors for use in deaf aids. The journal pointed out that the transistors then current consisted of minute junctions which were housed in what were relatively whacking great cans. A percipient plea indeed, and one that was answered in later years.

With semiconductors becoming smaller, what other components are also undergoing a continual process of shrinkage? Resistors, for a start. Obviously, a resistor has to have a certain minimum volume in relation to the power it has to dissipate. But the transistor circuits in which the resistors are used tend, themselves, towards reduced dissipation in the associated components, whereupon it becomes possible for resistors to become more and more diminutive as development proceeds. Capacitors also become smaller, if only because the voltages associated with transistors are so low.

The ultimate in miniaturisation is, to date, the integrated circuit. This is already ousting individual transistors in many items of domestic electronic equipment, including in particular radio and television receivers. There is some way to go before all the components of a receiver, apart from the controls and speaker, etc., can be packed into a few integrated circuits but progress towards that end is nevertheless under way. In computers the integrated circuit gained precedence over the transistor many years ago and we now see the situation where each generation of integrated circuits is being superseded by more efficient and even smaller types.

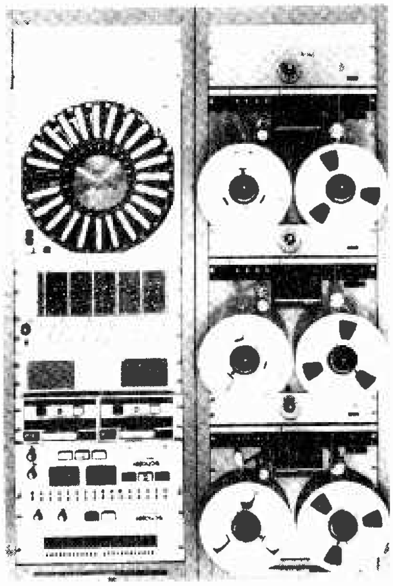
Perhaps one of the fascinations of electronics is that it never stands still. Every year brings forth its crop of exciting new devices and principles, and nearly all of these lead the way to equipment of more Lilliputian dimensions. I can visualise the day when a low cost mass-produced radio is encompassed in the same space as a wrist watch, and when an inexpensive mass-produced TV set has dimensions which are not very much greater than the screen which reproduces the picture.

AUTOMATED RADIO

When the little green men finally overtake the world they may find that many of our activities are being run by machines. The accompanying photograph illustrates an example of this trend and shows a radio broadcasting system that is fully automated.

The equipment is a typical item in the Schafer 900 series of modular broadcasting units and it consists of tape playback decks, both reel-to-reel and cartridge, which are controlled by prior programming in the memory store of the system control unit.

EMI Electronics and Industrial Operations, Hayes, Middlesex, now have exclusive marketing rights (outside North America and Mexico) for these systems, which are stated to be the most flexible series of a.m. and f.m. radio automation equipments available.



An automatic broadcasting system, marketed by EMI Electronics and Industrial Operations, which can be operated completely unmanned. Both reel-to-reel and cartridge tape playback facilities are available

YEAR'S END

These represent my final jottings for 1972. Looking back, it has been, I feel, quite an outstanding year for this journal. We certainly intend to keep up the standard in 1973 and already have some really appetising radio and electronic constructional goodies lined up for publication.

In the meantime take advantage of the Festive Season, go easy on the pud and, above all else, have a truly Happy and Merry Christmas.

See you next year! ■

In your workshop

Dick and Smithy are relaxing in the last few hours before the Christmas holiday when we join them this month. During their welcome break from servicing Smithy re-introduces Dick to the fascinating world of digital logic, and demonstrates to him the number of different gate functions which can be provided by the quadruple NAND gate type 7400.

"AH," SAID DICK LAZILY, AS HE settled himself more comfortably on his stool. "now this really *is* nice and Christmassy."

It was the afternoon of the last working day before Christmas. Both he and Smithy had been toiling feverishly in order to clear the rush of faulty receivers which inevitably appeared in the Workshop just before the Yuletide holiday. The "Repaired" racks now bulged with serviceable receivers, whilst the "For Repair" racks were gratifyingly empty.

An atmosphere indicative of the festive season pervaded the Workshop. Its utilitarian bleakness had already been relieved by the setting up, by Dick of a number of gaily coloured paper chains across the ceiling together with the application of red and mauve crepe paper to the walls behind the benches. An improbable series of imitation drops of snow garnished the windows in neat horizontal rows, and gave evidence of Dick's adroit application of judiciously controlled squirts from a Gilette Foamy Shaving Cream aerosol.

"Yes," spoke up Smithy, similarly relaxing at his own bench, "you're dead right, Dick. I can already feel the Christmas spirit soaking into my bones."

The pair grunted contentedly.

LOGIC CIRCUIT

"Do you know," said Dick, "there's something about Christmas that fits exactly into the logic of life. It seems to be perfectly logical that the Christmas Holiday should commence just before the end of the year, and just before we go into the worst of the winter."

"True enough," agreed Smithy. "It's funny, though, that you should have mentioned the word 'logic'."

"Why's that?"

"Because I was also thinking of logic," replied Smithy, "but in a completely different sense. I was thinking of those logic integrated circuits which are all the rage these days. As it happens, I've bought a selection of these devices and I was going to play around with them during the holiday. I've already knocked up a stabilized power supply for them."

Dick's ears pricked up.

"Logic i.c.'s, eh?" he said keenly. "Have you got them with you here?"

Smithy opened a drawer in his bench and took out a small cardboard box. Dick rose eagerly from his stool and hurried over to Smithy's side.

"Here you are," stated the Serviceman, taking the lid off the box, "take a look at these."

Dick gazed into the box, which contained about a dozen dual-in-line integrated circuit modules, in company with an equal quantity of integrated circuit holders.

"Gosh," he said, picking up one of the modules and examining it closely. "Are all these integrated circuits digital types?"

"They are."

"I always look upon digital i.c.'s as coming close to black magic," confessed Dick. "When you look at circuit diagrams incorporating digital i.c.'s all you can see are individual blocks with lines joining them. There are hardly any external components in the circuit diagrams at all."

"That's one of the charms of working with digital integrated circuits," stated Smithy. "You simply connect the output of one integrated circuit

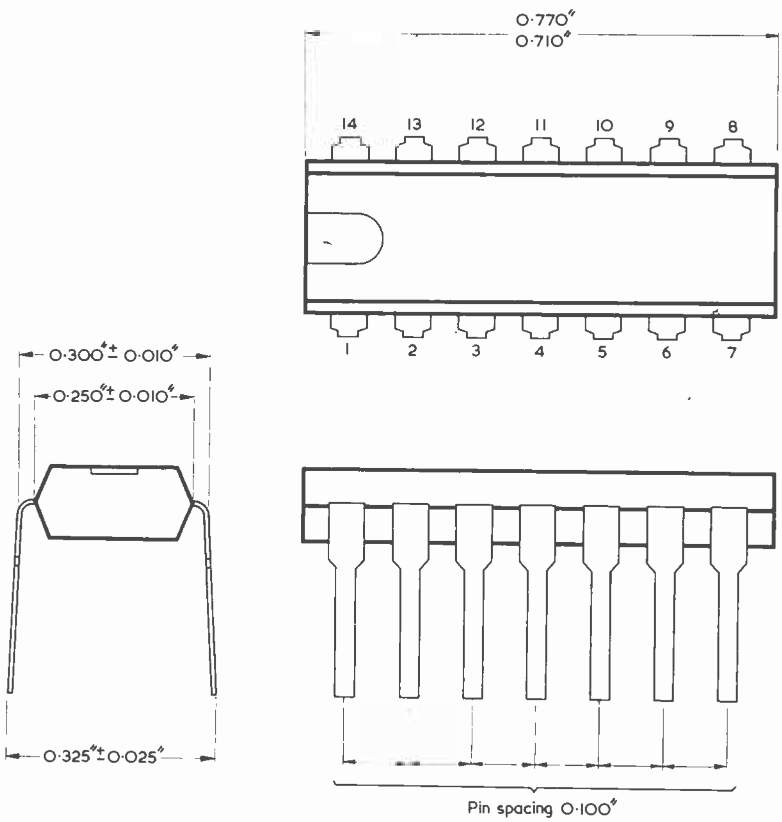


Fig. 1. The principal dimensions of a 14 pin dual-in-line plastic integrated circuit

section direct to the input of another integrated circuit section. You can look upon each i.c. section as a 'black box' and you don't need to think too much about what's inside it at all. So far as circuit diagrams incorporating i.c.'s are concerned, another unfamiliar aspect is that the power supply connections are usually omitted. Each i.c. has a tag for positive and negative supplies and it is automatically assumed that these are connected to the supply circuit."

"Would the i.c.'s you've got here," asked Dick doubtfully, "be what are known as t.t.l. types?"

"They would," confirmed Smithy. "The letters 't.t.l.' stand for 'transistor transistor logic' and the term arises from the fact that t.t.l. devices are a development from the earlier diode transistor logic or d.t.l. devices, and resistor transistor logic or r.t.l. devices. These t.t.l. circuits are capable of working faster than the older types. The ones I've got here are from the well-known 74 series. This name arises because the Texas Instruments type numbers for the series consist of 'SN74' plus two or three other numbers according to function. Also, there's usually a suffix letter to denote the type of case and terminals employed. With Texas Instruments i.c.'s, the letter 'N' indicates a plastic case and dual-in-line terminal pins, and this is by far the best version to use for home-constructor work."

"I suppose," said Dick, returning the integrated circuit to the box, "that the pins are spaced out in a standardised manner."

"That's true," confirmed Smithy. "There's 0.1 inch spacing between pin centres, and there's 0.3 inch spacing between the two lines of pins. Amongst other things, this pin spacing allows dual-in-line i.c.'s to be fitted directly to 0.1 inch Veroboard." (Fig. 1.).

"I wonder," asked Dick eagerly, "if we could try out one of these i.c.'s. Just so that I can get the feel of them."

Smithy looked at the Workshop clock.

"All right," he agreed. "We've got a couple of hours to spare, so I can see no harm in trying out some simple logic set-ups here and now. Let me think for a moment."

Smithy stroked his chin reflectively and studied the contents of the cardboard box. Eventually, he took out one of the integrated circuits.

"This will be a good one to start you off with," he remarked. "The i.c. I've selected is an SN7400, and it is a quadruple 2-input positive NAND gate."

Dick's face fell.

"I knew that this logic business just *couldn't* be all that easy," he sighed. "What on earth does 'quadruple 2-input positive NAND gate' mean?"

"All it means," replied Smithy soothingly, "is that the i.c. has four separate NAND gates, and that each of these has two inputs. The positive bit arises from the fact that the gates work on positive logic."

"And what's that?"

"It's logic in which the figure 1 is represented by a high voltage and in which the figure 0 is represented by a low voltage."

"Well," said Dick, brightening visibly, "that doesn't sound too bad after all. I suppose that the figures 1 and 0 came into the picture because all these digital i.c.'s work in binary notation."

"That's right," confirmed Smithy. "There are only the two figures, 1 and 0, in binary. Now, I've got a data sheet for the 7400 somewhere around so I'll show you the pin layout."

Smithy looked through some papers and extracted the data sheet in question. He laid it on his bench and indicated the pin layout diagram to his assistant. (Fig. 2).

"There you are," he remarked. "This diagram uses logic symbols and you can see the four NAND gates all drawn out separately. Pins 1 and 2 are the inputs for the first gate and pin 3 is the ouput of the first gate. There are three other groups of three pins for the remaining gates. Pin 7 is the 'ground' pin and the negative side of the supply is coupled to this. At the same time, pin 14 is the Vcc pin, and it takes the positive side of the supply. These two pins supply power to all the gates in the i.c. but, as I said earlier, this fact is not indicated in the logic diagram, in which the supply connections are assumed. Don't forget, by the way, that this is a top view of the integrated circuit. The pins point away from you."

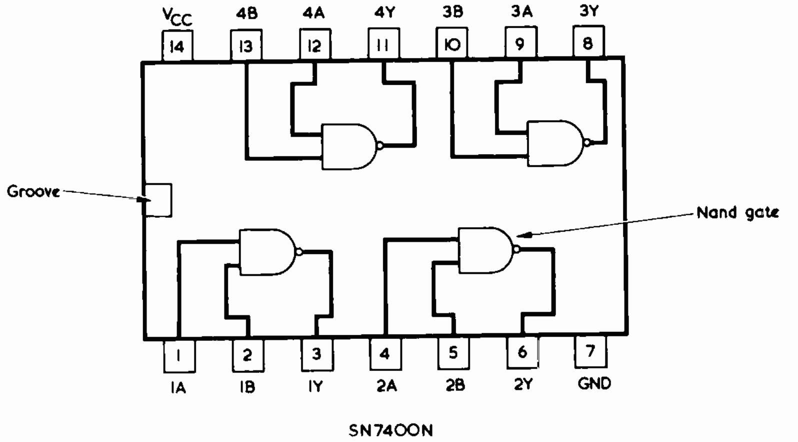


Fig. 2. Top view showing the pin layout for the 7400 integrated circuit in dual-in-line. A small groove identifies the end at which pins 1 and 14 appear

INTERNAL CIRCUIT

"I wonder," mused Dick, "what the internal circuit of each of the NAND gates looks like."

"There's a diagram showing this on the data sheet," replied Smithy, pointing to the circuit. (Fig. 3). "It's a standard t.t.l. NAND circuit."

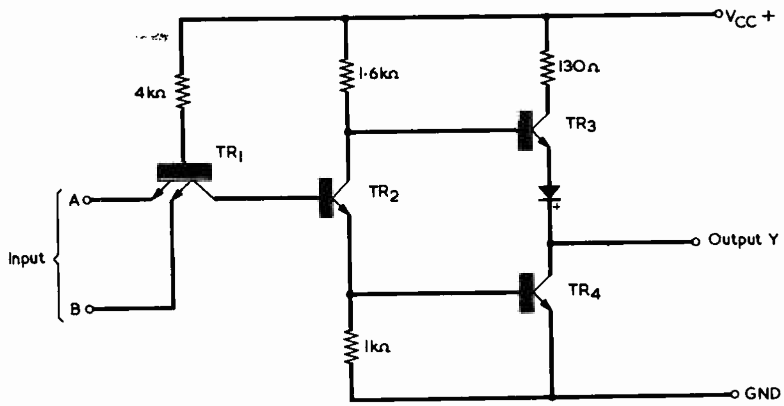


Fig. 3. Internal circuit of one of the NAND gates in a 7400 integrated circuit. The resistance values are nominal

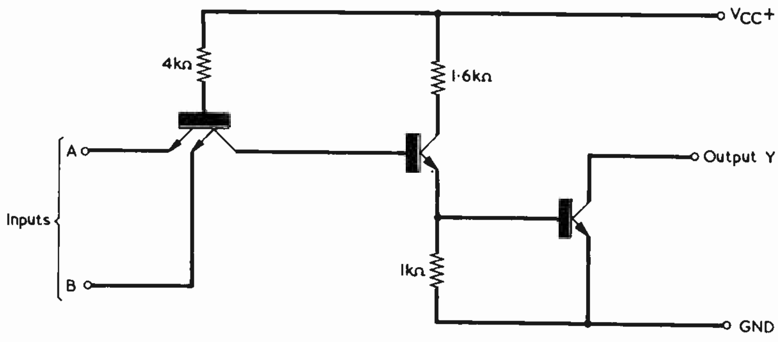


Fig. 4. A NAND gate with open-collector output. Four gates of this nature appear in the 7401 integrated circuit

"It looks rather familiar," commented Dick as he peered at the circuit. "I seem to remember having seen something like this before."

"You saw it several years ago," replied Smithy,* "when we had a discussion on different types of NAND gate. However, it will do no harm to go quickly through the theory of the t.t.l. NAND gate once more. Don't forget that a NAND gate is the same as an AND gate with the output inverted. With an AND gate you get an output 1 only when *all* the inputs are 1. So, with a NAND gate you get an output 0 only when all the inputs are 1. For all other input conditions the NAND gate output is 1. Now, if you look at the two inputs of the gate circuit you'll see that these go to two separate emitters in transistor TR1. If both of these inputs are at a low positive potential corresponding to 0, they hold the base of TR1 down at a low potential too. Under these conditions the transistor is turned hard on and its collector voltage is only a little higher than its emitter voltage. Because of this, TR2, is turned off and TR3 draws base current via the 1.6kΩ resistor. TR3 is turned on and the output of the gate is at a high positive potential, corresponding to 1."

"What happens if one of the inputs goes positive, up to 1?"

"Transistor TR1 still remains hard on by virtue of the remaining emitter," said Smithy. "It only needs one emitter at a low voltage to keep TR1 hard on and its base at a low potential. If *both* the emitters go positive to 1, then quite a different state of affairs takes place. The voltage at the base of TR1 rises and a collector current now flows into the base of TR2. This transistor comes on and draws current through the 1.6kΩ resistor, thereby causing TR3 to turn off. TR2 also allows current to flow into the base of TR4, which comes hard on. As a result, the output of the gate goes down to a low potential, corresponding to 0, and the NAND function has been carried out. The particular NAND gate we're looking at has two inputs only. You can get NAND gates with more than two inputs, each connecting to a separate emitter at TR1. These gates operate in the same manner and *all* the inputs have to go up to 1 before the output falls to 0. Okay?"

"Sure," said Dick confidently. "Can you connect the output of a NAND gate to the input of another NAND gate?"

"Oh yes," confirmed Smithy. "The only thing you mustn't do is to connect the output of a NAND gate of this type to the output of another NAND gate of similar type. The output circuit of this type of NAND gate is referred to as a 'totem pole' output because the two transistors and the associated components are all in a vertical line in the circuit diagram, just like a totem pole. The output of a totem pole circuit is at low impedance for both the high and the low conditions and, if two output circuits were connected together, heavy currents could flow if they were in different states. There is, however, a version of the NAND gate having what is called 'open-collector output', and the outputs of two NAND gates of this type can be connected together. With the open-collector output, the second transistor simply couples into a third transistor which comes hard on when the second transistor conducts. The collector circuit to Vcc for the open-collector output has to be completed via an external resistor." (Fig. 4.)

"I see," said Dick reflectively. "What *is* the Vcc voltage, by the way?"

"For 74 series i.c.'s," said Smithy, "It's 5 volts nominal, and it is recommended that it should not be greater than 5.25 volts or lower than 4.75 volts. With the 7400 gate, the maximum Vcc voltage must not exceed 7 volts, and the input voltages must not exceed 5.5 volts. Well now, let's start getting practical and think of wiring up an actual gate circuit. As I mentioned earlier, I've already knocked up a power supply for these i.c.'s, so we might as well bring it into use."

Smithy reached over to the back of his bench and produced a small neatly assembled power supply. (Fig. 5.)

"There's nothing out of the ordinary in this supply," he went on. "It uses a standard zener diode and emitter follower arrangement, and the output current is about 1 amp maximum. The mains transformer can be any 6.3 volt heater transformer offering a secondary current of 1 amp or more."

"Blimey, Smithy," said Dick excitedly, "I'm just itching to try my hand out at making up a NAND circuit."

"You can start right now," remarked Smithy, reaching for his note pad. "Here's a circuit for a NAND gate using the gate which connects to pins 1, 2 and 3 of the 7400. You needn't worry about the other gates; and they can just be left disconnected. If you had unused gates in a permanent working set-up it might be preferable to have their inputs all commoned and coupled to the positive supply line via a 1kΩ resistor. But for a temporary application such as we have here the unused gates may be ignored."

Smithy scribbled out the circuit for the single NAND gate. (Fig. 6.)

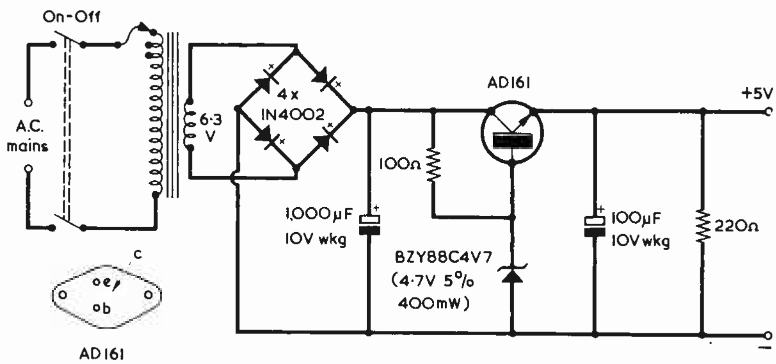


Fig. 5. The stabilized power supply constructed by Smithy. Both resistors are ½ watt. The AD161 may be mounted on a small heat sink about 1½ ins. square

* 'In Your Workshop', *The Radio Constructor*, October 1970.

"What," asked Dick, "are the two switches for?"

"To give you your two input signals," explained Smithy. "If a switch arm connects to the negative zero voltage line this corresponds to an input signal of 0, and if it connects to the positive line it corresponds to an input signal of 1. I'd suggest that you next hunt out an odd bit of chassis with holes in it of the right size for two changeover toggle switches. You'll need to mount a few tagstrips on it for the other connections as well."

As Dick searched hastily for the requisite hardware, Smithy looked around him musingly.

"I must confess," he remarked cheerfully, "that this is an excellent way of spending the last few hours before the Christmas holiday."

"I'll say it is," replied Dick enthusiastically, as he returned with a small piece of metal and proceeded to mount two toggle switches and several tag-strips on it. "Working on stuff like this is a holiday in itself."

Smithy's assistant soon had the switches and tagstrips mounted, and then he turned expectantly to the Serviceman.

"Well," replied Smithy, "there are the obvious ones of using narrow gauge solder and a small soldering iron bit. Oh yes, and there's another important one I nearly forgot. The connecting wire to the holder, or to the i.c. itself if you were wiring directly to it, should consist of a very thin *flexible* wire. Don't use single strand solid wire. The pins of an i.c. and the pins of most i.c. holders are not at all strong and can easily be bent out of position or even broken off if you use wire that isn't sufficiently flexible. If the wire is stiff, the pin just bends over as the wire is moved."

"Righty-ho," said Dick. "Well, I'm starting off this moment. Hey, wait a minute, though! What about that voltmeter you included in your circuit?"

"You can use the bench testmeter switched to a voltage range for that," stated Smithy. "Wire the gate output to a tag on one of the tagstrips and clip the positive testmeter lead to that tag."

INVERTER FUNCTION

Peering closely at the integrated circuit holder Dick commenced the

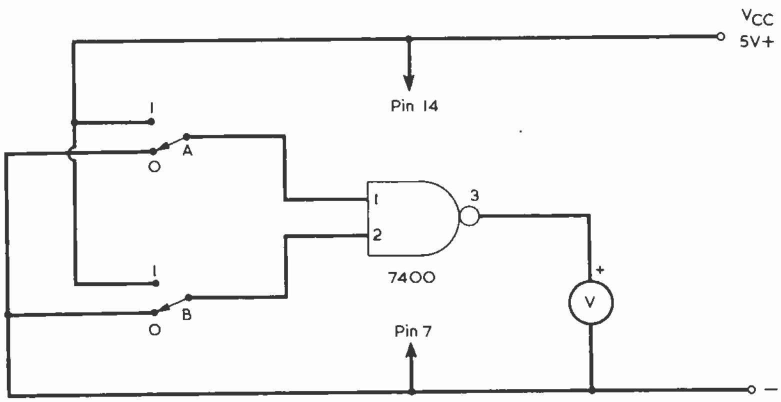


Fig. 6. Using the NAND gate which connects to pins 1, 2 and 3 of the 7400. Note also the supply connections to pins 14 and 7 of the integrated circuit

"You can next," pronounced that worthy, "wire up the NAND circuit. I must pass on a few words of warning here, though. To start off with, and seeing that this is your first attempt at wiring to a dual-in-line i.c., I'd advise that you use an integrated circuit holder instead of wiring directly to the integrated circuit itself. The terminal pins are very close together and they are quite fragile, and it's less expensive if you wreck a holder than an integrated circuit! You can insert the integrated circuit after you've completed the wiring to the holder. For the present exercise the holder can be suspended in the wiring or rested on a piece of Paxolin; it need not be mounted firmly."

"Any other points to watch?"

wiring.

"Stap me," he remarked. "These pins aren't half close together!"

"They are rather," chuckled Smithy, as he watched him. "They don't represent the sort of wiring-up job you'd welcome first thing on New Year's Day!"

"You must speak for yourself there," remarked Dick airily. "I myself am always full of vim and vigour on January the First. I like to start the New Year fresh and clear-eyed."

By now Dick had completed the few connections that were needed to the integrated circuit holder and was wiring his test circuit to Smithy's 5-volt power supply.

"All I can say," commented Smithy drily, "is that in the past I must have encountered you on the wrong New Year's Days."

"There must always, of course," responded Dick carelessly, "be exceptions to even the strictest of rules."

"In your case," replied Smithy, "I'd have thought that the exceptions *were* the rule."

"I've finished wiring up now," said Dick, bringing this unprofitable topic of conversation to an abrupt end. "What do I do next?"

"Fit the integrated circuit into its holder," said Smithy. "Be careful while you're doing this, as it's a bit of a fiddling process and you have to hold the i.c. pins in a little. You'll soon get the hang of it after you've done it a couple of times. And don't put it in wrong way round!"

Frowning with concentration, Dick succeeded in inserting the integrated circuit in its holder.

"Right," said Smithy. "We're off. Put both the input switches to 0 and turn on the 5 volt supply."

Dick carried out Smithy's instructions. The needle of the testmeter measuring the output voltage at once rose to 3.6 volts.

"Good," commented Smithy. "That's the high output and it corresponds to 1. Now put one of the input switches to 1."

Dick turned the switch. The meter reading was unaltered.

"Return the switch to 0," said Smithy, "and put the other switch to 1."

Dick clicked the switches over. Again, the meter reading remained the same.

"Now put both switches to 1."

Dick did so. At once the meter needle dropped to a reading just above zero volts.

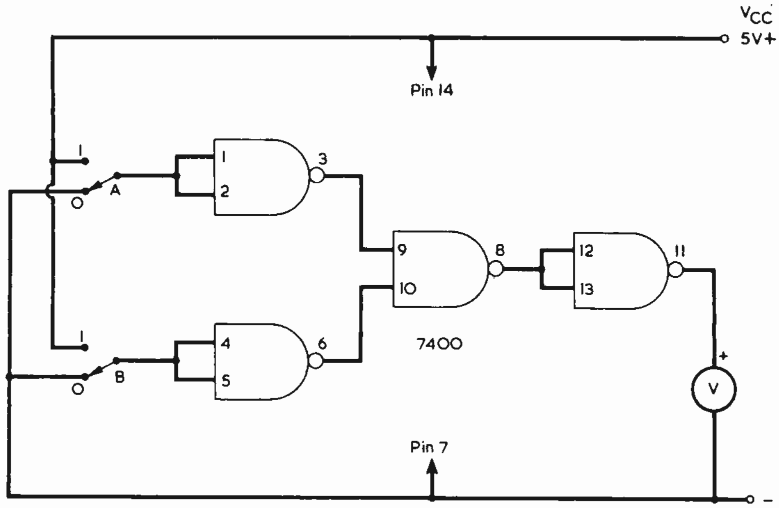
"Gosh," said Dick impressed. "That gate's working right first go! It's only when *both* inputs are 1 that the output is 0."

"Excellent, excellent," enthused Smithy. "We can now make up a truth table for that NAND gate. A truth table is, of course, simply a table that indicates the state of affairs existing in a logic circuit."

Smithy drew out the truth table on his note-pad. (Fig. 7.)

A	B	OUTPUT $\overline{AB}$
0	0	1
1	0	1
0	1	1
1	1	0

Fig. 7. Truth table for the circuit of Fig. 6. The term AB means 'A and B', whilst the horizontal line above these letters indicates 'not'



(a)

Fig. 8 (a). Two NAND gates connected together to form an AND gate. The second gate functions as an inverter (b). Truth table for the AND gate

A	B	OUTPUT AB
0	1	0
1	0	0
0	1	0
1	1	1

(b)

"This table," he went on, "Tells us that the output is 1 when either both or one input is at 0, and that it goes down to 0 when *all* inputs are 1."

"Why," asked Dick, "didn't the output go all the way up to 5 volts when it was in the high condition?"

"Because of voltage drop in the upper output transistor of the gate, in the resistor above it and in the diode below it," explained Smithy. "This voltage drop varies from i.c. to i.c. and it also varies according to the load which is connected to the output. If used under proper conditions, the high output voltage of a 7400 is typically 3.3 volts and is never less than 2.4 volts. The low output voltage is more closely defined because it corresponds to the lower output transistor being turned hard on, and it has a maximum of 0.4 volts."

"Is this important?"

"It can be," said Smithy, "if the output of a NAND gate is coupled to the input of another NAND gate. More input current flows to the second NAND gate when its input is at 0 than when it is at 1, because the input current then has to pull down the base of the first transistor in the second NAND gate. That higher current can be supplied very reliably when it is derived from a hard-on transistor in the first gate."

"Oh, I see," said Dick. "Is there anything more we can do with this NAND gate?"

"Yes," said Smithy promptly. "we can turn it into an AND gate!"

"Blimey," expostulated Dick. "How on earth do we do that?"

"By coupling the output of the NAND gate to another NAND gate wired up as an inverter," said Smithy. "If you join all the inputs of a NAND gate together you get an inverter. This is obviously the case because, when all the inputs of a NAND gate are at 0, the output is at 1, and when all the inputs of a NAND gate are at 1 the output is at 0. A NAND gate can also act as an inverter if you simply apply the input signal to one input and leave the other input or inputs floating. However, it's not always good practice to leave gate inputs floating and so we'll make up our own inverter with both inputs of the second gate connected together."

Smithy scribbled out a circuit on his note pad. (Fig. 8(a).)

"Here you are," he said, "there's only a few more connections to make."

Dick soon carried out the new wiring required and he then checked the result. When either or both of the input switches was at 0 the output of the second gate, as indicated by the testmeter, was also at 0. The output only rose to 1 when both inputs were at 1. Smithy drew out a truth table for this new set of circumstances. (Fig. 8(b).)

OR AND NOR GATES

"Gosh," said Dick, as he watched Smithy completing the truth table. "This is *fascinating*. You just connect up these i.c.'s in the correct way and they do any logic function you want. Is there any other sort of gate you can make up with this 7400?"

"You can," replied Smithy, "use three of its gates to make up an OR gate. Here's the circuit."

Smithy pulled the top sheet from his pad and drew out the circuit on the fresh page underneath. (Fig. 9(a).)

"This looks fairly easy," said Dick, glancing at the circuit cautiously. "So far as I can see, the first two gates are wired as inverters."

"That's right," confirmed Smithy. "We'll draw the truth table for this before you wire it up. We need three columns once more, these now being 'A', 'B' and 'A+B'. The last column represents the output, and you may recall that the plus sign in logical calculations means 'or'."

Smithy drew up the columns on his note-pad. (Fig. 9(b).)

"Now," he went on, "let's say that both inputs are at 0. The outputs of the two inverters will be at 1, whereupon the output of the third gate, which functions as a true NAND gate, is 0. Let's next put input A to 1 and input B to 0. The inverter outputs will be 0 and 1 respectively and the output of the third gate will be 1. The same will happen if input A is at 0 and input B is at 1. When both inputs are at 1 the inverter outputs will both be at 0 and the third gate output will remain at 1."

Smithy showed Dick the completed truth table.

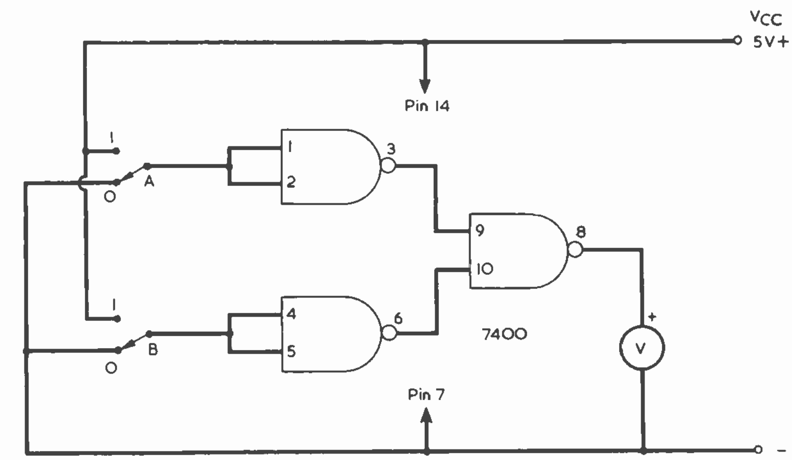
"Let's see now," said Dick concentrating. "What the table tells us is that the output is at 1 when either one input or both inputs are at 1."

"Correct," replied Smithy, "and that is exactly what is required of an OR gate. Wire up the circuit and see if this truth table works out in practice."

Dick set to work energetically and after some ten minutes or so announced that the new circuit was completed. With eager figures he tried it out.

The circuit functioned exactly as Smithy had predicted. With both switches in the 0 position the output was similarly 0. When either switch or both switches was set to the 1 position the output rose to 1.

"This is incredible," pronounced Dick as he continually tried the

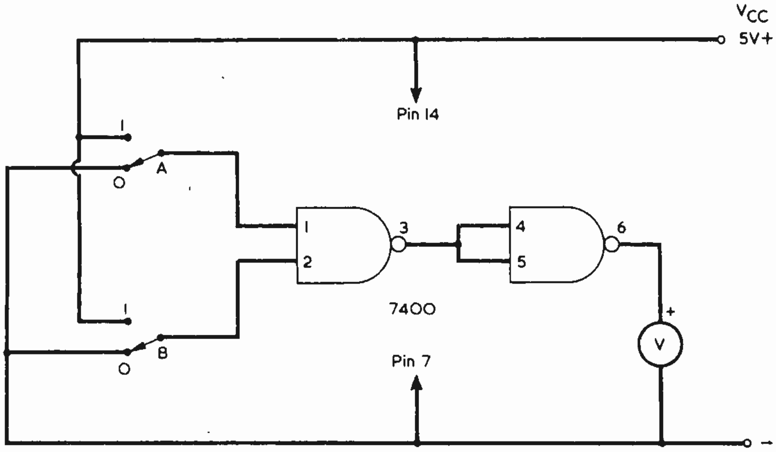


(a)

A	B	OUTPUT A + B
0	0	0
0	1	1
1	0	1
1	1	1

(b)

Fig. 9 (a). Three NAND gates connected to provide an OR gate
(b). Truth table for the gate of (a). The plus sign indicates 'or'



(a)

Fig. 10 (a). All the gates of a 7400 integrated circuit may be connected together to form a NOR gate
(b). The NOR gate has the truth table shown here

A	B	OUTPUT $\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

(b)

switches in their different settings. "We've already made up a NAND gate, an AND gate and an OR gate. There's only a NOR gate left."

"That can be obtained quite easily," said Smithy, again busy with his notepad. (Figs. 10(a). and (b).) "All we have to do here is stick another inverter on the output of our OR gate. This will automatically change it to a NOR gate."

Dick quickly set to work wiring in the fourth NAND gate, now functioning as an inverter, of the integrated circuit. He transferred the positive lead of the testmeter to its new circuit position and checked circuit operation. In this case the output was at 1 when both switches were at 0, and fell to 0 when either one or both switches was set to 1.

LAMP INDICATOR

"There you are," said Smithy. "That performance corresponds to the truth table for a NOR gate."

"Well, I've certainly discovered a few new things today." said Dick happily. "I've first of all learned that these logic circuits aren't half as frightening as they look once you've started wiring them up in practice. The second thing I've found out is this truly delightful business of directly coupling gates together by pieces of wire so that they give exactly what is theoretically expected of them. It's like drawing diagrams with a soldering iron! The third thing I've discovered is that after you've been playing with these logic i.c.'s for even a very short time you start thinking in terms of gates as complete entities without worrying at all about what goes on inside them. And the fourth thing I've learned is that you can wire up NAND gates to form inverters and any other forms of gate."

"It's the adaptability of NAND gates that has made them so popular," said Smithy. "NAND gates are probably the simple gates that are most commonly used, with NOR gates coming next. AND gates and OR gates aren't so useful because they can't be combined to form other gates as readily as can NAND and, for that matter, NOR gates. There are, of course, all sorts of other gates in t.t.l. integrated circuits but the simple ones you've been playing with here make a good introduction to this particular branch of electronics. I think we've done enough for today so far as logic integrated circuits are concerned, but it's a subject we could usefully turn to again in the future."

"I hope we do," said Dick. "I've really enjoyed myself this afternoon. There's only one thing I'm not too happy about."

"What's that?"

"This business of showing an output with the aid of a voltmeter. Isn't it possible to have something with a slightly more dramatic effect to show when an output is 1?"

Smithy thought for a moment.

"Well," he said, "you could have a bulb that lit up when an output was at 1 and which was extinguished for an output of 0. This idea can be carried out quite easily with the aid of an n.p.n. transistor. Its emitter would connect to the negative line and its collector to the positive line via the bulb. The base connects to the output that being monitored via a 2.2kΩ resistor."

Smithy picked up a box of spare transistors that was lying on his bench, and poked a finger through its contents.

"We'll need a small power transistor," he continued. "Ah, this one will do! I've got an AC127 here, and this can be used in conjunction with a 6 volt 60mA or 6 volt 100mA bulb." (Fig. 11.)

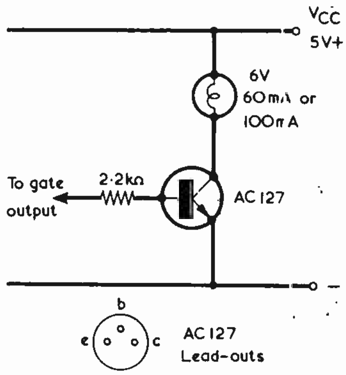


Fig. 11. Smithy used an AC127 to control a bulb which became illuminated when a gate output was 1. Any small n.p.n. power transistor of reasonable gain may be employed instead of the AC127

Dick took the transistor from Smithy, walked over to the spares cupboard for a suitable bulb and bulbholder, then wired up the lamp circuit. He next checked it out and found that the bulb lit up when the output to which the 2.2kΩ resistor was coupled was high, and became extinguished when the output was low.

YEAR'S END

"That," he remarked cheerfully, "works very nicely, too."

"Yes," concurred Smithy, "it's a pretty fool-proof arrangement. Any small n.p.n. transistor of reasonable gain which is capable of handling the bulb current could, of course, be used instead of an AC127. If you liked, you could add further transistor and bulb circuits to the outputs of the intermediate gates which form a composite gate. They would then tell you the condition of each section in the logic chain."

"That's quite a good idea," said Dick, as, with an air of finality, he switched off the 5-volt power supply. "Well, it looks as though this is the end of electronics for us before Christmas. These gate circuits have certainly rounded things off nicely."

"Perhaps," commented Smithy mysteriously, "there's something further that's needed to finally carry us through to the holiday period."

Whilst Dick raised a quizzical eyebrow, Smithy walked over to the filing cabinet where the service sheets were kept. As he returned there was a pleasant chink of glass against bottle.

"Good old Smithy," chuckled Dick. "That filing cabinet was as good a hiding-place as any."

"It was the best place I could think of," chuckled Smithy as he carefully started to fill the glasses. "Knowing you, the last place *you'd* go to would be the service manual cupboard!"

He handed a charged glass to Dick and then picked up his own.

"Well, my lad," he said warmly, "a Merry Christmas to you."

"And the same to you," responded Dick, sipping appreciatively. "Come on, Smithy, let's be upstanding."

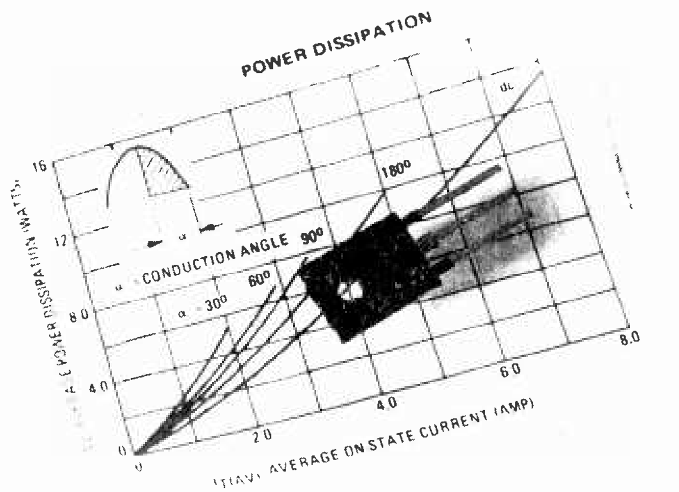
The pair rose.

"Let's next," said Smithy, raising his glass, "also wish a very Merry Christmas and a truly Happy New Year to all the readers who've put up with our antics during 1972."

They drank.

"And," concluded Dick, "let's finish, as we have done on so many previous Christmasses, by saying 'God Bless Us, Every One!' " ■

NEW PRODUCT



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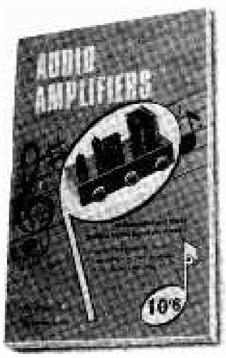

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12AU6	21	EABC80		EL84	.21		.75	UF85	.34	OC82	.11
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	Dia. $\frac{1}{2}$ in.				Dia. $\frac{5}{8}$ in.			
Turns	l = $\frac{1}{4}$ in.	l = $\frac{1}{2}$ in.	l = $\frac{3}{4}$ in.	l = 1 in.	l = $\frac{1}{4}$ in.	l = $\frac{1}{2}$ in.	l = $\frac{3}{4}$ in.	l = 1 in.
4	0.21	0.14	0.10	0.082	0.29	0.20	0.15	0.12
6	0.47	0.31	0.23	0.18	0.63	0.45	0.34	0.27
8	0.84	0.55	0.41	0.33	1.2	0.80	0.60	0.48
10	1.3	0.86	0.64	0.51	1.8	1.3	0.93	0.76
12	1.9	1.2	0.92	0.73	2.6	1.8	1.4	1.1
14	2.6	1.7	1.3	1.0	3.6	2.5	1.8	1.5
16	3.4	2.2	1.6	1.3	4.7	3.2	2.4	2.0
18	4.3	2.8	2.1	1.7	6.0	4.5	3.1	2.5
20	5.3	3.4	2.6	2.0	7.4	5.0	3.8	3.1
25	8.2	5.4	4.0	3.2	12.0	7.8	5.9	4.8
30	12.0	7.8	5.8	4.6	17.0	11.0	8.3	6.9
35	16.0	11.0	7.8	6.3	22.0	15.0	12.0	9.4
40	21.0	14.0	10.0	8.2	29.0	20.0	15.0	12.0
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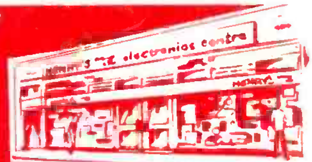

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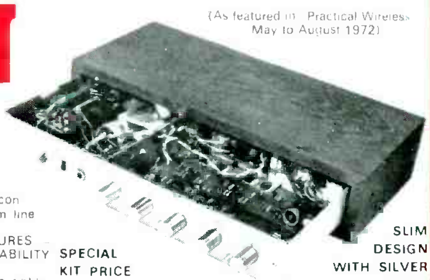

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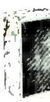

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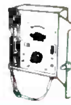

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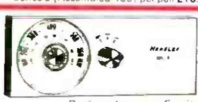

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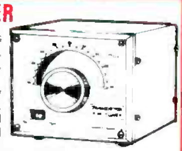

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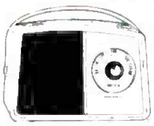

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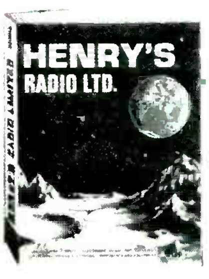

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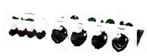

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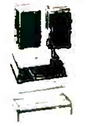

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