Easy to build projects for everyone

Everyday ELECTRONICS

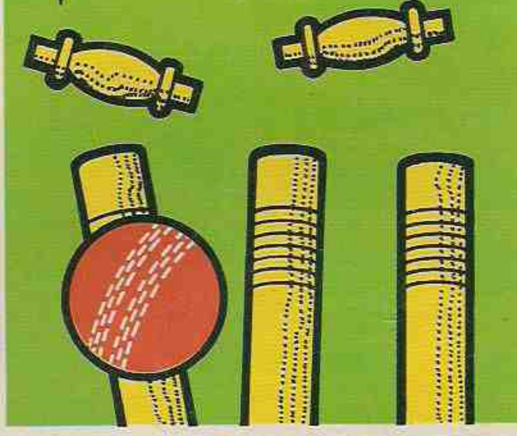
KIOSKS
McLeod

AUG 80
50p

WEATHER CENTRE

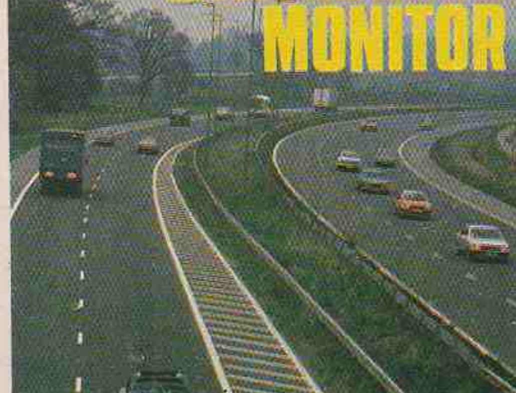
HOWZAT!

BOWL'EM OVER WITH OUR CRICKET GAME



AUDIO MILLIVOLTMETER

BRAKESAFE MONITOR



Australia $1·00 South Africa R1·00 New Zealand $1·10 Malaysia $3·50

WATFORD ELECTRONICS

35 CARDIFF ROAD, WATFORD, HERTS., ENGLAND
MAIL ORDER, CALLERS WELCOME. Tel. Watford 40588/9

ALL DEVICES BRAND NEW, FULL SPEC. AND FULLY GUARANTEED ORDERS DESPATCHED BY RETURN OF POST. TERMS OF BUSINESS: CASH/CHEQUE/ P.O.s OR BANKERS DRAFT WITH ORDER. GOVERNMENT AND EDUCATIONAL INSTITUTIONS' OFFICIAL ORDERS ACCEPTED. TRADE AND EXPORT INQUIRY WELCOME. P&P ADD 30p TO ALL ORDERS UNDER £10·00. OVERSEAS ORDERS POSTAGE AT COST. AIR/SURFACE. (ACCESS orders by telephone welcome).

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We stock many more items. It pays to visit us. We are situated behind Watford Football Ground. Nearest Underground/BR Station: Watford High Street. Open Monday to Saturday 9.00 am–6.00 pm. Ample Free Car Parking space available.

POLYESTER CAPACITORS: Axial lead type (Values are in μF)
400V: 1nF, 1n5, 2n2, 3n3, 4n7, 6n8, 10n, 15n **9p**; 18n **10p**; 22n,'33n **11p**; 47n, 68n **14p**; 100n **17p**; 150n, 220n, **24p**; 330n, 470n **41p**; 680n **52p**; 1μF **64p**; 2μ **82p**.
160V: 39μF, 100n, 150n, 220n **11p**; 330n, 470n **19p**; 680n, 1μF **22p**; 1μ5, 2μ2 **32p**; 4μ7 **36p**.
1000V: 10nF, 15n, **20p**; 22n **22p**; 47n **26p**; 100n **38p**; 470n **53p**; 1μF **175p**.

POLYESTER RADIAL LEAD CAPACITORS (250V)
10nF, 15n, 22n, 27n, **5p**; 33n, 47n, 68n, 100n **7p**; 150n **10p**; 220n, 330n **13p**; 470n **17p**; 680n **19p**; 1μF **22p**; 1μ5 **30p**; 2μ2 **34p**.

RECTANGULAR LEDs Red, Green or Yellow with Clips **30p** only

ELECTROLYTIC CAPACITORS: (Values are in uF) 500V: 10 **50p**; 47 **78p**; 250V: 100 **65p**; 63V 0·47, 1·0, 1·5, 2·2, 2·5, 3·3, 4·7, 6·8, **8p**; 10, 15, 22, **11p**; 47, 32, 50 **12p**; 63, 100 **27p**; 50V 50, 100, 220, **25p**; 470 **32p**; 1000 **80p**; 40V: 22, 33, **9p**; 100 **12p**; 2200, 3300 **85p**; 4700 **98p**; 35V: 10, 33 **8p**; 330, 470 **32p**; 25V: 10, 22, 47, 100 **8p**; 160, 220, 250, **15p**; 470 **25p**; 640, 1000 **35p**; 1500 **40p**; 2002 **52p**; 3300 **77p**; 4700 **85p**; 16V: 10, 40, 47 **7p**; 100, 125 **8p**; 220, 330 **14p**; 470 **20p**; 1000, 1500 **30p**; 2200 **36p**; 10V: 100 **7p**;
TAG-END TYPE: 450V: 100μF **180p**; 70V: 4700 **165p**; 64V: 3300 **150p**; 2500 **110p**; 50V: 4700 **150p**; 3300 **135p**; 2200 **99p**; 40V: 4700 **130p**; 4000 **92p**; 3300 **98p**; 2500 **85p**; 2200 **85p**; 2000 + 2000 **120p**; 30V: 4700 **110p**; 25V: 15000 **195p**; 6800 **120p**; 4700 **100p**; 3000 **85p**; 2200 **60p**.

TANTALUM Bead Capacitors 35V: 0·1μF, 0·22, 0·33, 0·47, 0·68, 1·0, 2μ2, 3·3μ, 4·7, 25V: 10, 20V: 6μ8, 16V: 2μ2, 4μ7, 10, **20p**. 16V: 22μ **32p**; 47, 100 **50p**; 220 **78p**. 10V: 15μ, 22, 33, **28p**. 3V: 100 **28p**.

MYLAR FILM CAPACITORS
100V: 0·001, 0·002, 0·005, 0·01μF **6p**; 0·015, 0·02, 0·04, 0·05, 0·056μF **7p**; 0·1μF **8p** **50V:** 0·47 **12p**

MINIATURE TYPE TRIMMERS
2-5·6pF, 3-10pF, 10-40pF **22p**
5-25pF, 5-45pF, 60pF, 88pF **30p**

COMPRESSION TRIMMERS
3-40pF, 10-80pF **30p**; 25-190pF **33p**
100 500pF **45p** 1250pF **58p**.

POLYSTYRENE CAPACITORS
10pF to 1nF **8p**; 1·5nF to 10nF **10p**.

SILVER MICA (Values in pF) 3·3, 4·7, 6·8, 10, 12, 18, 22, 33, 47, 50, 68, 75, 82, 85, 100, 120, 150, 180 **11p** each 220, 250, 270, 300, 330, 360, 390, 470, 600, 800, 820 **16p** each 1000, 1200, 1800, 2000, 3300 **25p** each

CERAMIC CAPACITORS: 50V 0·5pF to 10nF **4p**; 22n to 100n **6p**.

EURO BREADBOARD £5·30.

POTENTIOMETERS: (ROTARY) Carbon Track. 0·25W Log & 0·5W Linear Value.
500Ω,1 K& 2K (Lin. only) Single **29p**
5K-2 MΩ single gang **29p**
5K-2 MΩ single with DP switch **69p**
5K-2 MΩ double gang **88p**

SLIDER POTENTIOMETER
0·25W log and linear values 60mm
5K Ω-500K Ω single gang **60p**
10K Ω-500K Ω dual gang **80p**
Self Stick Graduated Bezels **36p**

PRESET POTENTIOMETERS
Vertical & Horizontal
0·1W 50 Ω–5MΩ Miniature **7p**
0·25W 100 Ω–3·3M Ω Horiz **10p**
0·25W 200 Ω–4·7MΩ Vert **10p**

RESISTORS: Carbon Film, High Stability, Low Noise, Miniature Tolerance 5%.

Range	Val.	1–99	100+
¼W 2Ω2–4M7	E24	2p	1p
½W 2Ω2–4M7	E12	2p	1p
1W 2Ω2–10M	E12	5p	4p
2% Metal Film 10Ω–1M		6p	4p
1% Metal Film 51Ω–1M		8p	6p

100+ price applies to Resistors of each value not mixed.

TGS 812 or 813 gas and smoke detector **415p**. Socket for above **30p**.

OPTO ELECTRONICS
LEDs plus clips
TIL209 Red **13**
TIL211 Grn **17**
TIL212 Yellow **18**
·2" Red **14**
2" Yellow Green **18**
Square LED **36**
OCP71 **120**
ORP12 **63**
ORP61 **85**
2N5777 **45**
7 Seg Displays
TIL312 C An 3" **105**
TIL313 C Cth 3" **105**
TIL321 C An 5" **115**
TIL322 C Cth 5" **115**
DL704 C Cth ·3" **99**
DL707 C.A. ·3" **99**
DL747 C.A. ·6" **180**
FND357 **120**
MAN3640 **175**
·3" Green C.A. **180**
·6" Green C.A. **225**
LCD 3½ Digit **875**
TIL32 Inf. Red **58**
TIL78 detector **70**
Opto Isolators
IL74 **48**
TIL111, 112, **75p.**
TIL116, 117 **100p.**
Bargraph Red. Ten segment **225p**

VOLTAGE REGULATORS*

1A	**TO3**	**+ve**	**–ve**	
5V	7805	**175p**	7905	**220p**
12V	7812	**175p**	7912	**220p**
15V	7815	**175p**	—	
18V	7818	**175p**	—	
1A	**TO220 Plastic Casing**			
5V	7805	**60p**	7905	**65p**
12V	7812	**60p**	7912	**65p**
15V	7815	**60p**	7915	**65p**
18V	7818	**60p**	7918	**65p**
24V	7824	**60p**	7924	**65p**
100mA	**TO92 Plastic Casing**			
5V	78L05	**30p**	79L05	**65p**
6V	78L62	**30p**	—	
8V	78L82	**30p**	—	
12V	78L12	**30p**	79L12	**65p**
15V	78L15	**30p**	79L15	**65p**



CA3085	**95**	LM325N	**240**	TDA1412	**150**
LM300H	**170**	LM326N	**240**	78H05	**595**
LM305H	**140**	LM327N	**270**	78H05+5V/5A	**595**
LM309K	**135**	LM723	**39**		
LM317K	**350**	TAA550	**50**	78HG 5V to 25V	**650**
LM323K	**625**	TBA625B	**95**		

SLIDE 250V:
1A DPDT **14p**
1A DP c/off. **15p**
½A DPDT **13p**
4 pole c/over **24p**
PUSH BUTTON
Spring Loaded
SPST on/off **65p**
SPST c/over **70p**
DPDT 6 Tag **85p**

SWITCHES
TOGGLE 2A 250V
SPST **28p**
DPDT **38p**
SUB-MIN TOGGLE
SP changeover **59p**
SPST on/off **54p**
DPDT 6 tags **70p**
DPDT c/off **79p**
DPDT Biased **115p**

SWITCHES Miniature Non-Locking
Push to Make **15p** Push to Break **25p**
ROCKER: SPST on/off 10A 250V **30p**
ROCKER: Illuminated (white)
Lights when on: 3A 240V **70p**
ROTARY: (ADJUSTABLE STOP) 1 pole/ 2-12 way 2p/2-6W, 3p/2-4W, 4p/2-3W. **43p**
ROTARY: Mains 250V AC, 4 Amp **52p**

DIL SOCKETS (Low Profile – Texas)
8 pin **10p**; 14 pin **12p**; 16 pin **13p**; 18 pin **43p**; 20 pin **22p**; 24 pin **30p**; 28 pin **35p**; 40 pin **40p**.

JACKSONS VARIABLE CAPACITORS

Dilicon		0 2 365pF with slow motion	
100/300pF	**205p**	Drive	**450p**
500pF	**250p**	00 208/176	**395p**
6·1 Ball Drive		,, ,, with slow	
4511/DAF	**145p**	motion drive	**410p**
Dial Drive 4103		C804-5pF 10 15	
6 1/36 1	**775p**	25 50 pF	**250p**
Drum 54mm	**55p**	100, 150pF	**335p**
0-1·365pF	**325p**	'L' 3 x 310pF	**725p**
00 2 365pF	**395p**	00·3 x 25pF	**550p**

DENCO COILS RDT2 **120p**
'DP' VALVE TYPE RFC 5 **120p**
Range 1 to 5 Bl., RFC 7 (19mH) **133p**
Rd., Yl. Wht. **106p** IFT 13; 14; 15; 6–7 B.Y.R. **95p** 16; 17 **110p**
1-5 Green **130p** IFT 18/1·6 **116p**
'T' 1 to 5 Bl., Yl., IFT 18/465 **132p**
Rd., Wht. **128p** TOC 1 **92p**
B9A Valve Holder MW5FR **112p**
35p MW/LW 5FR **134p**

VEROBOARD

	0·1	0·15	0·15
	(copper clad)	(plain)	
2½ × 3½	**66p**	**59p**	**42p**
2½ × 5	**75p**	**69p**	—
3¾ × 3½	**75p**	—	—
3¾ × 5	**86p**	**72p**	**65p**
2½ × 17	**240p**	—	—
3¾ × 17	**296p**	**200p**	—
4¾ × 17	**387p**	—	**280p**
Pkt of 35 pins			**20p**
Spot face cutter			**107p**
Pin insertion tool			**147p**

DIODES

AA129	20
BA100	10
BA102	30
BY126	12
BY127	12
CRO33	158
OA9	45
OA47	18
OA70	12
OA79	15
OA81	15
OA85	14
OA90	7
OA91	6
OA95	8
OA200	8
OA202	8
IN914	4
IN916	5
IN4001/2	5
IN4003	6
IN4004/5	6
IN4006/7	7
IN4148	4
IS44	20
3A/100V	18
3A/400V	20
3A/600V	27
3A/1000V	30

We stock a wide selection of Electronic Books and Magazines

ZENERS
Range 2V7 to 39V 400mW **8p each**
Range 3V3 to 33V. 1·3W **15p each**

NOISE
Z5J **180**

BRIDGE RECTIFIERS
(plastic case)

1A/50V	20
1A/100V	22
1A/200V	25
1A/400V	29
1A/600V	34
2A/50V	35
2A/100V	44
2A/200V	46
2A/400V	53
2A/600V	65
4A/800V	120
6A/100V	73
6A/200V	78
6A/400V	85
BY164	56
VM18 DIL	60

DIAC
ST2 **25**

SCRs Thyristors

1A/50V	37p
1A/100V	42p
1A/400V	55p
1A600V	70
5A300V	35
5A600V	43
8A300V	48
8A500V	58
8A600V	65
12A300V	59
12A500V	92
15A/700V	195p
2N4444	140p
2N5062	28
2N5064	35
BT106	150
C106D	38
TIC44	25
TIC45	45

TRIACS

3A100V	48
3A200V	49
3A400V	50
8A100V	54
8A400V	64
8A800V	108
12A100V	60
12A400V	70
12A800V	130p
16A100V	95
16A500V	150
25A800V	295
25A1000V	480p
T28000D	120

TTL 74

		74126	55	LS54	30	LS673	750	4095	105	ICM7217A	790
7400	11	74128	74	LS55	70	LS674	850	4096	105	ICM7555	89
7401	12	74132	70	LS63	150			4097	350	LD130	452
7402	12	74136	65	LS73	40	**CMOS**		4098	115	LF356	98
7403	14	74141	85	LS74	40	4000	18	4099	190	LM10	395
7404	14	74142	195	LS75	48	4001	18	4160	125	LM300H	170
7405	18	74143	350	LS76	45	4002	24	4161	125	LM301A	23
7406	48	74144	350	LS78	45	4006	92	4162	125	LM308	70
7407	48	74145	90	LS83	105	4007	22	4163	125	LM318	205
7408	22	74147	180	LS85	105	4008	82	4174	130	LM324	45
7409	22	74148	145	LS86	45	4009	40	4175	120	LM339	70
7410	19	74150	150	LS90	50	4010	48	4194	125	LM348	90
7411	25	74151	75	LS91	125	4011	24	4408	790	LM380	80
7412	20	74153	75	LS92	75	4012	24	4409	790	LM381	145
7413	33	74154	140	LS93	75	4013	45	4410	790	LM382	125
7414	52	74155	75	LS95	115	4014	85	4411	1020	LM1458	40
7416	31	74156	80	LS96	180	4015	85	4412F	1520	LM3900	60
7417	31	74157	75	LS107	45	4016	42	4412V	1520	LM3909N	70
7420	19	74159	185	LS109	75	4017	82	4415F	850	LM3911	125
7421	38	74160	99	LS112	80	4018	88	4415V	850	LM3914	240
7422	26	74161	99	LS113	65	4019	48	4419	320	LM3915	240
7423	32	74162	99	LS114	49	4020	99	4422	570	M253AA	795
7425	30	74163	99	LS123	95	4021	105	4432	1050	MC1310	149
7426	44	74164	120	LS124	180	4022	95	4435	1050	MC1312P	195
7427	32	74165	120	LS125	60	4023	25	4440	999	MC1488	85
7428	35	74166	155	LS126	60	4024	75	4450	350	MC1489	90
7430	20	74167	240	LS132	95	4025	25	4451	350	MC1494	595
7432	28	74170	230	LS136	55	4026	180	4452		MC1495	350
7433	38	74172	420	LS138	70	4027	48	4490F	750	MC1496	92
7437	35	74173	120	LS139	90	4028	82	4490V	750	MC1710	79
7438	30	74174	105	LS151	96	4029	105	4501	28	MC3340P	120
7440	20	74175	82	LS153	85	4030	60	4502	125	MC3360P	120
7441	74	74176	90	LS155	96	4031	225	4503	75	MC3401	52
7442	71	74177	90	LS156	96	4032	125	4506	75	MC3403..	135
7443	120	74178	149	LS157	76	4033	175	4507	60	MFC6040	97
7444	116	74180	90	LS158	85	4034	210	4508	325	MK50398	635
7445	116	74181	290	LS160	120	4035	125	4510	99	MM5307	1275
7446	132	74182	88	LS161	98	4036	365	4511	150	MM57160	620
7447	99	74184	145	LS162	110	4037	115	4512	98	NE518	210
7448	99	74185	145	LS163	100	4038	118	4520	115	NE543	210
7450	20	74188	299	LS164	115	4039	360			NE544	185
7451	20	74190	135	LS165	155	4040	105	**LINEAR IC's**		NE555	22
7453	20	74191	135	LS168	210	4041	80	702	75	NE556	55
7454	20	74192	135	LS170	288	4042	80	709C 14 pin	35	NE560	325
7460	20	74193	135	LS173	105	4043	95	710	67	NE561	395
7470	41	74194	105	LS174	147	4044	95	741C 8 pin	17	NE562	410
7472	31	74195	198	LS175	110	4045	175	747C	78	NE564	425
7473	40	74196	130	LS181	295	4046	130	748C	36	NE565	120
7474	34	74197	90	LS183	298	4047	98	753	185	NE566	160
7475	56	74198	195	LS189	120	4048	65	810	159	NE567	170
7476	41			LS190	120	4049	45	2102	120	NE570	395
7480	55	**74LS**		LS191	120	4050	48	2112	110	NE571	420
7481	120	LS00	13	LS192	125	4051	80	2114	295	S556B	275
7482	75	LS01	13	LS193	125	4052	80	81LS97	140	SAB3209	425
7483	94	LS02	15	LS194	125	4053	80	AY-1-0212	580	SAB3210	275
7484	113	LS03	15	LS196	120	4054	130	AY-1-1313A	660	SN76003	210
7485	121	LS04	20	LS197	120	4055	135	AY-1-1320	315	SN76013	170
7486	33	LS05	23	LS199		4056	135	AY-1-5050	190	SN76023	170
7489	215	LS06	23	LS200	345	4057	2850	AY-1-5051	160	SN76033	240
7490	57	LS09	23	LS202	345	4059	575	AY-1-6721/6	210	SN76477	175
7491	85	LS10	20	LS221	120	4060	130	AY-3-8500	390	TBA120F	70
7492	59	LS11	32	LS240	225	4061	1225	AY-5-1224A	235	TBA641	250
7493	59	LS12	32	LS241	225	4062	995	AY-5-1230	450	TBA800	90
7494	95	LS13	40	LS242	232	4063	120	CA3018	68	TBA810	96
7495	75	LS14	75	LS244	225	4066	58	CA3023	170	TCA965	120
7496	95	LS15	40	LS245	270	4067	430	CA3028A	80	TDA1008	310
7497	180	LS20	21	LS247	135	4068	26	CA3035	235	TDA1022	575
74100	130	LS21	32	LS251	130	4069	26	CA3043	275	TDA1024	105
74104	62	LS22	40	LS253	130	4070	30	CA3046	71	TDA2020	320
74105	62	LS26	48	LS257	115	4071	25	CA3048	214	TLO61	54
74107	35	LS27	45	LS258	120	4072	25	CA3080E	65	TLO71	45
74109	60	LS28	48	LS259	160	4073	25	CA3081	190	TLO74	140
74110	54	LS30	24	LS261	450	4075	25	CA3085	85	TLO81	42
74111	68	LS32	30	LS266	75	4076	99	CA3089E	215	TLO83	95
74112	150	LS33	39	LS273	180	4077	48	CA3090AQ	375	TLO84	120
74116	198	LS37	39	LS279	88	4078	30	CA3123E	150	UAA170	175
74118	99	LS38	39	LS280	250	4081	28	CA3130	85	UAA180	175
74119	125	LS40	28	LS299	420	4082	28	CA3140	48	Z80CPU	990
74120	105	LS42	80	LS324	200	4085	90	ICL7106E	795	ZN414	95
74121	42	LS47	85	LS367	85	4086	90	ICL7107	975	ZN424E	130
74122	55	LS48	120	LS368	65	4089	150	ICL8038	340	ZN425E	415
74123	95	LS49	120	LS373	180	4093	89	ICM7205	1150	ZN1034	200
74125	45	LS51	25	LS670	270	4094	240	ICM7216	1950	ZN1040E	685

TRANSISTORS

				BDY17	195	MJ2955	90	TIP36A	145	2N2905A	22
AC125	35	BC172	11	BDY56	170	MJE340	54	TIP36C	185	2N2906	22
AC126	25	BC173	11	BDY60	110	MJE370	58	TIP41A	50	2N2926G	10
AC127	22	BC177	15	BDY61	165	MJE371	54	TIP41B	55	2N3053	19
AC128	20	BC178	14	BF115	26	MJE2955	99	TIP42A	72	2N3054	55
AC141	27	BC179	15	BF154	25	MJE3055	70	TIP42B	82	2N3055	48
AC142	28	BC181	10	BF156	29	MPF102	66	TIP2955	60	2N3121	40
AC176	25	BC182	10	BF167	30	MPF103	38	TIP3055	48	2N3133	43
AC188	24	BC182L	10	BF173	25	MPF104	35	TIS43	30	2N3135	33
ACY17	60	BC183	10	BF177	24	MPF105	40	TIS44	45	2N3250	30
ACY18	60	BC183L	10	BF178	25	MPF106	40	TIS88A	35	2N3442	140
ACY19	60	BC184	10	BF179	30	MPSA05	15	TIS90	20	2N3663	14
ACY20	53	BC184L	10	BF180	38	MPSA06	16	TIS91	24	2N3702	10
ACY21	35	BC187	22	BF194	10	MPSA12	22	ZTX107	11	2N3703	10
ACY22	60	BC212	9	BF195	11	MPSA55	22	ZTX108	11	2N3704	10
ACY28	60	BC212L	9	BF196	12	MPSA56	22	ZTX109	11	2N3705	10
ACY39	80	BC213	9	BF197	12	MPSU05	50	ZTX300	13	2N3706	10
AD140	70	BC213L	9	BF198	16	MPSU06	56	ZTX301	13	2N3707	10
AD149	75	BC214	10	BF199	18	MPSU56	60	ZTX302	20	2N3708	11
AD161	42	BC214L	10	BF200	29			ZTX303	25	2N3709	11
AD162	42	BC307	12	BF224A	18	OC28	120	ZTX304	17	2N3710	10
AF114	60	BC308	12	BF244B	18	OC35	125	ZTX314	24	2N3711	10
AF115	68	BC327	12	BF244	30	OC36	130	ZTX326	45	2N3713	215
AF116	75	BC328	12	BF256	60	OC41	125	ZTX341	20	2N3771	179
AF139	40	BC338	12	BF256B	45	OC42	48	ZTX500	15	2N3772	195
AF178	75	BC441	27	BF257	30	OC43	55	ZTX501	15	2N3773	283
AF180	70	BC461	27	BF258	28	OC44	55	ZTX502	17	2N3819	20
AF186	50	BC447	35	BF259	28	OC45	30	ZTX503	15	2N3820	45
AF239	42	BC477	35	BF274	38	OC46	28	ZTX504	25	2N3882	130
BC107	11	BC547	10	BF594	30	OC70	35	ZTX531	25	2N3823	70
BC107B	11	BC548	11	BF595	20	OC71	28	ZTX550	25	2N3866	90
BC108	11	BC549C	7	BFR39	25	OC72	35	2N696	36	2N3903	20
BC108B	11	BC557	15	BFR40	28	OC74	50	2N697	25	2N3904	18
BC108C	12	BC558	10	BFR41	24	OC76	45	2N698	40	2N3905	18
BC109	11	BC559C	10	BFR79	24	OC77	76	2N699	30	2N3906	17
BC109B	12	BCY70	14	BFR80	24	OC81	36	2N706	19	2N4037	52
BC109C	12	BCY71	16	BFR81	24	OC82	50	2N708	19	2N4058	17
BC117	20	BCY72	16	BFX29	28	OC83	48	2N918	33	2N4061	17
BC119	23	BD131	42	BFX81	45	OC84	48	2N930	18	2N4859	65
BC137	20	BD132	42	BFX84	26	OC140	110	2N961	61	2N5135	42
BC140	26	BD133	50	BFX85	26	OC170	85	2N1131	22	2N5136	42
BC142	26	BD135	30	BFX86	26	OC171	45	2N1132	24	2N5138	20
BC143	26	BD136	30	BFX87	28	OC202	95	2N1302	35	2N5179	60
BC147	8	BD137	30	BFX88	30	TIP29	31	2N1303	50	2N5180	80
BC148	8	BD138	35	BFY50	24	TIP29C	60	2N1304	50	2N5191	70
BC149	9	BD139	30	BFY51	21	TIP30	32	2N1305	35	2N5305	40
BC153	20	BD140	30	BFY52	21	TIP30C	43	2N1671B	120	2N5457	32
BC154	13	BD142	60	BFY56	30	TIP31A	38	2N2160	350	2N5458	32
BC157	10	BD145	175	BFY71	20	TIP31C	50	2N2219A	22	2N5459	32
BC158	10	BD205	110	BRY39	39	TIP32A	40	2N2220A	23	2N5485	35
BC159	11	BD222	75	BSX20	20	TIP32C	55	2N2222	20	2N5777	45
BC160	28	BD378	70	BSY65	30	TIP33A	40	2N2369	15	2N6027	40
BC167A	11	BD434	70	BSY95A	18	TIP33C	55	2N2476	125	3N128	112
BC168	10	BD517	70	BU105	115	TIP34A	63	2N2484	25	3N140	112
BC169	10	BD659A	65	BU205	125	TIP34C	75	2N2646	48	40360	43
BC170	15	BD695	85	BU208	215	TIP35A	135	2N2894	30	40361	45
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by Trevor Raven.
C.Eng. AMBIM. MIERE

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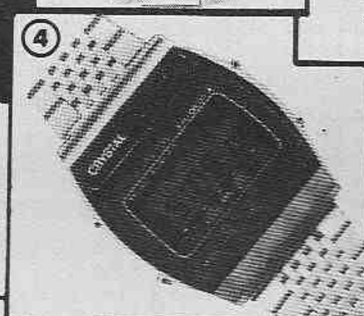

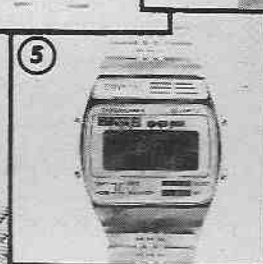

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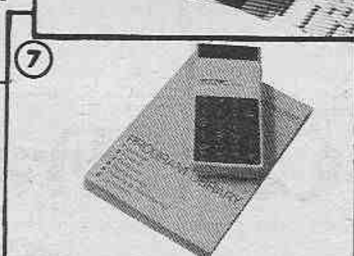

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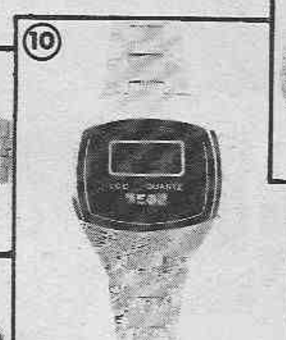

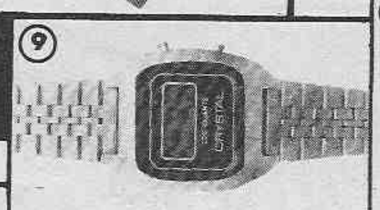

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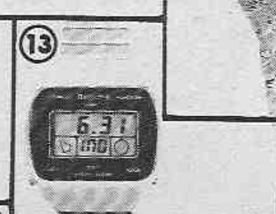

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Projects... Theory... and Popular Features...

Our *Weather Centre* is one of the larger kind of projects that appear from time to time in our pages. The "largeness" in this case is not entirely due to electronics. A project of this nature inevitably involves a fair amount of metal working in the construction of the sensing apparatus. Nevertheless, this should not be beyond the capabilities of the average handyman. But if necessary it should be possible to enlist the services of a friend who is a dab hand at metal work.

The *Weather Centre* is a natural for a school or other establishment where a team composed of individuals having different handicraft talents can be engaged upon this task. Genuine side benefits arise: permanent display of the team's achievement, and the acquisition by the school of a useful aid for natural science studies at a minimum expenditure. In these days of stringent economies enforced upon our Education Authorities, the do-it-yourself philosophy assumes greater relevance at school, no less, indeed, than it does at home.

More than this though; a deeper purpose is served by any stimulation of interest in technical creative work amongst students, especially in difficult times like the present.

Today countless youngsters face an unpredictable future. Job prospects for the school leaver are not good. The older, traditional industries are contracting, if not vanishing. The almost universal gloom is pierced only by light emitted from the high-technology-based industries. It is therefore a reasonable presumption that skilled personnel will be in constant demand to instal, maintain and service the growing electronic-based systems and equipments which (seen or unseen) are playing ever increasing parts in our lives.

Thus today's youngsters could do much worse than to acquire a lively interest in electronics whilst they are still at school. Knowledge and practical experience so acquired could stand them in good stead in the search for a job with some prospects in the future.

This month we are including an extra part of the *Teach-In* series, but less the experiments. These will be published next month together with the final part of this series.

Fred Bennett.

Our September issue will be published on Friday, August 15. See page 497 for details.

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Readers should note that we do not supply electronic components for building the projects featured in EVERYDAY ELECTRONICS, but these requirements can be met by our advertisers.

Everyday ELECTRONICS

VOL. 9 NO. 7 AUGUST 1980

CONSTRUCTIONAL PROJECTS

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OUR REGULAR FEATURE FOR BEGINNERS

SQUARE one

See Page 518

Cricket Game

MAKE A BIG HIT WITH YOUR FELLOW PLAYERS

by D. Kenyon

THE game of cricket is traditionally played outdoors in fine weather, but the electronic version to be described here can be played at anytime, in or out-of-doors in all weathers. This portable game is suitable for two or more players. It can also provide amusement for a single player.

The batsman can be either bowled or caught out. No facility has been incorporated for an "l.b.w." but rules for this could be concocted if desired.

CIRCUIT DESCRIPTION

The complete circuit diagram of the Cricket Game is shown in Fig. 1.

Gates IC6a and IC6b are wired to form a square wave oscillator, the frequency of which is controlled by C3 and the resistor chain R5 to R9. This is the clock for the system and feeds the counters IC7, and IC3b. Decade counter IC7 has ten outputs (only eight used here). Only one is on at any one time changing with the number of pulses fed to pin 14. The effect therefore of a train of pulses to IC7 pin 14 is to produce a running light from D1 to D8. This simulates the moving cricket ball.

Although the clock is running all the time that power is applied, the running output is only produced when the clock enable input, pin 13, is low. The clock enable inputs of IC7 and IC3a are both controlled by the Q output from IC4, a D-type flip-flop.

The function of IC3a is to cause the clock rate to change during the game as the BAT button is pressed. Any "bounce" this push button may have is removed by the monostable composed of IC1a and IC1b. Thus each time S1 is pushed, a clean single pulse is produced at IC1b pin 4 to the input of IC2a.

The other input to IC2a is from the seventh output of IC7, the ball position closest to the wicket (D8). When this goes high, and the BAT button pressed simultaneously, an output results at IC2a pin 3 which is counted by IC3a. This causes the binary count from IC3a to advance and close one or more switches within IC5, a quad-bilateral switch i.c. This alters the effective resistance in the oscillator circuit thus changing its rate.

DISPLAY

At the same time this pulse from IC2a, is fed to a second monostable composed of IC1c and IC1d which is turned on (output goes high) for a time set by R3 and C2. The high output enables IC3b and allows the pulses from the oscillator to be counted by IC3b, decoded by IC8 and displayed on X1. When the output from IC1d goes low, IC3b count is frozen and its value displayed on X1. The falling monostable output triggers IC4 which produces a low on the Q output to freeze the count on IC7 and IC3a.

Gates IC2b and IC2c reset IC3b after a count of six.

If the BAT button is not pressed while IC7 pin 5 is high, then pin 6 goes high and D8 lights up and stays on to show that the wicket has been struck by the ball. No output therefore is produced from IC2a. This high level at pin 6 sets IC4 (pin 6) and resets IC3a (binary 0 output). The setting of IC4 results in Q changing which freezes the condition of IC7; D8 remains lit.

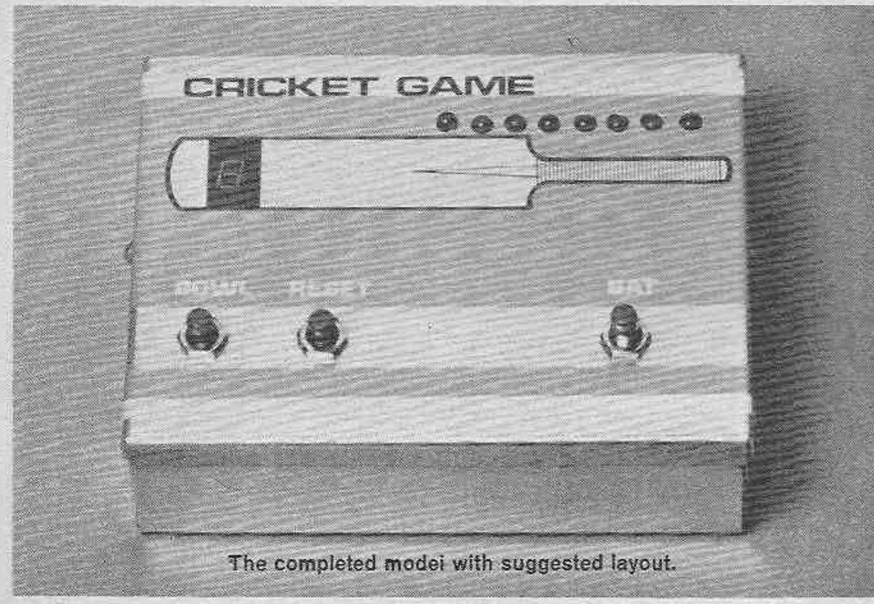
The RESET button returns the ball to the bowling end (D1) and D8 is extinguished.

Pressing S2 resets IC4 whose output enables IC7 (causing the ball to be bowled) and IC3a (allowing the BAT switch to be effective).

CONSTRUCTION starts here

CIRCUIT BOARDS

The prototype unit was constructed using four separate 0·1 inch plain matrix boards mounted in tiers. This method of construction is by no means essential and may be replaced by a single board layout. However, it is required that the opto components i.e. l.e.d.s and display, be mounted high enough above the board to allow them to protrude through the lid.



The completed model with suggested layout.

POWER SUPPLY

In the author's unit, the battery was not incorporated in the case as use with a battery eliminator was planned. A larger case than seen will need to be selected if an integral battery is desired. It is unlikely that a PP3 will provide a satisfactory power source. A PP6 battery will be better without the need for a very much larger case.

The layout of the components on the topside of the boards and the interconnections on the underside are shown in Figs. 2 and 3. All inter-board connections are made via Veropins; double-sided types are required in some positions and it is advised that these are used throughout. The i.c.s are mounted in sockets.

Begin by drilling the board fixing holes and inserting the Veropins and i.c. sockets. The latter can be held in place by bending over two diagonally opposite pins. Assemble components

Fig. 1. The complete circuit diagram of the Cricket Game.

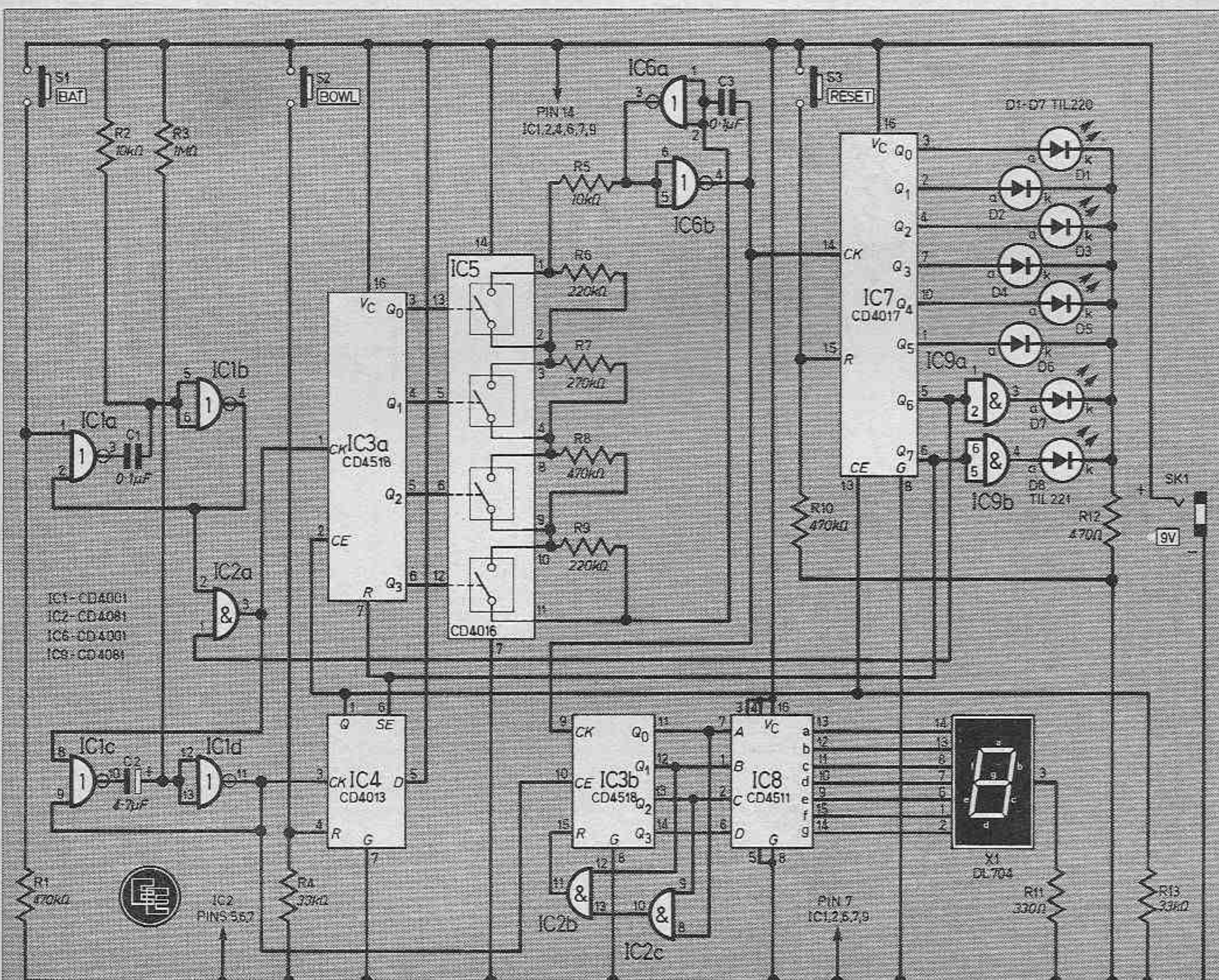
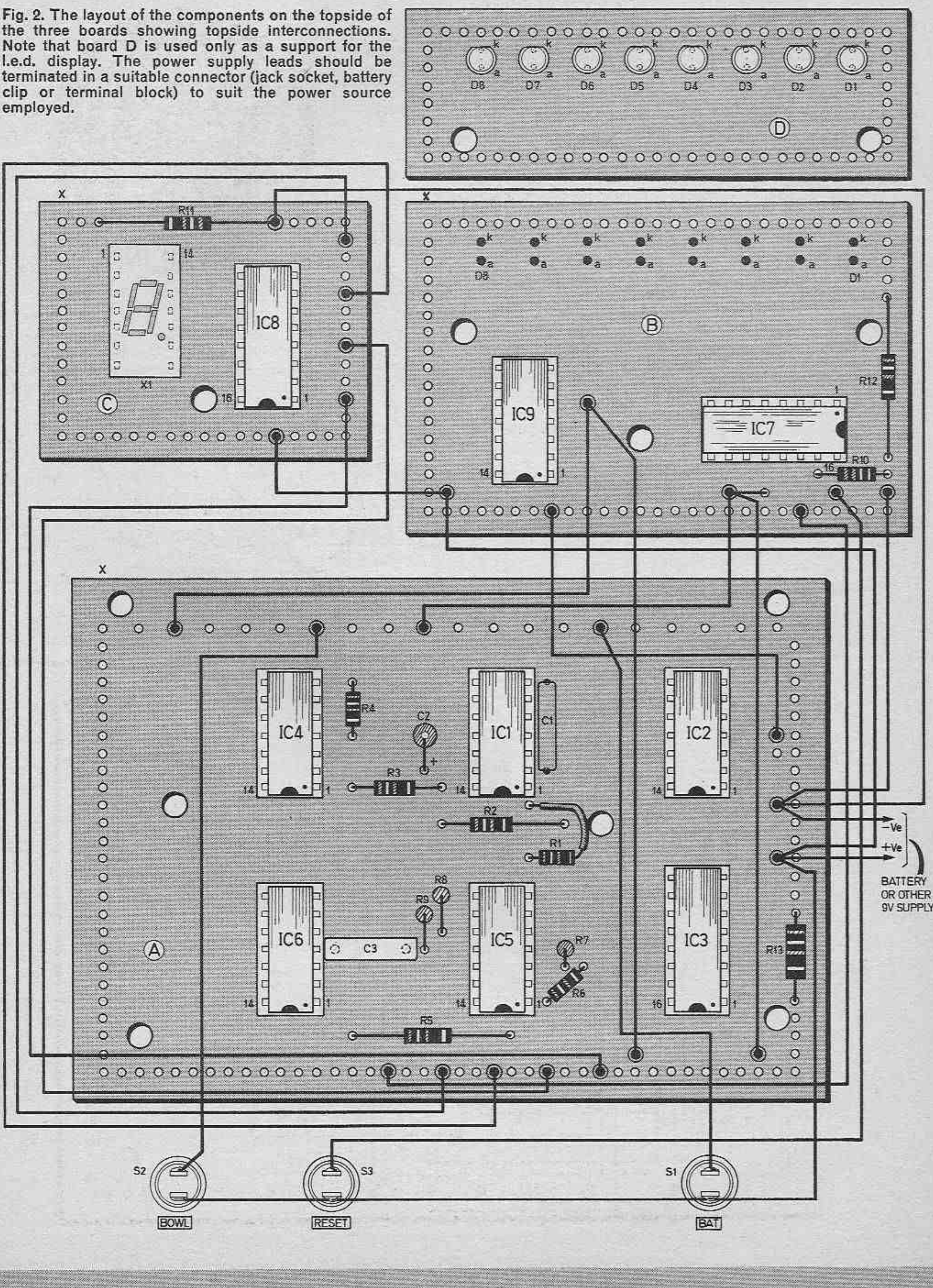


Fig. 2. The layout of the components on the topside of the three boards showing topside interconnections. Note that board D is used only as a support for the l.e.d. display. The power supply leads should be terminated in a suitable connector (jack socket, battery clip or terminal block) to suit the power source employed.



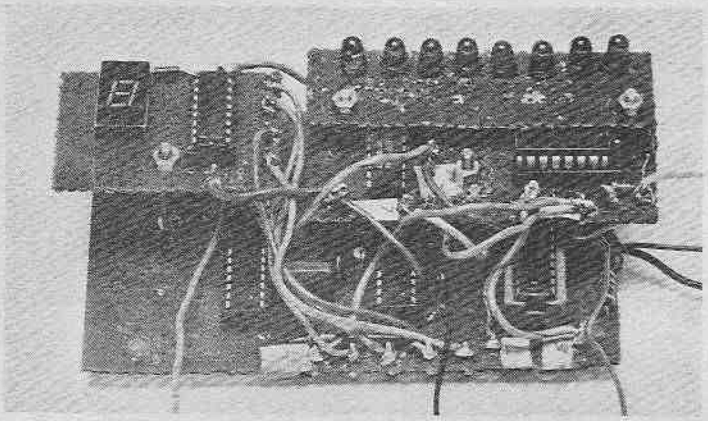
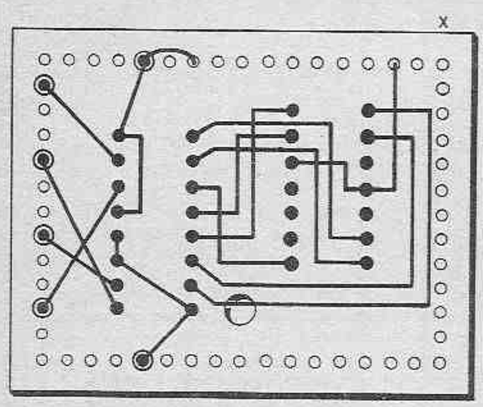


Fig. 4. Tier arrangement of circuit boards in the prototype.



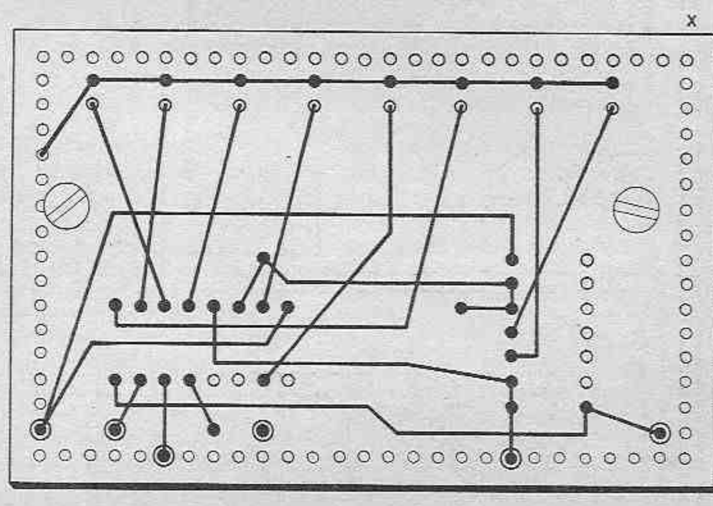
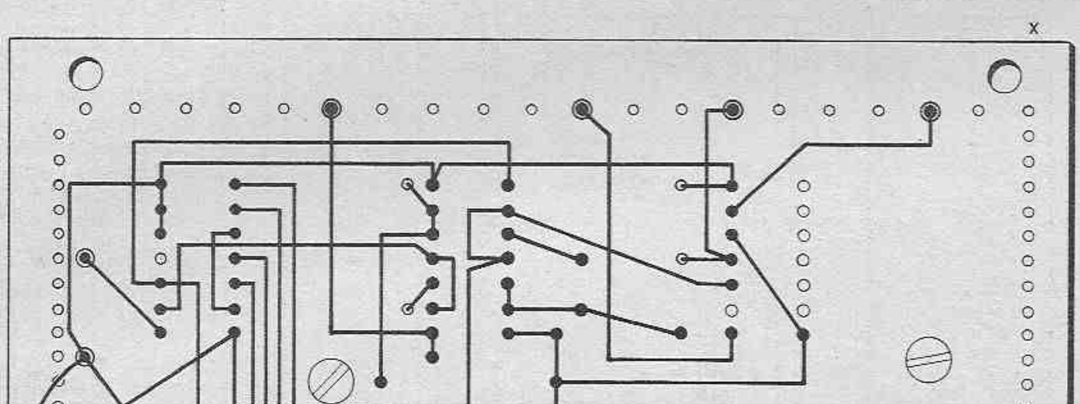
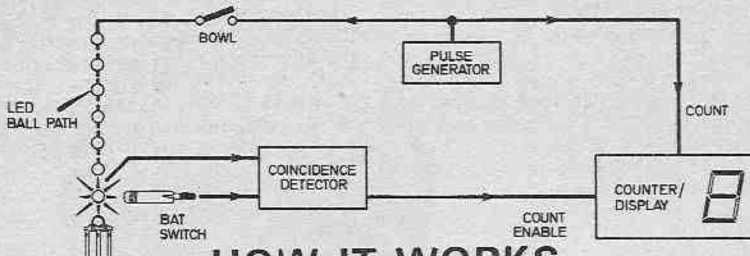


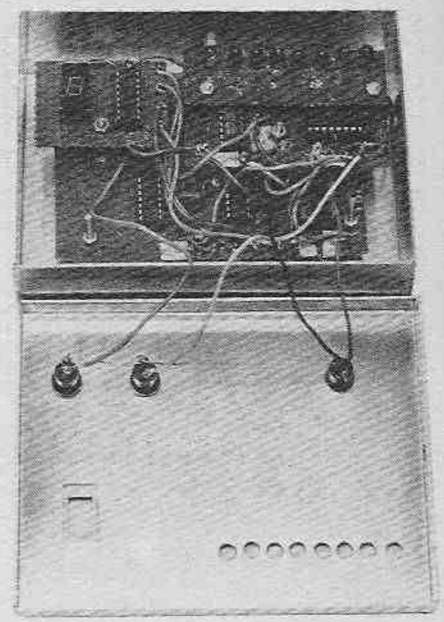
Fig. 3. Wiring on the underside of each of the three boards; p.v.c. covered wire is advised for all interconnections.





HOW IT WORKS

When the BOWL switch is closed pulses from the generator are fed to the pitch to simulate a ball moving towards the batsman. If the BAT switch is operated at the same time that the ball reaches its last position, this is detected and a signal produced to allow the generator pulses to be counted. This signal lasts for about two seconds resulting in a frozen displayed number after this time, and equal to the "runs" made. If the BAT switch is not operated within the time that the last ball l.e.d. is on (lit), then the very last l.e.d. in the chain lights up indicating a fallen wicket.



Final stages of construction.

on each board and interwire the underside as detailed. There are many connections to be made on the undersides of the boards, especially board A. It is therefore essential that p.v.c. sleeved wire is used here as there are numerous "crossings" of these conductors. Do not connect any flying leads at this stage.

When the individual boards are complete and thoroughly checked, mount them as shown in Fig. 4. It is a good idea at this stage to position the assembly in its drilled case and adjust the positions of the boards to site the opto boards at the correct height. When satisfied, the securing nuts and shakeproof washers can be tightened.

The inter-board wiring can now be carried out. Stranded wire is recommended, 7/0·2mm p.v.c. covered is suitable. It is wise to use as many different wire colours as possible to enable easier fault tracing should this be necessary. As each connection is made, it should be crossed off in Fig. 2, or better still traced with a coloured pencil of the same colour as the wire used.

When complete, wire the switches to the boards and connect a suitable voltage source which can be in the range 6 to 12 volts.

COMPONENTS

Resistors

R1	470kΩ	R6	220kΩ	R11	330Ω
R2	10kΩ	R7	270kΩ	R12	470Ω
R3	1MΩ	R8	470kΩ	R13	33kΩ
R4	33kΩ	R9	220kΩ		
R5	10kΩ	R10	470kΩ		

All ¼W carbon ± 5%

Capacitors

C1 0·1μF plastic or ceramic
C2 4·7μF 12V elect.
C3 0·1μF plastic or ceramic

Semiconductors

IC1 CD4001 CMOS quad 2-input OR gates
IC2 CD4081 CMOS quad 2-input AND gates
IC3 CD4518 CMOS dual b.c.d. up-counter
IC4 CD4013 CMOS dual D-type flip-flop
IC5 CD4016 CMOS quad bilateral switch
IC6 CD4001 CMOS quad 2-input OR gates
IC7 CD4017 CMOS decade counter/divider
IC8 CD4511 CMOS b.c.d./7-segment latch/decoder/driver
IC9 CD4081 CMOS quad 2-input AND gates
X1 DL 704 common cathode 7-segment display
D1-D7 TIL220 red l.e.d.
D8 TIL221 green l.e.d.

Miscellaneous

SK1 miniature jack socket (optional)
S1-S3 momentary action push-to-make switch (3 off)
Plain matrix board; 0·1 inch pitch, 40 × 26, 27 × 17, 17 × 13, 27 × 8mm; i.c. sockets, 16 pin (3 off), 14 pin (6 off); double sided Veropins; 6BA fixings; case to suit; battery connector (optional)

COMPONENTS approximate cost £11 excluding case

See Shop Talk page 481

PLAYING THE GAME

Three push buttons appear on the front panel labelled BAT, RESET and BOWL. When the unit is first switched on, pressing the RESET button places the ball at the bowler's end (extreme right).

The ball is bowled by pressing BOWL and is seen to move down the pitch towards the wicket by the string of l.e.d.s turning on and off. When the ball reaches the position just before the wicket (green l.e.d.), the batsman can make his play by pressing BAT. If a successful hit is made, the display will indicate the runs made from his strike. If he misses, the wicket will be hit by the ball and indicated by the green l.e.d. lighting up. The batsman is then out.

The display will indicate a number between 0 to 6 inclusive. All numbers with the exception of "5" are regular "runs" to be made, although 5 runs are possible, such as might result from an overthrow, it is very rarely seen. A display of 5 can therefore be used to indicate that the batsman has been caught out.

The RESET button must be pressed after the result of each "delivery" to return the ball to the bowling end.

To introduce an l.b.w. the reset gates (IC2b and c) could be modified to allow the display to count up to 7, this count indicating an l.b.w. Alternatively a sequence of runs, e.g. 2, 2, 2, or 1, 2, 3, or some other could be used for this. ⌘

By Dave Barrington

Aerial

Using experience gained in designing TV aerials for confined locations, such as caravans, Maxview Aerials have introduced a new 6-element array intended for viewers where space is at a premium.

Known as the Colour-Max the aerial is claimed to cover the entire u.h.f./TV spectrum and is supplied with an angled fitment terminating in two suction pads to enable it to be fitted to any smooth surface, such as a window or tiled wall. When the bracket has been secured the aerial is rotated towards the direction of best reception and locked in position by tightening a wing nut.

The aerial pack comes complete with 5 metres of low-loss coaxial cable, including plug, and a station guide leaflet to assist correct aerial orientation. For further details readers should contact Maxview Aerials Ltd., Dept EE, Maxview Works, Setch, King's Lynn, Norfolk, PE33 0AT.

CONSTRUCTIONAL PROJECTS

Rumour has it that there is a general shortage of components in the market place at the moment and readers are advised, in cases of delayed orders, to check supplies with our advertisers. This is due, we are informed, to the increase prices of replacement stocks and shortages from some manufacturers.

Weather Centre

Our major project this month is the *Weather Centre* and calls for some special items.

The mains transformer type MT150 and the panel meter are available from Bi-Pak Semiconductors. Order as 2025 for the transformer and 1303 for the meter.

The reed switches and magnet are RS Components types and should be ordered through RS stockists. This also applies to the flashing l.e.d.

The infra red detector (TIL78) and the infra red emitter (TIL32) seems to be available from various sources and should not be difficult to obtain.

The rectangular l.e.d.s required for the compass points are stocked by Watford Electronics, price 36p each. However, as eight are required they are prepared to supply them at 30p each, including mounting clips. These devices are available in red, green or yellow.

To give the centre a professional appearance most of the electronics were housed in a Contil CON127 series case available from West Hyde Developments, Unit 9, Dept EE, Park Street Industrial Estate, Aylesbury, Bucks, HP20 1ET. These cases are fairly expensive and any similar dimensioned case may be used, at the cost of the final appearance of course.

Cricket Game

The 4000 series of CMOS integrated circuits for the *Cricket Game* are stocked by most component suppliers and should not give any problems.

The 7-segment display is the DL704 and is a fairly common device stocked by most advertisers. Any seven segment common cathode display can be used but the wiring may need altering to cater for the differing pinning arrangements.

As the unit is likely to be used where easy access to mains supply for a battery eliminator could be a problem, we suggest a larger case be used to incorporate a PP6 battery to power the circuit. This will make the game truly portable and help to pass the time during the usual "rain stopped play" intervals.

Auto Lighting-Up Warning

The "heart" of the circuit for the *Auto Lighting-Up Warning* is a silicon controlled switch type BRY39. This device may prove troublesome to locate but is listed in the Ace Mailtronix and Electrovalue catalogues. Also, it appears in the latest Watford Electronics advertisement and can be purchased through RS Component stockists.

The rest of the items for this project should be readily available from most sources.

Audio Millivoltmeter

The close tolerance resistors called for in the *Audio Millivoltmeter* are from the E24 range stocked by most suppliers. However, some advertisers may supply resistors rated at ½ watt, these are quite suitable provided their resistance values are 2 per cent or better.

Although this project uses an edgewise meter there is no reason why an ordinary standard 1mA moving coil meter could not be used, making sure of course it will fit in the case.

Brakesafe Monitor

No buying problems are envisaged for the *Brakesafe Monitor*. The buzzer used in the prototype was a 6V type obtained from Maplin.

BOOK REVIEWS

INTRODUCTORY CIRCUIT THEORY

Author	J. K. Fidler
Price	£5·95
Size	227 × 152mm 214 pages
Publisher	McGraw-Hill Ltd.
ISBN	0 07 084095 4

Back in the days of steam radio and the BBC Light Programme, the answer to the question "How are you at mathematics", would always seem to be "I speak it like a native!"

Unfortunately few of us have quite the same assurance and any undergraduate text that leads the student through the mathematical minefield of electrical theory is usually well received.

This book provides a logically developed introduction to a subject that lies at the foundation of electrical science.

Circuit analysis techniques for both linear and non-linear circuits are described and a thorough grounding in the basics of time domain and frequency domain analysis is also provided.

S.E.D.

TWO-METRE ANTENNA HANDBOOK

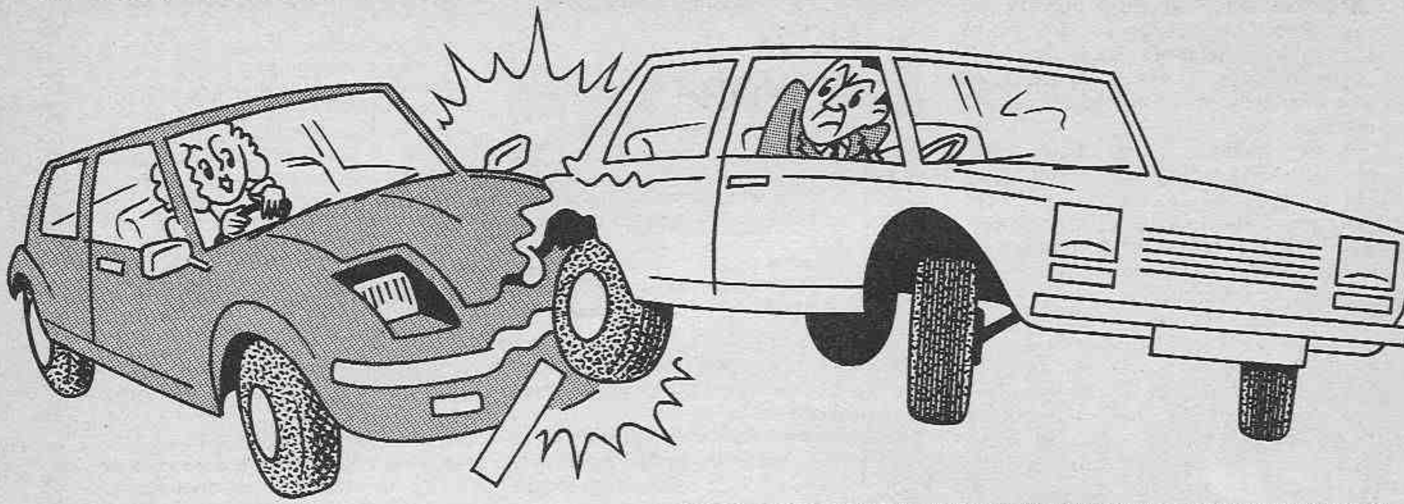
Author	F. C. Judd, G2BCX
Price	£3·95 paperback
Size	185 × 120mm 160 pages
Publisher	Newnes Technical Books
ISBN	0 408 00402 9

This compact book is intended primarily for newcomers to the highly popular 144-146MHz amateur band which, because of the impact of the Class B v.h.f.-only (no Morse) licences, is undoubtedly the most popular of all amateur bands in the UK and most other European countries. It provides a thoroughly practical guide to v.h.f. propagation, transmission lines, antenna tuning and matching units, the by no means easy task of measuring antenna performance, plus full constructional details of a number of useful omnidirectional (including colinear types) and beam antennas, including the installation of the associated rotor mechanisms. The directional designs include a number of Yagi arrays of varying complexity, v.h.f. "quad" (double diamond) arrays and several "driven" arrays such as the HB9CV and ZL-Special designs with which the author has been associated for many years.

The treatment is essentially non-mathematical but there is little doubt that this little book will be found useful (and not only by beginners) to those listening or transmitting on "two metres".

P.H.

IT SHOULDN'T EVER HAPPEN TO YOU... WITH OUR



BRAKESAFE MONITOR

BY O. N. BISHOP

How good are your reflexes? Even if they are as good as they should be, it is not safe for you to drive less than 60 yards behind another car when you are both travelling at 60 m.p.h. Sixty yards is about 13 average car lengths yet we frequently see cars travelling at high speed with much less than this distance between them.

Presumably the following driver is relying on the low chance that the driver in front will suddenly apply his brakes, but what happens if he does?

REACTION TIME

If you are too close to the car in front and it begins to decelerate then you may well be in trouble. It takes a few moments to become aware of the deceleration of the car in front, then you have to decide to apply the brakes, then there is a time delay during which your brain activates your leg muscles to press on the brake pedal and finally the brake mechanism requires time before the braking force begins to act.

This period is known as the reaction time and is usually about two seconds in fine conditions. Under bad conditions such as rain, fog, snow or darkness this can be extended as far as five seconds.

At 60 m.p.h. you will travel about 60 yards in two seconds. This means that if you are following the car in front closer than 60 yards and it brakes suddenly, you will not have time to brake before you run into it.

TABLE 1
Braking Distances and Stopping Times

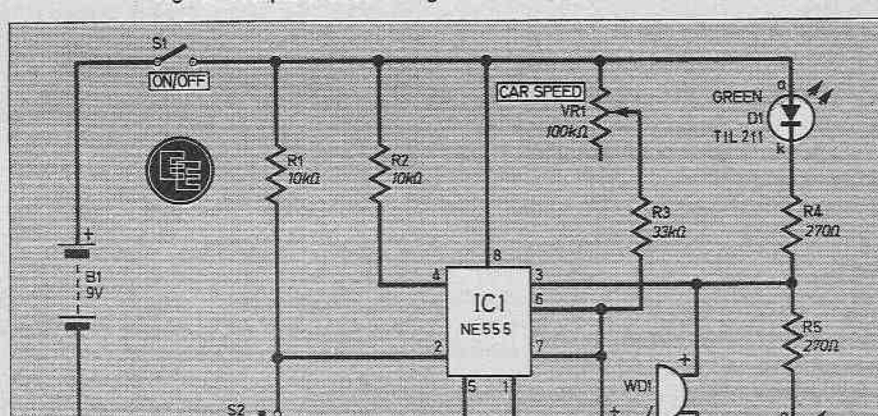
Speed (m.p.h.)	Braking Distance (yards)	Time to Stop (secs)
10	5	2·0
20	15	2·7
30	25	3·4
40	40	4·1
50	58	4·8
60	80	5·4
70	105	6·1

The important thing to remember is that it is the time difference between you and the car in front (measured in seconds) that matters and not the distance. If your time difference is less than two seconds you can only avoid a collision by steering to one side.

BAD VISIBILITY

Another type of problem arises when driving in conditions of bad visibility, especially in fog. Drivers are often unable to brake and halt

Fig. 1. Complete circuit diagram of the Brakesafe Monitor.



when an obstruction on the road ahead suddenly appears out of the fog. Motoring handbooks list tables of braking distances such as those shown in Table 1. This lists the times and distances necessary to come to a complete halt.

In fog, distance matters because we are usually heading for a stationary object, and not, as in the previous example, following a decelerating car. The object is standing stationary on the road from the moment you see it.

Given the braking distances calculated by experts, and assuming that deceleration is at a uniform rate, we can calculate how long it takes to bring the car to a halt. These times are shown in the third column of Table 1, and include reaction time. At 10 m.p.h. we can stop the car practically as soon as we have had time to react to the sight of the obstruction.

At 70 m.p.h. however several seconds elapse while the car is decelerating, no matter how good the brakes may be. We need to be able to see over 100 yards ahead.

The Brakesafe Distance Monitor can be set to sound for various times ranging from two seconds to seven seconds. The extra 0·9 seconds at 70 m.p.h. allows a little extra for safety, especially necessary as many drivers do not brake fully when first seeing an obstruction.

The Brakesafe Distance Monitor therefore measures time difference. It is a training aid to help you get the feel of driving with a safe distance between you and the car in front and also to help maintain a safe speed in foggy conditions.

Reckoning in time rather than in distance has the advantage that we can use an electronic timer operated from within the car.

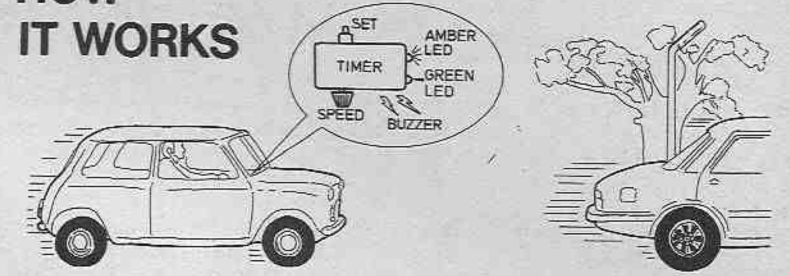
CIRCUIT

The full circuit of the unit is shown in Fig. 1. This consists basically of a 555 timer i.c. connected in the monostable mode. When S1 is first turned on, the output of IC1 (pin 3) is low, that is at 0V. Current flows through D1, the green l.e.d. and into the i.c. at pin 3.

When the SET button, S2, is briefly pressed, the trigger input, pin 2, which was formerly held high by current flowing through R1, is briefly grounded. This triggers IC1 and timing begins. Current flows through VR1 and R3 to charge capacitor C2. The time taken to charge C2 depends on its value, the value of R3 and the setting of VR1.

While charging is taking place, the output of the i.c. goes high, that is to nine volts. The l.e.d. D1 is extinguished and now a current flows through D2, the yellow l.e.d. and through the buzzer.

HOW IT WORKS



A simple timer i.c. forms the basis of this unit. An external variable resistor controls the timing period and the circuit is used to drive a buzzer and l.e.d.

To gauge the following distance the unit is set for a two second timing period and a roadside object, such as a lampost, is used for reference.

To gauge the correct speed in poor conditions, such as fog, the unit is set to a time period corresponding to the speed of the vehicle. If the alarm remains on after a reference point is passed then the vehicle is travelling too fast and should slow down.

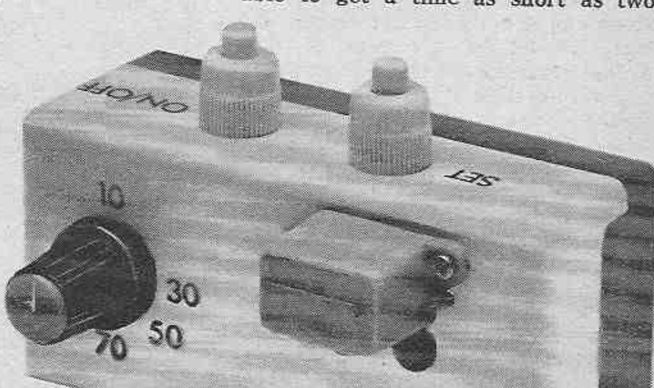
When the capacitor is charged to two-thirds of the supply voltage, which in this case would be six volts, the i.c. rapidly grounds pin 7, discharging the capacitor. The l.e.d. D1 comes on once again and D2 is extinguished, turning off the buzzer.

CONSTRUCTION starts here

STRIPBOARD

The circuit may be accommodated on a small piece of 0·1 inch matrix stripboard, 29 holes by 8 strips, with the exception of the push buttons, battery buzzer and variable resistor. This is shown in Fig. 2.

First cut the stripboard and check that it fits into the chosen case. In the prototype a Verobox, type 202-21028-A, was used although any small enclosure will be just as good. Make the breaks in the copper strips and then solder the components in place, leaving the i.c. until last. The two l.e.d.s should be left with long leads so that they stand off the board.



The recommended buzzer is a solid state device so the leads must be connected up the right way round, the red wire being the positive connection.

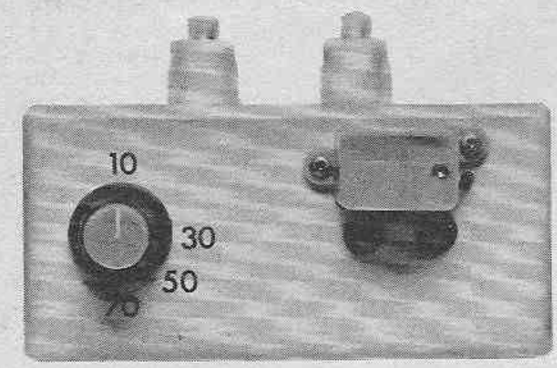
When the circuit board is finished, the off-board components can be mounted in the case and interwiring completed.

TESTING

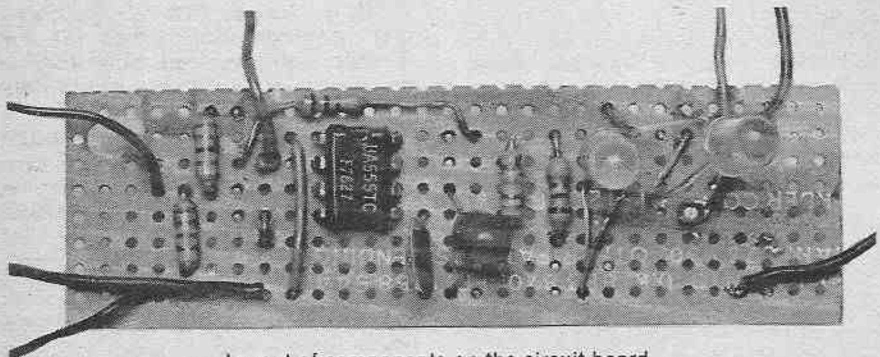
When VR1 is at or near its minimum setting, the yellow l.e.d. D2 should be on for about two seconds. With VR1 at its maximum setting, D2 should be on for seven seconds. The buzzer may be disconnected while performing these tests and whilst calibration is being carried out. The range of two to seven seconds should preferably take the whole sweep of VR1.

Since the capacitance of C2 may differ by as much as 20 per cent from its nominal value you may not be able to get a time as short as two

BRAKESAFE MONITOR



Outside view of the finished unit. Note position of l.e.d.s and calibration of speed control



Layout of components on the circuit board

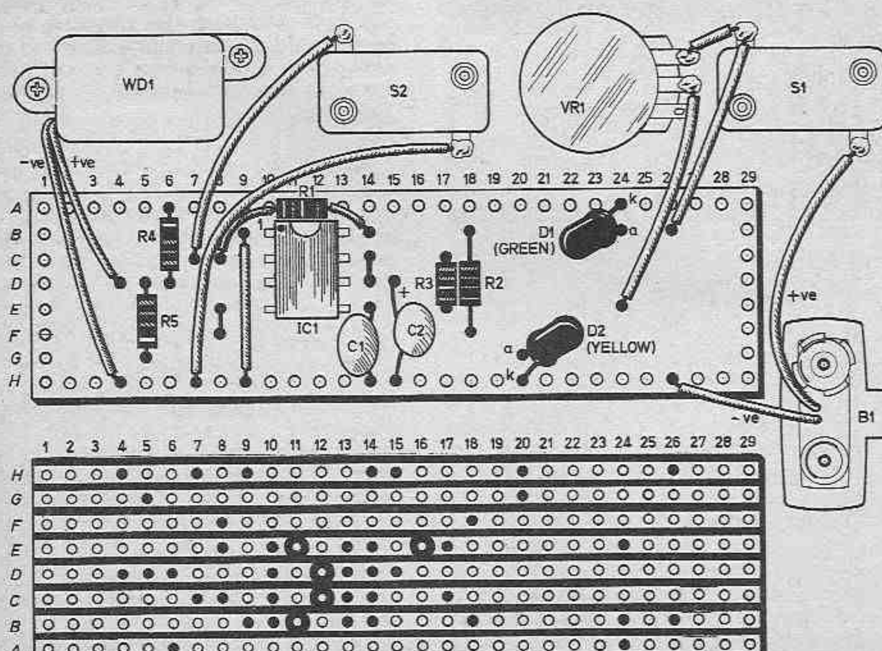


Fig. 2 (left). The completed circuit board. Note that the off-board components are not in their final mounting positions and that the l.e.d.'s D1 and D2 stand up off the board.

COMPONENTS

See **Shop Talk** page 481

Resistors
- R1 10kΩ
- R2 10kΩ
- R3 33kΩ
- R4 270Ω
- R5 270Ω

All ¼W carbon ± 5%

Capacitors
- C1 0·01μF ceramic disc
- C2 47μF 16V tantalum bead

Semiconductors
- IC1 NE555 timer i.c.
- D1 TIL211 green l.e.d.
- D2 TIL212 yellow l.e.d.

Miscellaneous
- VR1 100kΩ miniature linear potentiometer
- S1 push-on/push-off switch (Castelco type 2634)
- S2 push-to-make release-to-break switch (Castelco type 2644)
- B1 9V PP3 type
- WD1 solid state buzzer, 6V or 12V type

Stripboard: 0·1inch matrix, 29 holes × 8 strips; case, 100 × 50 × 40mm (Vero-box type 202-21028A or similar); control knob; battery connector; mounting bushes for l.e.d.s; connecting wire; foam packing.

COMPONENTS approximate cost £6·00

seconds or as long as seven seconds. If this occurs, try using another capacitor of the same nominal value.

Alternatively try changing R3. Using a higher value will increase the time, and vice versa.

As can be seen from the accompanying photographs, the l.e.d.s are mounted directly onto the circuit board. These protrude through holes in the front of the case with the circuit board just resting inside the case and held in position with foam packing.

Before joining the two halves of the case together, check the alignment of the l.e.d.s so that they slide smoothly into the holes provided for them. The leads may be bent as required to align them correctly but beware that they do not touch or short circuit against any metal parts.

CALIBRATION

This is simply a matter of marking a scale on the front panel to show the correct settings of VR1 for the various times listed in Table 1. Working out the precise location of each calibration mark is largely a matter of trial and error and precise times are not essential. If in doubt, err on the side of a slightly longer time rather than a slightly shorter one. In the prototype only settings for 10, 30, 50 and 70 m.p.h. were marked. Intermediate speeds can be set by estimation.

USING THE DEVICE

The Monitor has two push buttons, one for on/off and the other for starting the timing sequence. The unit is first switched on by pressing S1. The green l.e.d. D1 lights up.

Suppose you wish to check whether you are too close to the car in front. The speed control, VR1, is set to minimum and the operator watches the car in front. At the exact instant that it passes some clearly defined object on the road side ahead, like a tree for example, the SET button is pressed and released.

This extinguishes D1 and lights up D2. At the same time the buzzer emits a loud tone. If your car passes the same point on the road while the l.e.d. is on and the buzzer is still sounding, then you are too close to the car in front and should drop back at once.

Your time difference is less than two seconds and if the car ahead were to break sharply you would need to swerve in order to avoid hitting it.

If the yellow l.e.d. goes out and the buzzer stops sounding before you get to that point on the road all is well.

If conditions are bad (for example heavy rain or snow), the reaction time needs to be rather longer—about five seconds. This can be achieved by turning VR1 to the 50 m.p.h. mark.

DRIVING IN FOG

When checking your stopping distance in fog you should proceed as follows.

The operator first sets the knob to the speed of the car. When some object close beside the road ahead just appears out of the fog, the operator presses the SET button. If the car passes the object while the buzzer is still sounding and D2 lit up, then the car is going too fast for the existing conditions.

If that object had been a fallen tree across the road, it would have been impossbile to stop the car before hitting it.

Remember that fog near the ground is often more dense than that at tree top level. It is best to use sightings of objects close to ground level.

Also remember that the fog ahead may be much denser than the fog through which you are travelling so give yourself a little extra safety margin.

It is not suggested that you should use the Monitor every time you take the car out. Use it once or twice every month or so for an occasional check on your driving habits. ⌑

Innovators

I am certain that among our readers, there are plenty of potential inventors. This is a welcome sign, because if there is one thing that the British are really good at, it is innovation.

However, when you have invented something, you are then faced with the agonising dilemma as to whether you should patent it or not. If you want my personal opinion, for what it is worth, I would give you the advice that Mr. Punch gave to those about to get married. "Don't"!!

Let me give you my reasons. The cost of taking out a provisional Patent, followed by a full Patent would be astronomical today. When you have done it, you cannot be sure it will sell in sufficient quantities, and even if it is a winner, some bright but unscrupulous firm will usually find a way round the Patent.

I have some personal experience of taking out Patents. Several years ago, I designed and patented a small pocket sized Course and Ground Speed Calculator for light aircraft. It was quite unique at the time, due to its size. Did the World beat a path to my door? It did not, and I still have several boxes full of them in my attic.

I think today, I would just register the design and hope for the best. You have been warned!

Old and New

Fashions, especially ladies fashions, are simply a rotation of styles, skirts go up and come down, trousers go from wide to narrow and back again. This is a splendid argument for telling your wife to hang on to what she already has and not waste your money, but I am glad to say that to a lesser degree it also happens in electronics. For example, the chaps who stuck with their valve amplifiers are now having the last laugh.

If like me, you find the rate of progress too fast, the best thing to do occasionally, is to say, "I will sit this one out". What you do then, is to scan the electronic journals, particularly the American ones, for the next new development. When you spot a likely one, you mug it up and bring it out at the right moment to astonish your friends.

I am in the process of doing this now, and am only waiting for a friend I dislike sufficiently, to say to me, "I say old boy, this new silicon chip XYZ is simply the last word, it can————". At this juncture I shall break into his conversation, giving him a pitying smile, and say," Really old man, silicon chips! You are way behind the times, they are far too slow, gallium arsenide is the thing now, it's twice as fast as silicon." "Really old man you must get with it." Collapse of old man, or it should be.

It is interesting to see how things change even with well established items such as transistors. Several years ago the Ladybird book publishers brought out an excellent little book on constructing transistor receivers. It is still on sale today, but unfortunately it was designed around the OC71 and OC45 and everything has now swung from germanium to silicon. OC71s and OC45s are fast becoming obsolete.

I wrote to the publishers and suggested they redesign it around BC108s or similar. In view of what I said previously, perhaps I should have just told them to shelve it for a few years and then bring it out again.

Part 10

By S. R. Lewis, B.Sc.

TEACH-IN 80

ONE of the key concepts in modern electronics is that of **feedback.** An understanding of the basic principles of feedback enable a circuit designer to apply it to enhance the performance of a circuit or to avoid it where it could cause problems. In this part of the series we will look at the controlled use of feedback to give us amplifiers with stable and predictable gain.

THE BASIC CONCEPT

Feedback in its most general form can be defined quite simply: it occurs when part of the *effect* is used to modify the *cause*.

Feedback takes place in all sorts of systems; mechanical, chemical, biological, social, and of course electrical. It can be a force for both good and evil. One of the "evil" aspects that occurs in public address systems is when part of the output of the loudspeakers reaches the microphone causing the characteristic wail to be produced.

There are two types of feedback which are given the names positive and negative feedback. **Negative feedback** occurs when the part of the output which is fed back causes the input to be *reduced.* **Positive feedback** is when the part of the output which is fed back causes the input to be *increased.*

Except in oscillators, positive feedback is seldom used so let us begin by looking at negative feedback, what it is and why it is so important.

NEGATIVE FEEDBACK

Consider the following problem: You are given a box which you are told contains a circuit which will amplify an input signal without distortion by a factor of 10,000 (Fig. 10.1). An amplifier with a gain of only 10 is required so what components must be added to the amplifier to do this?

A simple solution is to precede the amplifying block by a potential divider which divides the input signal by 1000 to give an overall gain of 10 (Fig. 10.2). This seems to fulfil the requirements with only two components and there are no obvious drawbacks.

The circuit of Fig. 10.3 shows a radically different approach to the problem. Again a potential divider has been used but this time it is put at the output and only divides by 10. The voltage which appears at the output of the potential divider has been fed back to a block which subtracts this voltage from the original input voltage.

The input voltage to the amplifying block is thus $V_{in}-(V_{out}/10)$ and this is amplified by 10,000 to produce the output voltage V_{out}. Equating the two voltages gives

$$V_{out} = 10{,}000 \times (V_{in} - (V_{out}/10))$$

$$=(10{,}000 \times V_{in}) - (1000 \times V_{out})$$

thus $$V_{out} = \frac{10{,}000}{1{,}001} \times V_{in}$$

Thus V_{out} is very nearly $10 \times V_{in}$ (within one part in 10,000).

The two circuits produce virtually the same output for a given input so what is all the fuss about negative feedback?

Suppose I now come along and tell you that instead of a gain of 10,000, the amplifying box only produces a gain of 9,000. How do the two circuits now compare?

The first circuit will simply divide the input signal by 1,000 and then amplify it by 9,000 giving an overall gain of 9, thus the drop in overall gain is equal to the drop in the gain of the amplifying block.

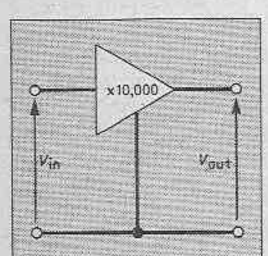


Fig. 10.1. A simple amplifier which takes a voltage and multiplies it by 10,000.

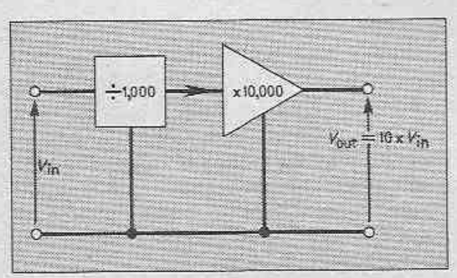


Fig. 10.2. To produce an overall gain of 10, the simple amplifier could be preceded by a potential divider to divide by 1,000.

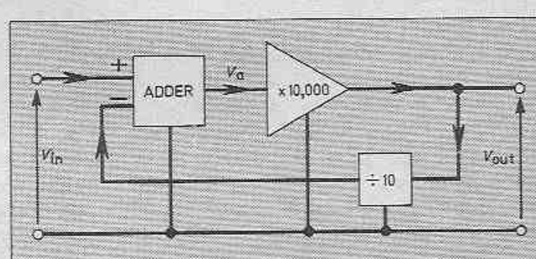


Fig. 10.3. A more complex solution is to use feedback as shown here though its implementation does not necessarily mean more components.

The other circuit however still feeds back one-tenth of the output voltage to be subtracted from the input voltage. Evaluating V_{out} as before:

$$V_{out} = 9{,}000 \times (V_{in} - V_{out}/10))$$
$$=(9{,}000 \times V_{in}) - (900 \times V_{out})$$
$$\text{thus} \quad V_{in} = \frac{9{,}000 \times V_{out}}{901}$$

The output voltage is still virtually ten times the input voltage, the error now being one part in 9,000. A really dramatic improvement on the first circuit!

The circuit of Fig. 10.3 is the basic negative feedback circuit and what we have been investigating in the previous exercise was the way in which negative feedback improves gain stability of a circuit.

We could have carried out a similar exercise to investigate how the two circuits compare when the amplifying block adds a distortion voltage to the amplified input voltage. Here again we would discover that the feedback circuit performs outstandingly better, the distortion voltage at the output being about a thousand times less than that with the simple circuit.

Real amplifiers inevitably vary in their gains since transistors cannot be made to all have the same gain. They also produce distortion so the use of negative feedback is really advantageous for producing amplifiers with predictable gain and low distortion.

FACTOR OF IMPROVEMENT

The factor of improvement can be calculated to be one plus the gain of the amplifying block divided by the overall gain of the circuit. The gain of the amplifying block is referred to as the **open loop gain** of the circuit and the overall gain is called the **closed loop gain.** It can be seen therefore that the amplifying block should be designed with as high a gain as possible so that the closed loop gain can take useful values.

The disadvantage of negative feedback when comparing the circuits of Figs. 10.2 and 10.3 seems to be that it requires an extra bit of circuitry: the subtractor. However, in many circuits the potential divider can be connected in such a way as to automatically subtract the portion of the output voltage from the input.

CIRCUITS WITH FEEDBACK

A very simple circuit which we have already looked at is in fact a negative feedback circuit. It is the simple emitter follower (Fig. 10.4).

In the emitter follower negative feedback is applied since the output voltage (that developed across the emitter resistor) is effectively in series with the input voltage so that any increase in the output voltage is subtracted from the input. In fact the feedback voltage is virtually all the output voltage so the closed loop gain of the circuit is virtually unity.

Another circuit which we have already looked at and which makes use of the negative feedback is the bias stabilisation circuit where the bias resistor is connected from the collector back to base (Fig. 10.5).

Here the situation is slightly more complex since one needs to use both voltages and currents to describe the feedback action. However on a qualitative basis one can see that the circuit uses negative feedback since an increase in base current from an external source produces a drop in collector voltage which, in turn, produces a drop in the current fed back to the base, thus reducing the original base current.

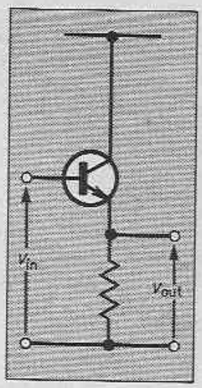
These two circuits in fact illustrate two ways in which negative feedback can be applied without using a specific subtractor. The emitter follower places the output in series with the input so that it opposes the input. The bias circuit makes use of the fact that the common emitter circuit is an inverting amplifier so that an increase at the input produces a decrease in the output.

OPERATIONAL AMPLIFIERS

At the end of the article last month the idea of operational amplifiers was introduced. We will now look in more detail at how they can be used with feedback components.

The operational amplifier itself is equivalent to the imaginary amplifying block which was discussed earlier. Its gain is extremely high so that closed loop gains of say 1,000 can be used whilst still getting the benefits of negative feedback.

The operational amplifier has two inputs which can either be



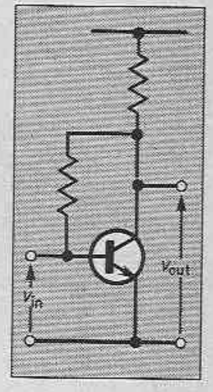


Fig. 10.4. An emitter follower can be thought of as an amplifier with heavy negative feedback.

Fig. 10.5. *(right)* The feedback resistor is used to stabilise the operating point of this simple amplifier.

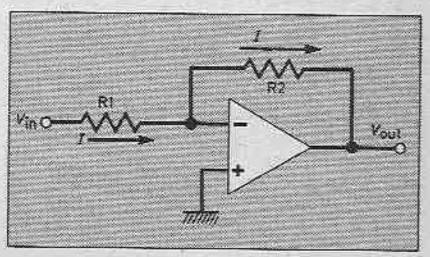


Fig. 10.6. An op-amp connected as an inverting amplifier. The same current flows through both the resistors.

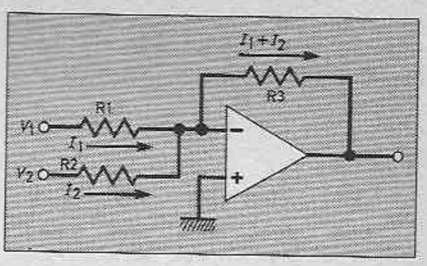


Fig. 10.7. Adding another input resistor converts the inverting amplifier into a summing amplifier.

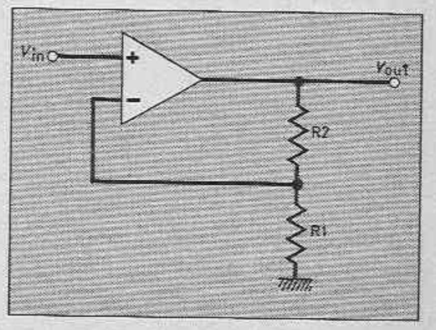


Fig. 10.8. Using the non-inverting input and connecting the feedback to the inverting input produces the non-inverting amplifier.

used individually by grounding the input which is not used, or together in which case the output voltage is the difference in the two input voltages multiplied by the gain of the amplifier.

INVERTING AMPLIFIER

Fig. 10.6 shows an operational amplifier with its non-inverting input grounded and two resistors added.

A perfect operational amplifier has an infinite input impedance so it would take no current at its input. Modern "op-amps" take so little current that we can ignore it.

The gain we take to be very high so for a voltage up to the maximum capability of the op-amp to exist at the output, the voltage at the input will be so small as to be negligible. For instance even with 15V at the output of a CA3140 op-amp the input is only 15/300,000V (about 50μV).

Since the op-amp input does not take any current, all the current flowing through R1 must flow through R2. The current in R1 is simply V_{in}/R1 since the voltage at the input to the op-amp we said was as good as zero.

This same current flowing in R2 produces a voltage across R2 of R2$\times V_{in}$/R1 and the voltage at the output must be negative since the direction of the current is from input to output. Thus for Fig. 10·6 the output voltage is given by

$$V_{out} = -\frac{R2}{R1} \times V_{in}$$

This circuit is the classic inverting op-amp circuit with gain simply the ratio of the two resistors.

SUMMING AMPLIFIER

Fig. 10.7 shows the same circuit but now with two input voltages and two input resistors. The voltage at the op-amp input will still be virtually zero but now the current flowing through the feedback resistor R3 will be the sum of the currents in the two input resistors, that is V_1/R1+V_2/R2.

The output voltage is now

$$V_{out} = -\left(V_1 \frac{R3}{R1} + V_2 \frac{R3}{R2}\right)$$

If all resistors are the same value then this equation reduces to

$$V_{out} = -(V_1 + V_2)$$

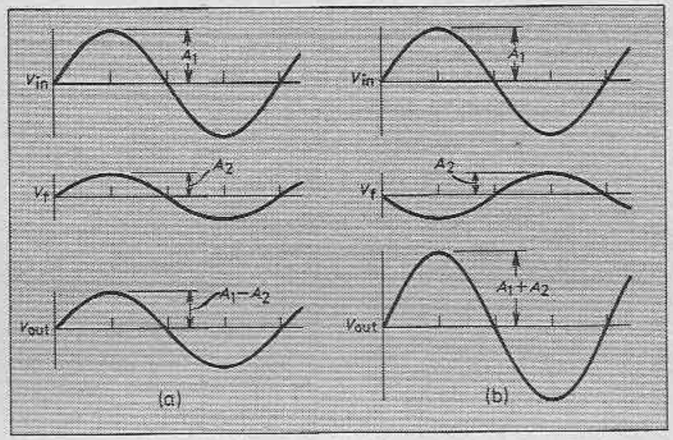


Fig. 10.9. Applying a.c. feedback in the wrong phase can produce the opposite effect to that desired. (a) shows the effect when the fed back voltage is in phase with the input and (b) when it is 180 degrees out of phase.

The circuit is known as the op-amp **summing** circuit since it produces an output voltage which is the sum of the two input voltages, though inverted. More input voltages and input resistors can be added so that the circuit can be used to add any number of voltages together.

NON-INVERTING AMPLIFIER

The circuit shown in Fig. 10.8 uses both inputs of the op-amp. A potential divider is placed at the output of the op-amp and the junction of the divider is taken to the inverting (−) input of the op-amp. Input voltage is applied directly to the non-inverting input (+).

To produce any reasonable voltage at the output, the difference between the two inputs (+ and −) is virtually zero so we can say the voltage at the junction of the potential divider is equal to the input voltage. This gives:

$$V_{out} \times \frac{R1}{R1 + R2} = V_{in}$$

So, $$V_{out} = \frac{R1 + R2}{R1} \times V_{in}$$

$$= \left(1 + \frac{R2}{R1}\right) \times V_{in}$$

What we have is a circuit which is virtually the implementation in real components of the circuit of Fig. 10.3. It is a non-inverting op-amp circuit with the gain given by one plus R2 divided by R1.

These few circuits illustrate how easy it is to use op-amps to produce accurate and reliable circuits.

FREQUENCY SELECTIVE FEEDBACK

So far all the circuits that we have looked at have used **d.c. feedback** but other types of feedback can be used. However when we come to look at **a.c. feedback** we have to be much more careful as it is not only the amplitude of the voltage or current that is fed back that is important, its phase relationship with the input must also be considered.

To understand why phase is important let us look at two feedback circuits which both generate exactly the same feedback voltage, the only difference being the phase relationship with the input (see Fig. 10.9).

In case (a) the feedback voltage is exactly the same phase as the input. When the feedback voltage is subtracted from the input voltage one will have a reduced input thus *negative* feedback takes place.

In case (b) the feedback voltage is 180 degrees out of phase with the input. When this is subtracted from the input the resultant voltage is bigger than the input so where we thought we had negative feedback we have in fact positive feedback!

One of the most useful forms of a.c. feedback circuit is the set of circuits known as **filters**. An electronic filter may be defined as a circuit which allows only a subset of a given set of input signals to pass through it. The most widely used filters discriminate between the frequencies of the input signals.

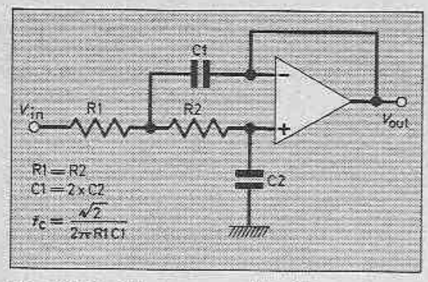


Fig. 10.10. A low pass active filter using an op-amp. This has unity gain until the cut-off frequency f_c is approached.

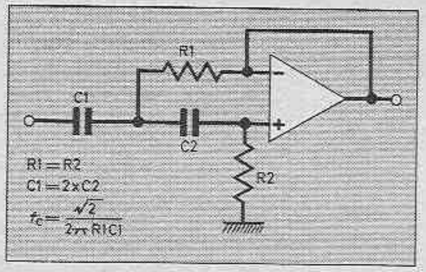


Fig. 10.11. A high pass active filter again with unity gain until the cut-off is approached.

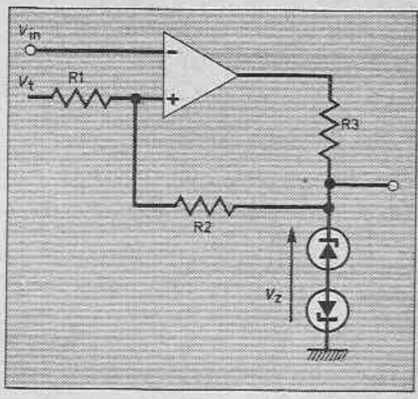


Fig. 10.12. Applying positive feedback around the op-amp causes a rapid transition from one state to the other. The Zener diodes are used to "clamp" the output at a known voltage.

Low pass filters allow only frequencies below a pre-set value to pass through whilst **high pass** allow only those above a given frequency to pass. **Band pass** filters allow only frequencies between two values to pass through.

Inductors or capacitors are used to form the frequency discriminating circuits though the trend today is away from inductors (which tend to be bulky at audio frequencies) and towards capacitors which, with clever circuit design can be made to do any job that an inductor can.

Figs. 10.10 and 10.11 show op-amp circuits for low pass and high pass filters respectively with the equations for the cut-off frequency, this being the frequency at which the output amplitude is half the input amplitude.

Connecting these two circuits so that the output of the low pass becomes the input of the high pass produces a band pass filter providing the cut-off frequency of the high pass section is greater than the cut-off frequency of the low-pass section.

The operation of these two circuits has not been described in detail since this would involve some complicated mathematics.

POSITIVE FEEDBACK CIRCUITS

It was stated earlier that positive feedback is seldom used but one area where it does find a use is in switching circuits where it can be put to use in speeding the switching action, that is making the transition from one state to the other as quick as possible.

A circuit which is very useful in taking slowly rising voltages and converting them into rapid changes at the output is known as the Schmitt trigger.

The op-amp version of the Schmitt trigger will be described since the feedback paths are more obvious than in the transistor version (Fig. 10.12).

First note that two Zener diodes are connected back-to-back at the output. This is so that a fixed voltage which cannot be exceeded will be produced at the output.

One resistor (R2) is connected from the "new" output back to the non-inverting input and another (R1) is connected to an imaginary voltage reference V_t.

Imagine first of all that the output of the op-amp is at its maximum positive value (this will be governed by the power supplies). The voltage on the Zeners will therefore be V_z. The voltage at the non-inverting input will be

$$\frac{R2\,V_t + R1\,V_z}{R1 + R2}$$

In order for the output of the op-amp to indeed be positive then V_{in} must be less than this voltage, which we will call V_a. What happens as V_{in} is increased?

As soon as V_{in} becomes slightly higher than V_a the voltage at the output of the op-amp will switch very rapidly to its maximum negative value causing the voltage at the top of the two Zeners to go to $-V_z$. As the voltage V_a begins to fall the difference between V_{in} and V_a will increase causing V_a to fall even more quickly. Positive feedback is causing a rapid change at the output with a slow change at the input.

PART 10 QUESTIONS

10.1. In Fig. 10.6 R1 is set to 10kΩ and R2 to 100kΩ. What is the gain of the circuit:
a) 1
b) 10
c) 100
d) 1,000

10.2. In Fig. 10.8 R1 is 10kΩ. What value must R2 be in order to give a gain of 5:
a) 50kΩ
b) 40kΩ
c) 30kΩ
d) 5kΩ

10.3. What is the cut-off frequency of Fig. 10.11 if C1 is 0·02μF, C2 0·01μF and R1 = R2 = 110kΩ:
a) 100Hz
b) 150Hz
c) 10Hz
d) 15Hz

10.4. What is the cut-off frequency of Fig. 10.10 when C1 = 940pF, C2 = 470pF, R1 = R2 = 24kΩ:
a) 1,000Hz
b) 10kHz
c) 20kHz
d) 25kHz

10.5. In Fig. 10·7 R1 = R2 = 10kΩ and R3 = 50kΩ. What will the output voltage be when V1 = 2V and V2 = 1V:
a) 15V
b) 1·5V
c) 3V
d) 30V

PART 9 ANSWERS

9.1 a). 9.2 b). 9.3 c). 9.4 b). 9.5 a).

NOTE: Question 9.4b) should read "2,500"

EXPERIMENT 10.1:

OP AMP ADDER

Components needed: 33kΩ ¼W resistors (2 off), 10kΩ ¼W resistor, CA3140 operational amplifier.

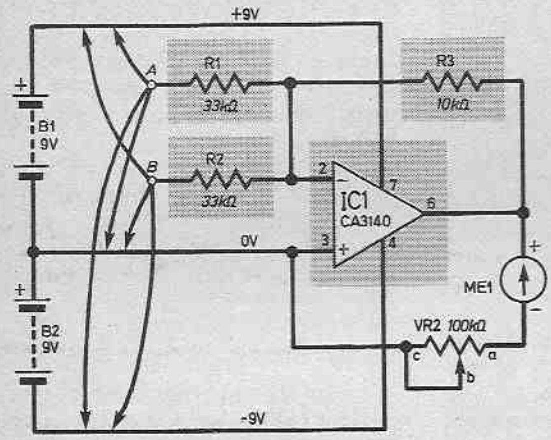


Fig. 10.14a. The circuit of Experiment 10.1.

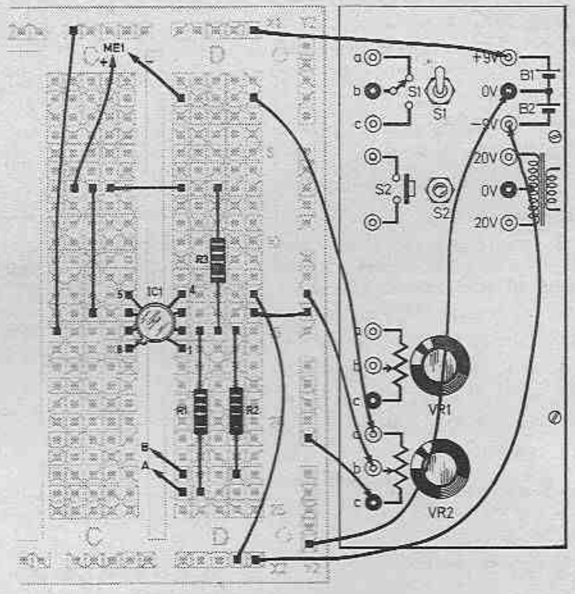


Fig. 10.14b. Layout of Experimental 10.1 on the Tutor Deck.

A simple adder circuit illustrating feedback around an operational amplifier is shown in Fig. 10.14a with the Tutor Deck layout in Fig.10.14b.

First connect wires from inputs *A* and *B* to the −9V line (X2). Now adjust the 100kΩ potentiometer until the meter just reads full scale. Move the wires from *A* and *B* to different power rails in all different combinations noting the meter reading for each case.

Connecting an input to the 0V rail will be found equivalent to leaving it open circuit since both conditions cause no current to flow in the respective resistor.

It should be found that one input the +9V gives half full scale meter reading.

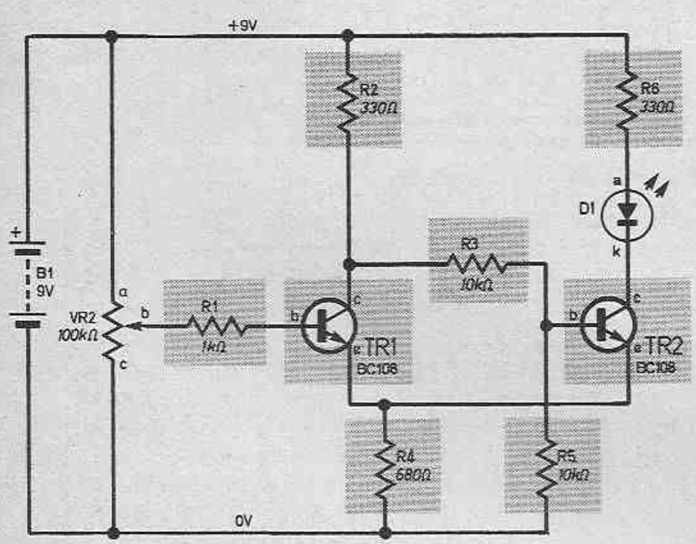


Fig. 10.15a. The circuit of Experiment 10.2.

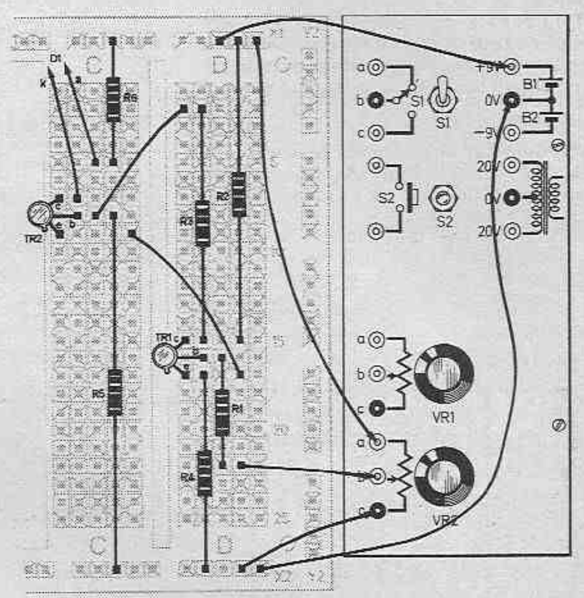


Fig. 10.15b. The layout of Experiment 10.2 on the Tutor Deck.

EXPERIMENT 10.2:

SCHMITT TRIGGER

Components needed: 1kΩ ¼W resistor, 330Ω ¼W resistor (2 off), 680Ω ¼W resistor, 10kΩ ¼W resistor (2 off), BC108 transistor (2 off).

A Schmitt trigger circuit which is used to drive a light-emitting diode is shown in Fig. 10.15a and the layout on the Tutor Deck in Fig. 10.15b.

The threshold point of the circuit can be found by first setting the potentiometer fully clockwise. TR1 will be cut off and TR2 conducting so the l.e.d. will be on. Slowly turn down the potentiometer and note how the l.e.d. suddenly goes off. The potentiometer has to be turned back a little to make the l.e.d. come on again illustrating the circuit's hysteresis.

To make the output switch back to its positive condition the input has to fall to a new value before the switching action occurs in the opposite way. Thus there is a difference between the voltages at which the output changes from high to low to that at which it changes from low to high.

HYSTERESIS

The difference between these two voltages is known as the **hysteresis** of the circuit. Hysteresis is a very useful property since it means that tiny changes in the input voltage will not produce wild fluctuations at the output.

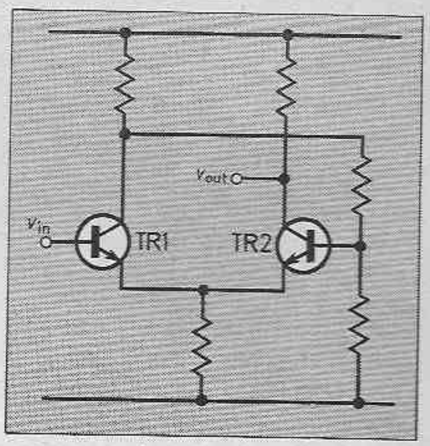


Fig. 10.13. A transistor Schmitt trigger based on the long-tailed pair

A transistor version of the Schmitt trigger is shown in Fig. 10.13. Note that it is basically the "long-tailed pair" circuit with feedback added from one of the outputs to one of the inputs. It has two states: one with TR1 conducting and TR2 cut-off, and the other with TR2 conducting and TR1 cut-off.

Again this circuit switches rapidly from one state to the other and also it can be designed with hysteresis.

Other important types of circuit where positive feedback is used are sinusoidal oscillators. *These, together with other types of oscillator, will be described in Part 11.*

EXPERIMENT 10.3:

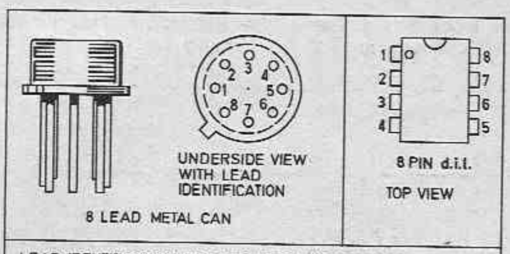
OP AMP INTEGRATOR

Components needed: 1MΩ ¼W resistor, 68kΩ ¼W resistor, 1µF 25V capacitor (2 off), CA3140 operational amplifier.

The circuit of Fig. 10.16a shows what is known as an integrating circuit using an op-amp and the layout on the Tutor Deck is shown in Fig. 10.16b.

Two capacitors have been used "back-to-back" so that the voltage at the output of the op amp can go either negative or positive without harming the dielectric of the capacitors. Pressing the pushbutton switch S2 momentarily will cause the meter reading to go to zero. When S2 is released the voltage at the output of the op-amp will be seen to either rise or fall steadily depending on the position of S1. A point will be reached where the voltage does not change any more since the output of the op-amp is virtually at the power supply voltage.

This circuit works by using the current through R1 to charge the capacitor C1 (or C2). Note that unlike the normal resistor-capacitor charging, the voltage on the capacitor rises linearly since the current is always the same and does not decrease as it does in the R-C circuit.



LEAD IDENTIFICATION FOR TWO VERSIONS OF I.C. TYPE CA3140

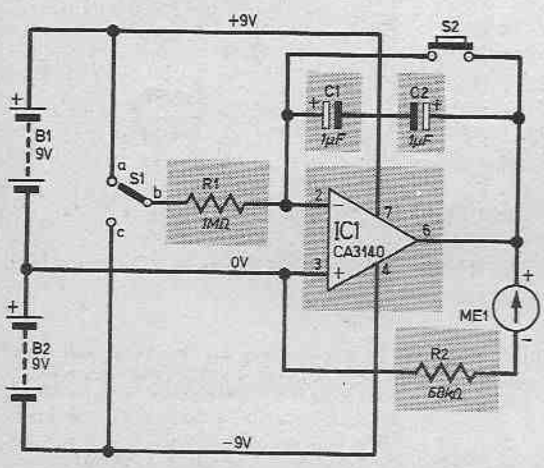


Fig. 10.16a. The circuit of Experiment 10.3.

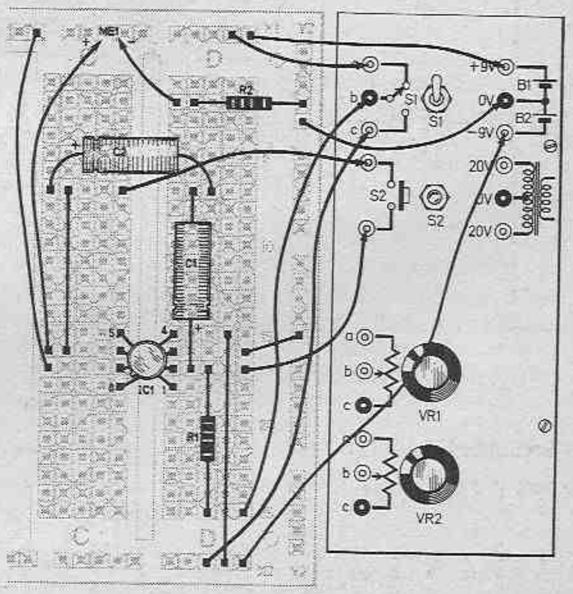


Fig. 10.16b. The layout of Experiment 10.3 on the Tutor Deck.

Part 11

By S. R. Lewis, B.Sc.

TEACH-IN 80

OSCILLATORS ARE circuits which continually alternate between two states. Many types of oscillator exist, but they may roughly be divided into two main groups: **sinusoidal** and **switching** (or non-sinusoidal).

Oscillations can occur in circuits which were designed as amplifiers if the designer is not aware of how oscillations can be produced. An example of this is the microphone - amplifier - loudspeaker arrangement where part of the output of the speaker gets back to the microphone causing a horrible wail to be produced. In this case the result of the unwanted oscillations is mainly annoyance but in certain circuits the unwanted oscillations can be disastrous.

OSCILLATOR WAVEFORMS

As an oscillator changes from one state to the other the voltages and currents go through changes. Oscillators can be designed so that the voltages are precisely defined functions and we will look at a few of the more common **waveforms** that are produced by different types of oscillator.

The most basic waveform is the **sinusoid** or **sine** wave as shown in Fig. 11.1(a). The changes are smooth and continuous and if converted into sound waves at an audible frequency the result is a very pure but uninteresting sound.

A waveform which sounds much more interesting at audible frequencies is the triangular shape illustrated in Fig. 11.1(b). The much "richer" sound is explained by the fact that the **triangular** waveform can be analysed into a whole series of sinewaves, each of which is a multiple of the basic frequency. We call these components of the waveform **harmonics.**

Another waveform rich in harmonics but slightly different ones is the **sawtooth** waveform of Fig. 11.1(c). At one point in the cycle there is a rapid transition from one voltage to another and this is always an indication that the waveform is rich in harmonics.

The **square** waveform of Fig. 11.1(d) simply consists of transitions from one voltage to another. This has a very interesting sound and can be filtered, as indeed can the triangular and sawtooth waveforms, to give a wide variety of pleasant sounds.

Other waveforms which may be encountered are shown in Fig. 11.1(e) and (f), these being the **pulse** waveform and the **trapezoidal** waveform.

SINUSOIDAL OSCILLATORS

It was mentioned how a microphone - amplifier - speaker system can sometimes give a horrible wail when the output is allowed to get back to the input.

What is happening in this situation is that positive feedback is occurring but because of the resonances of the hall and the amplifying system, a certain frequency tends to dominate, thus converting what is supposed to be an amplifier into an oscillator.

By controlling the frequencies of the signals which are fed back in a positive feedback circuit such as has been described, and also by controlling the gain of the amplifier, sinusoidal oscillations can be sustained without either building up or decaying away.

The conditions for oscillation are that the signal which is fed back to the input should be exactly 360 degrees out of phase with the input which is producing it at only one frequency. The gain of the system must be exactly one to just maintain oscillation; if it is below one the oscillations will die away and if it is over one they will gradually build up in amplitude.

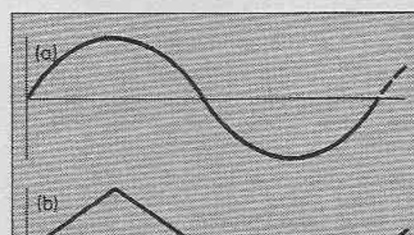


Fig. 11.1. Typical waveforms that are produced by oscillators. (a) shows a sine wave (b) a triangular wave (c) a sawtooth (d) a square wave (e) a pulse and (f) a trapezoidal waveform.

Fig. 11.2 shows a network which produces a 360 degree phase shift at the output at only one particular frequency. At this frequency the amplitude at the output will be one-third the input amplitude.

We can make use of this network in conjunction with an op-amp as shown in Fig. 11.3.

Here the network has been connected to the output of the op-amp and the output of the network has been connected to the non-inverting input of the op-amp. Because the network reduces the amplitude of the signal by one-third, the op-amp must be made to have a gain of three so that the closed loop gain is one.

In a real oscillator a voltage stabilisation circuit is sometimes included so that if the oscillations tend to build up or decay then the amplification factor is automatically changed to compensate.

Another sinusoidal oscillator circuit is shown in Fig. 11.4. In this, three *R-C* networks are cascaded so that the overall phase shift is 180 degrees. The transistor is connected as an inverter so it supplies the other 180 degrees shift to bring the output 360 degrees out of phase with the input.

The transistor is arranged to have sufficient gain to overcome the loss of amplitude through the *R-C* network.

SWITCHING OSCILLATORS

The oscillators described in the preceding section used the linear amplifying properties of an op-amp or transistor, but oscillators can be produced which make use of the two-state capability of transistors (or indeed op-amps).

In Fig. 11.5(a) there is shown a switching circuit using two transistors in two identical stages which are connected to a switch. When the switch is moved from the 5V rail to the 0V rail the capacitor cannot change its state of charge instantaneously so the voltage at the base of TR1 drops by 5V to $-4 \cdot 3$V thus switching it off and causing the collector voltage to rise to 5V.

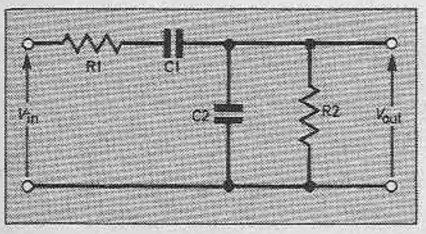


Fig. 11.2. This network of two capacitors and two resistors produces a 360 degree phase shift at only one frequency as given by the formula (see Fig. 11.3.).

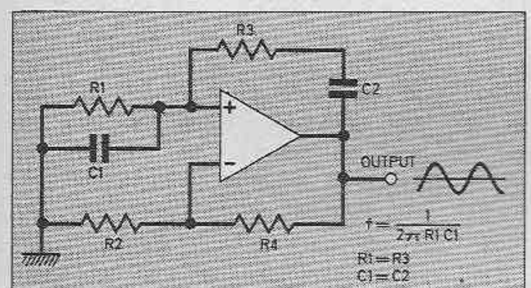


Fig. 11.3. The network of Fig. 11.2 has been connected around an op amp with the loss in amplitude compensated by the gain produced by R4 and R3 to form a Wien Bridge oscillator.

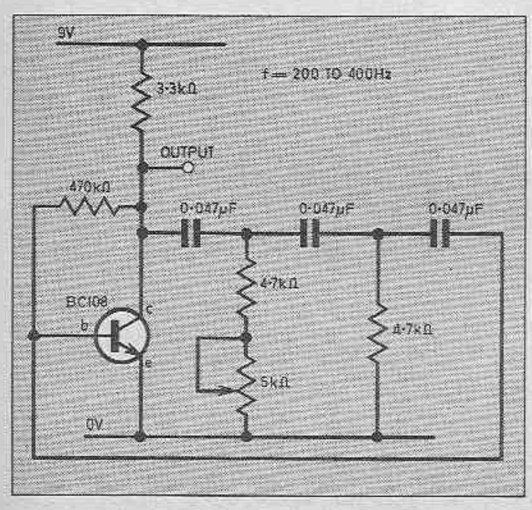


Fig. 11.4. This circuit is known as a phase shift oscillator. The capacitor-resistor network produces a phase shift of 180 degrees at a frequency in the range 200 to 400Hz, dependent on the setting of the 5 kilohm potentiometer. The attenuation is compensated by the gain of the transistor.

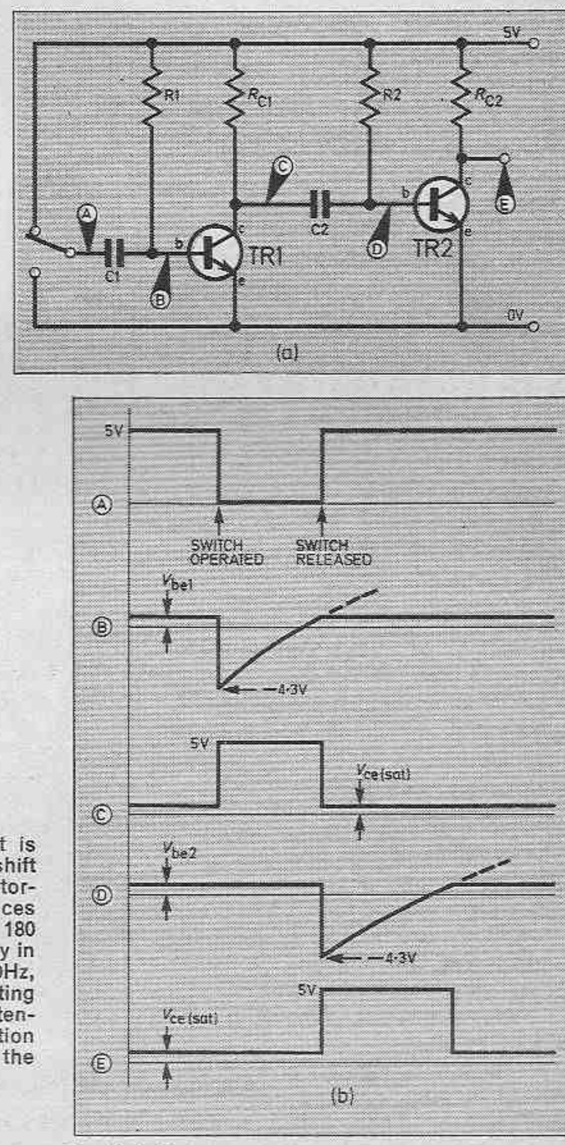


Fig. 11.5. This two-stage circuit with a switch shows how a delayed pulse can be produced at the collector of TR2. The waveforms at various points in the circuit are shown at (b).

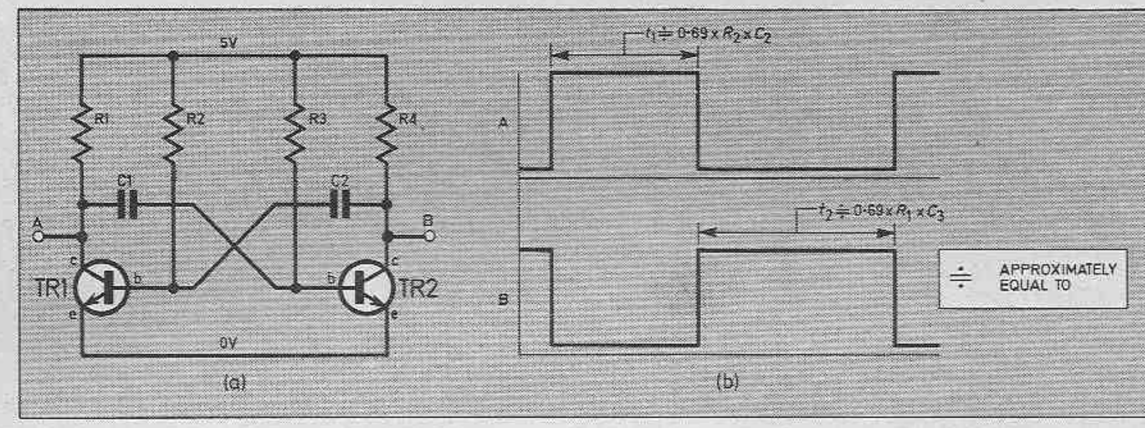


Fig. 11.6. The circuit of Fig. 11.5 without the switch has been redrawn in the conventional multivibrator configuration. The timing of the output waveforms is shown at (b). Note that the waveform at B is the inverse of that at A.

C1 begins to charge through R1, its voltage rising towards 5V but as soon as it reaches 0·7V TR1 is forward biased and switches on again making its collector voltage drop to about 0·2V.

Capacitor C2 will pull TR2 base to −4·3V when TR1 collector goes low, switching off TR2 until C2 has charged up via R2 to 0·7V at which point TR2 will switch on again. Fig. 11.5(b) shows the waveforms present at various points in the circuit.

If we now couple the transition at TR2 collector back to C1 then the circuit would continue oscillating between the two states indefinitely. Fig. 11.6(a) shows the same circuit redrawn in its more usual form.

The circuit that has been described is known as an **astable multivibrator** circuit and is so versatile and easy to use that it appears many times in designs.

RELAXATION OSCILLATORS

Another class of oscillators makes use of a special property of some devices or circuits known as **negative resistance.**

We are all familiar with **positive resistance** as it is the property possessed by the common or garden resistor: an increasing current through a positive resistance produces an increasing voltage Some circuits or devices can be made to go into a state where an increasing current produces a falling voltage. Usually this state is reached at some threshold voltage.

The block diagram in Fig. 11.7(a) shows how such a component can be used to make an oscillator. Imagine that the device draws no current when the voltage at its input is below the threshold. On switching on, the capacitor begins to charge towards the power supply rail.

When the threshold is reached the device goes into a negative resistance region so that as current begins to increase through it the voltage at the input actually drops. This will go on until the capacitor has discharged all its voltage.

The device now has not enough voltage across it to maintain the negative resistance state and so switches back to its high impedance condition. The capacitor begins to charge and the cycle starts again.

The circuit described is useful for producing sawtooth waveforms as shown in Fig. 11.7(b). This type of waveform is useful as it contains a large number of harmonics.

The two types of semiconductor component most often used in **relaxation oscillator** circuits are unijunction transistor, which is a cheap simple device most suitable for relatively low frequency work, and the **tunnel diode** useful at radio frequencies. These two devices will not be described in detail here but their circuit symbols are shown in Fig. 11.8.

MODULATION

Modulation is the process whereby the amplitude or frequency (or any other parameter) of an oscillation is varied under the influence of another signal.

Modulation is used extensively in radio circuits and in musical synthesisers. In radios use is made of the fact that high frequency electromagnetic waves can be propagated long distances and received with fairly simple equipment.

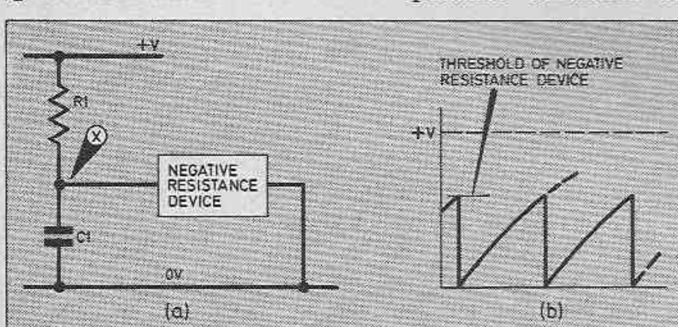


Fig. 11.7. This diagram (a) illustrates the use of a negative resistance device to form a relaxation oscillator. When the threshold voltage is reached the device goes into its negative resistance region and discharges the capacitor. This action is shown graphically at (b).

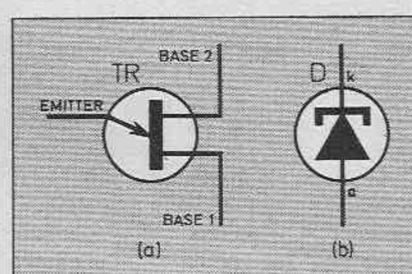


Fig. 11.8 (a) shows the symbol for a unijunction transistor and (b) the symbol for a tunnel diode. Both devices have negative resistance regions.

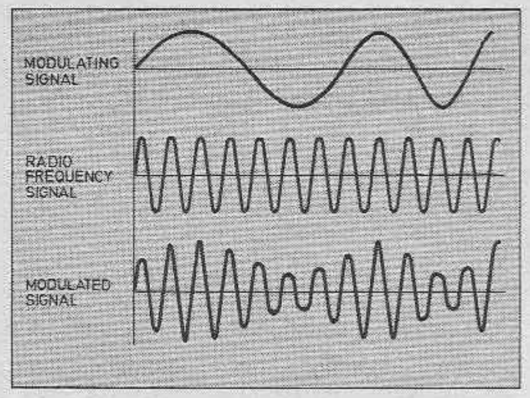


Fig. 11.9. A typical set of waveforms in an a.m. system.

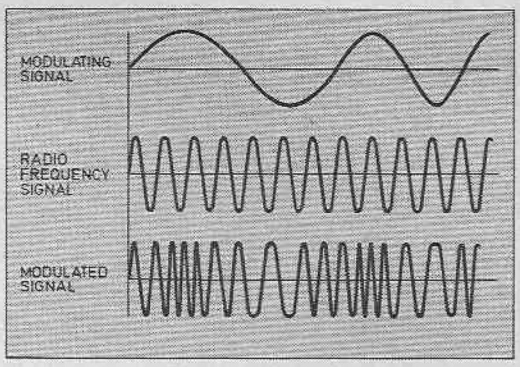


Fig. 11.10. A typical set of waveforms illustrating f.m. modulation.

There are two principal ways in which **audio frequencies**, which most often make up the information which we want to transmit, can be superimposed upon the **radio frequency** waves. The two methods are known as **amplitude modulation (a.m.)** and **frequency modulation (f.m.)**.

In amplitude modulation the instantaneous value of the amplitude of the audio signal is used to control the amplitude of the radio frequency oscillations whose frequency is kept constant. Fig. 11·9 shows a typical set of waveforms.

At the receiver a circuit is used which takes the amplitude of the radio frequency signals and uses it to recreate the audio signal for amplification.

Frequency modulation uses the instantaneous amplitude of the audio signal to control the frequency of the radio frequency signal. A typical set of waveforms is shown in Fig. 11.10. Note that the amplitude of the frequency modulated wave is constant.

Amplitude modulated radio signals are much more prone to interference than frequency modulated signals although the receiving equipment is less complicated and thus less expensive. The trend today is towards f.m. radio since more and more people are demanding the quality of reception that is only achievable with f.m.

Of course, a simple audio signal is not the only signal that can be used as the modulating signal. In television transmissions the modulating signal is a combination of the brightness of the particular portion of the scene which the camera is viewing together with information about the colour.

In stereo transmissions two separated microphones produce signals from different parts of the studio. Two signals are then produced from this information: a left−right signal and a left+right signal. Both of these are used to modulate the radio frequency signal. Normal mono receivers use only the left+right information whilst stereo receivers regenerate the left and right signals by adding and subtracting the left+right and left−right signals.

Normal telephone cables have a very small frequency range, sufficient to carry voice signals only, rather than the full audio spectrum. In these days of digital computers, the need arises to be able to pass digital signals along the telephone lines.

The method that is used is to use two frequencies, both within the bandwidth of the telephone lines, but well separated. One frequency is used to represent a logic 1 and the other to represent a logic 0. The digital signal therefore sounds like a warbling note as the signal is passed along the line. This is a form of frequency modulation since the amplitude of the signals does not vary but the frequency is modulated by the digital signal.

PART 11 QUESTIONS

11.1. Which of the following waveforms has no harmonics:
a) square wave
b) sine wave
c) triangular wave
d) sawtooth wave

11.2. What is the frequency of oscillation of a Wien Bridge oscillator with both resistors = 200kΩ and both capacitors 0·01μF:
a) 800Hz c) 80Hz
b) 8kHz d) 8Hz

11.3. A multivibrator is constructed as in Fig. 11·6 with R2 = 100kΩ, R3 = 100kΩ, C1 = 0·01μF and C2 = 0·03μF. What is the frequency of the oscillations:
a) 357Hz c) 1,428Hz
b) 3,570Hz d) 476Hz

11.4. What is the ratio of the on-time of TR1 to the on-time of TR2 in the multivibrator of the previous question:
a) 3 : 1
b) 1 : 3
c) 4 : 1
d) 1 : 4

11.5. What value of C1 would increase the frequency of the multivibrator in 11·3 to twice its original value:
a) 0·01μF
b) 0·02μF
c) 0·03μF
d) 0·04μF

PART 10 ANSWERS

10.1 b). 10.2 b). 10.3 a). 10.4 b). 10.5 a).

MUSICAL SYNTHESISERS

Musical synthesisers are used to generate a wide variety of sounds under the control of the operator.

There are usually separate modules for controlling the frequency, the amplitude and the waveform. The basic sound generator is most often the oscillator, though many sounds are based on random noise.

Either frequency modulation or amplitude modulation or a combination of the two effects can be achieved simply by inter-connecting modules. The frequency modulation is carried out in units called **voltage controlled oscillators (v.c.o.s).**

These are oscillators which produce constant amplitude oscillations, the frequency of which is completely determined by the voltage at their input. The voltage can be either a d.c. signal (so that the frequency is always the same) or a varying signal to produce interesting effects.

Amplitude modulation is carried out in units called **voltage controlled amplifiers (v.c.a.s).** Again the modulating signal can be either d.c. (which gives a constant amplitude output) or a varying signal. We call the amplitude of the modulated signal the **envelope** and voltage controlled amplifiers are often referred to as **envelope controllers.**

The waveform of the signal depends to a large extent on the waveform of the signal produced by the oscillator. It can be a simple sine wave or a square or triangular wave. Both the square and triangular waveforms have a large number of harmonics and these can be modified by passing the signals through another module, a **voltage controlled filter (v.c.f.).**

Voltage controlled filters can be low pass, band pass or high pass, but the thing that they all have in common is that the cut-off frequency is under the control of an external voltage. Passing a square wave into a voltage controlled filter and rapidly changing the cut-off frequency produces the characteristic "waa-waa" sound, often used with electric guitars.

UNWANTED OSCILLATIONS

It has been pointed out that unwanted oscillations can occur in amplifiers. How can a designer make sure that they do not occur?

Oscillations will take place if there is positive feedback around a circuit with a 360 degree phase shift and the loop gain is at least one. The answer to the problem is therefore to make sure that no signals **at any frequency** can be fed back to the input of the amplifier with 360 degree phase shift and with a loop gain of one. The phrase "at any frequency" is the important point since it may be the very high frequency response of the amplifier that allows oscillations to occur.

In the case of integrated circuit amplifiers, the manufacturers may include special components inside the package such that positive feedback cannot occur. However, this means that the bandwidth of the amplifier is restricted.

On the other hand the makers may supply a diagram of the frequency response of their amplifier so that the designer can choose his external components to give maximum bandwidth whilst never allowing oscillations to occur.

The position is much more difficult in the case of multistage discrete transistor amplifiers. It becomes very complicated to analyse the frequency response of the whole system and it may depend a lot on the physical layout of the components. The designer can either add components at every stage of the circuit so that when they are joined up he can easily predict what frequencies, if any, are critical, or else he may add components across the whole system making sure that oscillations cannot occur.

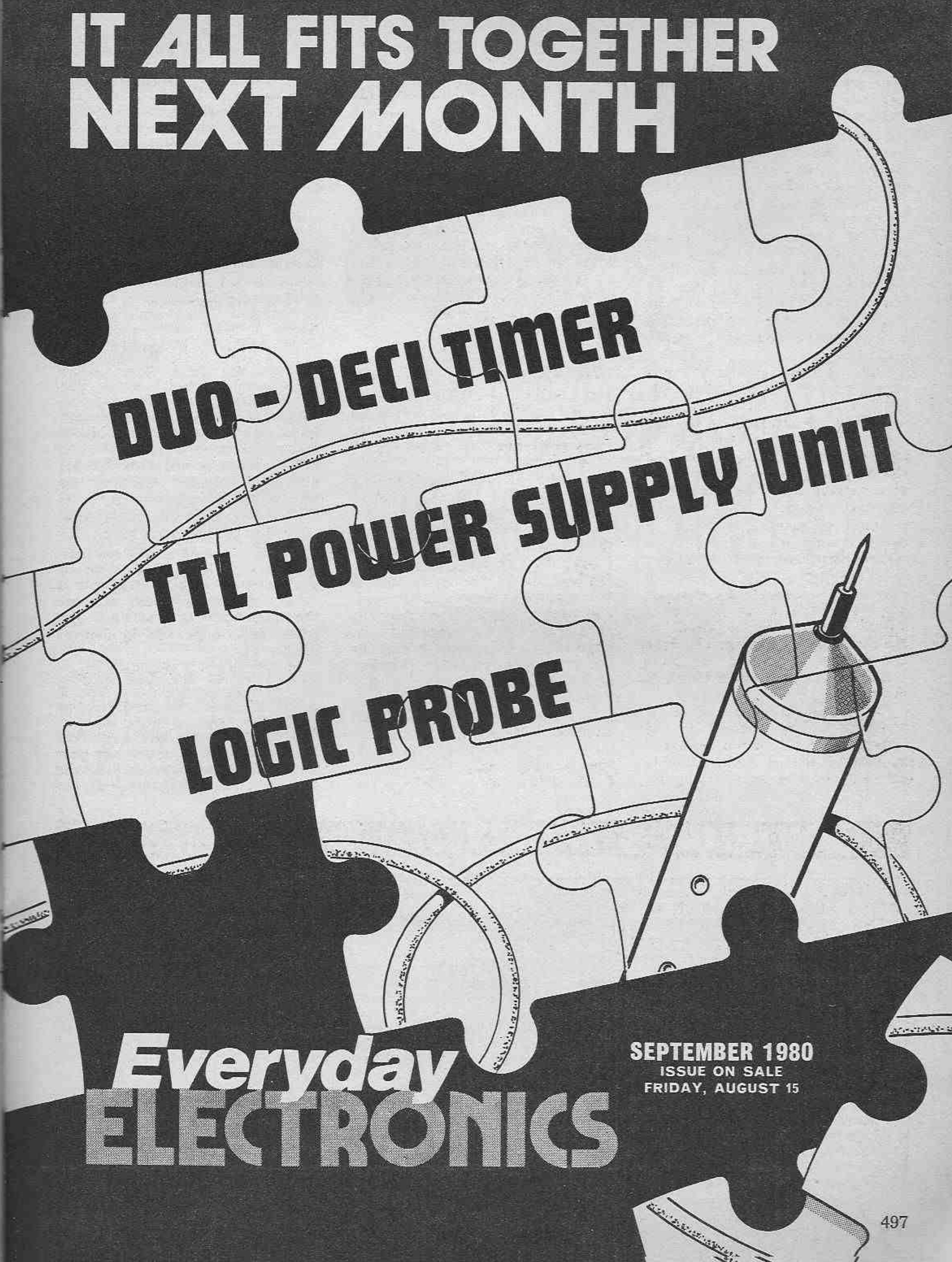
The sort of components that are added will vary, but often they consist of small value capacitors (a few picofarads or so) connected so as to change the frequency characteristic of the stage. Very high frequency oscillations can often be eliminated by using **ferrite beads** in certain lines. These increase the inductance of the lines and act so as to oppose rapid changes in current.

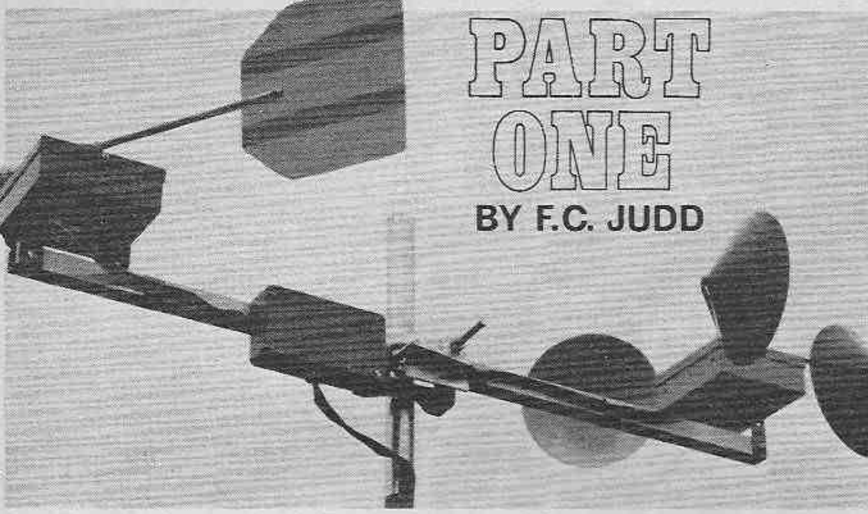
In the end it sometimes comes down to trial and error, but of course designers try to avoid this situation.

Next month: Experiments for Part 11 will appear in the September issue, which will also include the the entire Part 12 of this series.

JACK PLUG & FAMILY...

BY DOUG BAKER

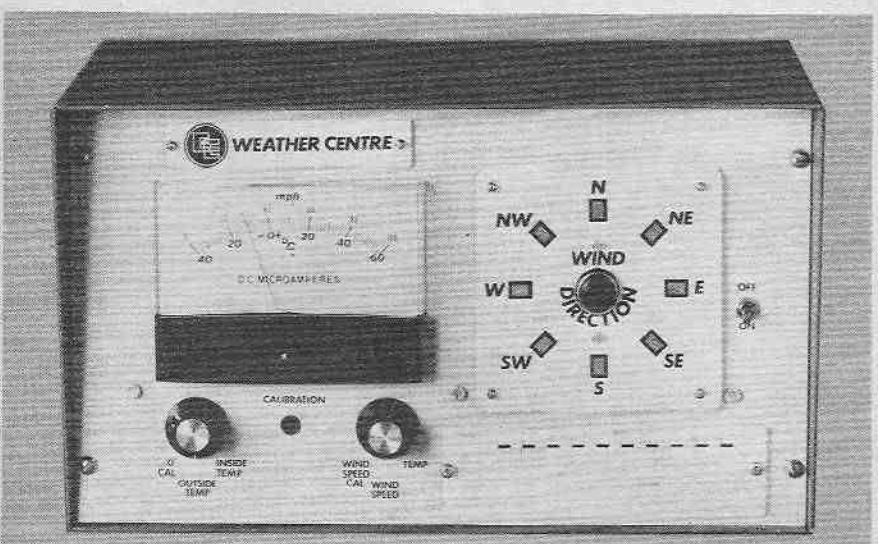

IT ALL FITS TOGETHER
NEXT MONTH
DUO - DECI TIMER
TTL POWER SUPPLY UNIT
LOGIC PROBE
Everyday
ELECTRONICS
SEPTEMBER 1980
ISSUE ON SALE
FRIDAY, AUGUST 15



PART ONE

BY F.C. JUDD

WEATHER CENTRE



METEOROLOGY, like many other sciences, depends on detailed observation and measurement. Unfortunately for the amateur weather watcher, this means either using precise but expensive recording equipment, or the rather less reliable method of thermometer and wet finger.

The Weather Centre described here will give the user a reliable indication of wind speed and direction and also temperature, both interior and exterior, at reasonable cost. Schools and colleges should find the unit very useful in helping them to complete the practical side of their meteorological courses.

Although the circuitry may appear a little complex, this is only made so by the switching involved to obtain temperature read out from two different sensors and also wind speed with one meter.

Naturally, some mechanical work is necessary in making the anemometer and wind direction indicator, as can be seen in the photographs, but this has been simplified as much as possible and each unit was made with only an electric drill and ordinary metal work tools such as a hacksaw and files.

The cost of the system has been kept to a minimum by adopting an analogue readout for temperature and wind speed. The fairly large extra cost involved by having digital readout was considered not to be worthwhile. The system permits indoor and outdoor temperature over the range −40 to +60 degrees Celsius, wind speed up to 100 m.p.h. and wind direction with a 16-point indication.

BLOCK DIAGRAM

The Weather Centre can be broken down into several distinct and separate stages, as can be seen in the block diagram, Fig. 1. There are two temperature detectors, one for internal temperature, one for external, which produce a d.c. voltage proportional to the temperature being observed. These are connected via a selector switch to a d.c. amplifier and from there the signal voltage passes via another selector switch to the meter.

Another section of the unit deals with wind speed indication. Here we have a beam of infra-red light passing from a special l.e.d. to a special phototransistor, in between which, is a disc containing a number of holes. This disc, which is attached to the same shaft as the rotating anemometer cups, interrupts the light beam causing a series of pulses of light to fall on the phototransistor. This in turn produces a series of electrical pulses, the frequency of which is proportional to the speed of rotation of the disc and hence the wind speed. These pulses are processed and arrive at the meter where they are integrated and can be directly measured.

The final section of the unit is the wind direction indicator. This consists basically of a set of switches connected directly to a corresponding set of l.e.d.s on the front panel. These switches, which are in fact reed relays, are activated by a magnet attached to the wind vane shaft. There is no actual signal processing or electronics involved here.

CIRCUITRY AND SYSTEM

In the full circuit, Fig. 2, the transistors TR1 and TR2 and associated temperature sensing diodes D1 and D7 cater for inside and outside temperature. As each circuit is identical, operation for TR1/D1 only will be explained. TR1 is a *pnp* transistor used as a constant current source in the bridge circuit formed by itself, D1, and the network R4, VR1 and R5.

Voltage at the collector of TR1 is set at zero by VR1 in conjunction with the diode resistance at a temperature of zero degrees Celsius. The resistance of a silicon diode changes linearly with temperature so at any temperature other than zero degrees, a positive or negative voltage will be produced across R6/VR2. This voltage is d.c. amplified by IC1 and used to drive the meter, ME1.

OFF-SET CONTROL

The meter must be made to read zero degrees at a suitable part of the scale (normally 0 to 100) so that a negative indication (that is a temperature below zero degrees) or positive indication (that is a temperature above zero degrees) can be displayed.

To achieve this the off-set control VR3 is used to set the meter reading for zero degrees. In effect this means that if the selected temperature detector is at zero degrees then a voltage will appear across the meter terminals, the size of which depends on the setting of VR3. The total range of the meter for temperature from either sensor is −40 to +60 degrees Celsius.

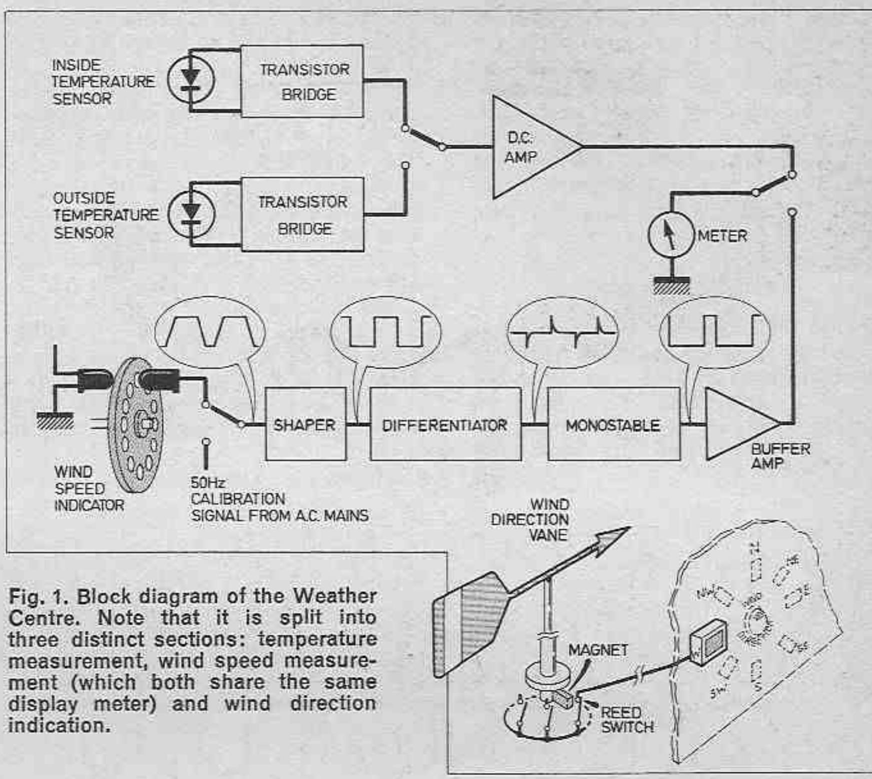


Fig. 1. Block diagram of the Weather Centre. Note that it is split into three distinct sections: temperature measurement, wind speed measurement (which both share the same display meter) and wind direction indication.

COMPONENTS

Resistors

R1	3·9kΩ	R29	12kΩ
R2	5·6kΩ	R30	1·2kΩ
R3	680Ω	R31	120kΩ
R4	1kΩ	R32	10kΩ
R5	68Ω	R33	1·2kΩ
R6	1·2kΩ	R34	5·6kΩ
R7	100kΩ	R35	100kΩ
R8	68kΩ	R36	56kΩ
R9	12kΩ	R37	5·6kΩ
R10	12kΩ	R38	5·6kΩ
R11	5·6kΩ	R39	2·2kΩ
R12	5·6kΩ	R40	2·2kΩ
R13	680Ω		
R14	3·9kΩ		
R15	5·6kΩ		
R16	680Ω		
R17	1kΩ		
R18	68Ω		
R19	1·2kΩ		
R20	220Ω		
R21	220Ω		
R22	200Ω		
R23	180Ω		
R24	58Ω		
R25	100Ω		
R26	6·8kΩ		
R27	6·8kΩ		
R28	1·2kΩ		

All ¼W carbon ± 5%

Potentiometers

VR1	200Ω multiturn trimmer
VR2	100kΩ miniature horizontal preset
VR3	10kΩ miniature vertical preset
VR4	200Ω multiturn trimmer
VR5	100kΩ miniature horizontal preset
VR6	100kΩ miniature horizontal preset

See **Shop Talk** page 481

Capacitors

C1	2200µF 25V elect.	C7	0·1µF polyester
C2	2200µF 25V elect.	C8	100µF 25V elect.
C3	1000µF 25V elect.	C9	4·7nF ceramic
C4	2200µF 25V elect.	C10	100µF 25V elect.
C5	1000µF 25V elect.	C11	0·02µF polyester
C6	1000µF 25V elect.		

Semiconductors

TR1	BC158 *pnp* silicon
TR2	BC158 *pnp* silicon
TR3	TIL78 infra-red phototransistor
TR4	BC108 *npn* silicon
TR5	2N2926G *npn* silicon
TR6	2N2926G *npn* silicon
TR7	BC108 *npn* silicon
IC1	µA741 op-amp 8 pin d.i.l.
D1	1N4148 small signal silicon diode
D2	BZX61C9V1 9·1V 1·3W Zener diode
D3-D6	W005 type 50V 1A bridge rectifier
D7	1N4148 small signal silicon diode
D8	flashing l.e.d. (R.S. type 587-080)
D9	BZX85C5V1 5·1V 1·3W Zener diode
D10-D13	W005 type 50V 1A bridge rectifier
D14	TIL32 infra-red l.e.d.
D15-D22	square-faced red l.e.d. (8 off)

COMPONENTS approximate cost £50 electronics only

Miscellaneous

T1	mains primary with two 12V 150mA secondaries (Bi-Pak type 2025 or similar)
ME1	100µA f.s.d. panel meter (Bi-Pak 1303 or similar)
S1, S3	4-pole, 3-way rotary switch (2 off)
S2	s.p.s.t. mains toggle
S4-S11	dry reed type reed relay with normally open contacts (8 off)
LP1	mains neon indicator with integral series resistor

Case for display unit size 305 × 178 × 178mm (Contil Eyebrow type with front panel and chassis or similar); small plastic containers for D1 and D7; four pieces of 0·1 inch matrix perforated s.r.b.p. board, one 73 × 61mm, one 88 × 32mm, one 117 × 67mm and one 80mm square; one piece 0·15 inch matrix perforated s.r.b.p. board 120 × 95mm; two knobs; Perspex for wind direction indicator panel; magnet to suit reed-relays; 12-way connector blocks (3 off); interconnecting wire; 10-way ribbon cable; single core screened cable; twin-core stranded wire.

Note that the 741 op-amp is isolated from the common earth and the negative supply rail of the remainder of the circuitry. It therefore has its own Zener diode controlled supply of 9V from diode bridge D3-D6 which is divided into ±4·5V. A "set temperature" calibrate facility is also provided (see later).

WIND SPEED INDICATOR

The wind speed indicator circuitry consists first of D14 (an infra-red emitter) and TR3 (an infra-red detector) which are built into the anemometer unit and provide the pulses necessary to drive TR4, TR5, TR6 and TR7.

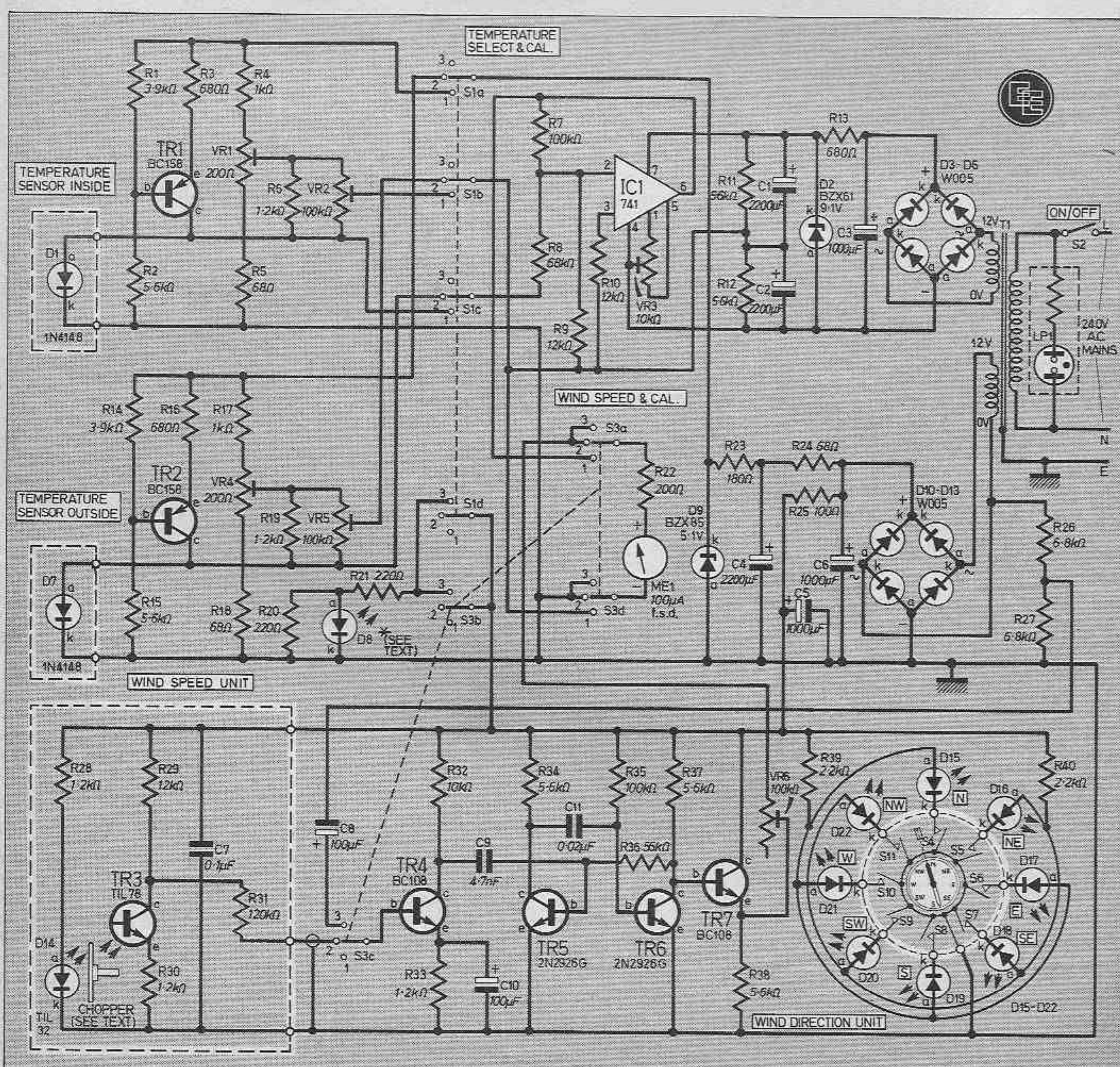
The infra-red beam from D14 is chopped by a rotating disc attached to the shaft of the anemometer cups. This disc has 18 holes around its periphery so the same number of pulses are generated for one revolution of the disc. The pulses picked up by TR3 are fully squared and then differentiated by TR4 (see Fig. 3).

The positive going short duration pulses from this are then used to drive the monostable circuit formed by TR5 and TR6. The output from this is a fairly narrow square wave with a recurrence frequency which is dependent on the speed of rotation of the anemometer. This is then buffered by TR7 and fed directly to the meter ME1 where it is integrated and shown as a d.c. level. Variable resistor VR6 is used as a "zero-adjust" control.

Facility for calibration of the meter for wind speed is provided by using the 50Hz pulses from one of the 12 volt secondary windings of T1. This is taken from the junction of R26 and R27 via C4 and S3c and fed into the base of TR4. The procedure for setting up and calibrating this part of the unit will be given later on.

The 12 volt power supply for this circuitry is derived from the diode bridge D10-D13.

Fig. 2. The complete circuit diagram of the Weather Centre.



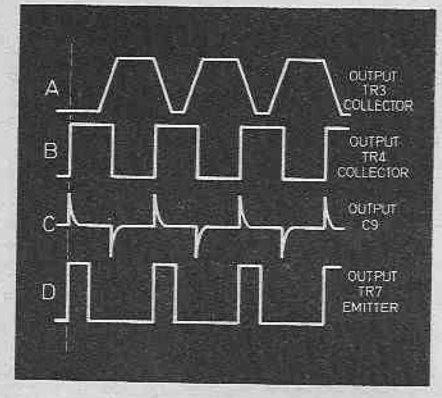
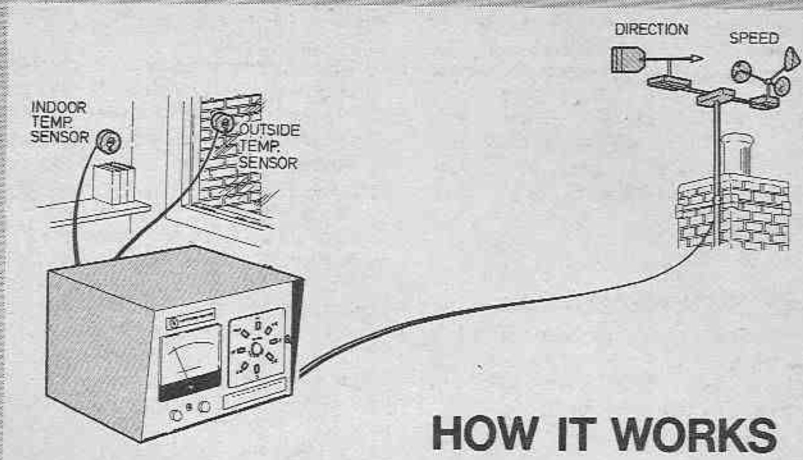


Fig. 3. Sample waveforms from the wind speed measurement part of the circuit. Note how the rough incoming square wave is converted into a narrow pulse train.



HOW IT WORKS

Wind direction is picked up by a wind vane connected to a switching system. There is one reed relay for each of eight compass points and these are actuated by the vane as it swings round in the wind. The reed relays switch corresponding l.e.d.s on and off in the display unit.

To sense wind speed an anemometer is connected to an electronic pulse generator. The frequency of these pulses is proportional to the speed of rotation of the anemometer and are fed to the display unit where they are rectified and displayed on a meter.

To sense temperature, a diode is used as a sensor and connected to a bridge circuit. This measures accurately the resistance of the diode, which is proportional to temperature, and displays this on the meter as a temperature reading.

The display unit features continuous display of all functions, and is installed at some convenient location indoors.

WIND DIRECTION

The wind direction indicator employs a series of reed relays which are actuated by a magnet attached to a shaft of the wind vane. Each reed relay is used to activate either one or two of the l.e.d.s on the instrument panel, these being arranged in a circle to provide eight compass points.

However, the magnet is arranged so that for a point, half way between any two reed switches, both will actuate providing a sixteen compass point readout, that is: N, NNE, NE, ENE, E and so on. Some observations on wind direction will be made later.

POWER SUPPLY

The power supply consists of two separate bridge rectifiers, D3-D6, and D10-D13, each fed from a separate 12V secondary winding on the transformer T1. The rectifier D3-D6 provides a stabilised 9V split rail for IC1. The 12V rail from D10-D13 supplies the wind speed circuitry and wind direction indicators, and also a 5V stabilised rail for the temperature bridge circuits. Zener diode D9 is used to clamp the output at 5V.

The l.e.d. D8 is a self-flashing type and used as a panel indicator to show when S1 or S2 are left in a calibrate position. A standard l.e.d. could be used here if preferred.

DISPLAY UNIT

Like any other weather monitoring system, the Weather Centre has two basic sections—a set of detectors and a display system. The construction of the sensors is described next month but for the moment we will concentrate on the display unit.

CONSTRUCTION starts here

This is housed in a Contil Eyebrow type case, size 305 x 178 x 178mm, and a look at the accompanying photographs will give a good idea of the general layout.

The first stage in construction is to mark up the chassis and front panel for drilling and cutting. The exact location of components is not critical and will depend to some extent on the actual components used.

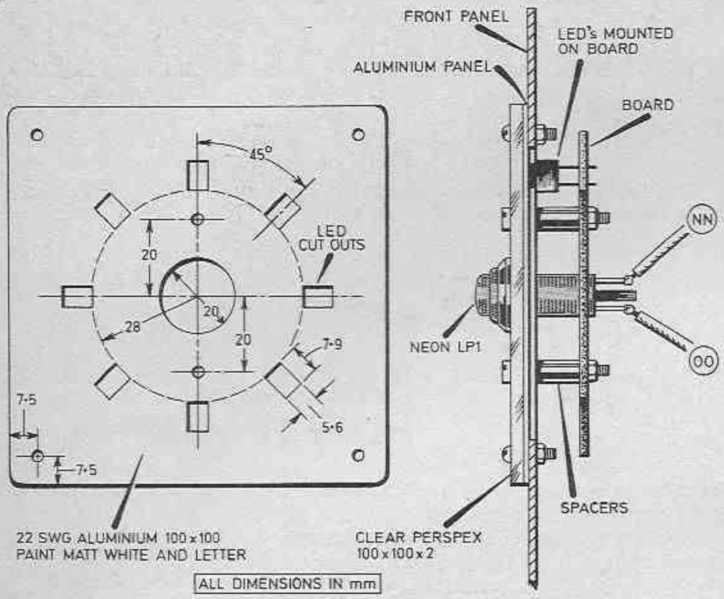
However, the layout used in the prototype works very well and little would be gained by changing it. Note that the wind direction display assembly will need a 80mm square cutout.

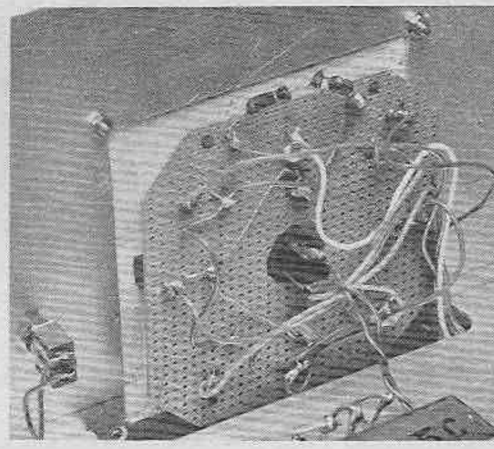
CHASSIS COMPONENTS

Once all the drilling and cutting has been completed, the chassis mounted components, that is the meter, transformer, connector block and switches, can be mounted in their respective positions. Don't bolt the circuit board brackets to the chassis at this stage. You will find it easier to fix the boards in position if the brackets are actually bolted to the boards first.

WIND DIRECTION PANEL

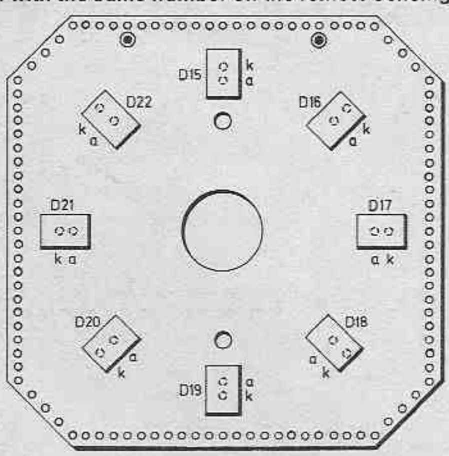
The next job to tackle is the wind direction indicator panel (see Fig. 4). This consists of a front panel of Perspex, a sub-panel of aluminium on which the l.e.d.s are mounted, and a rear panel of plain 0·1 inch matrix perforated board on which connections to the l.e.d.s are made, all arranged in a form of sandwich and held together with 6BA nuts, bolts and spacers.

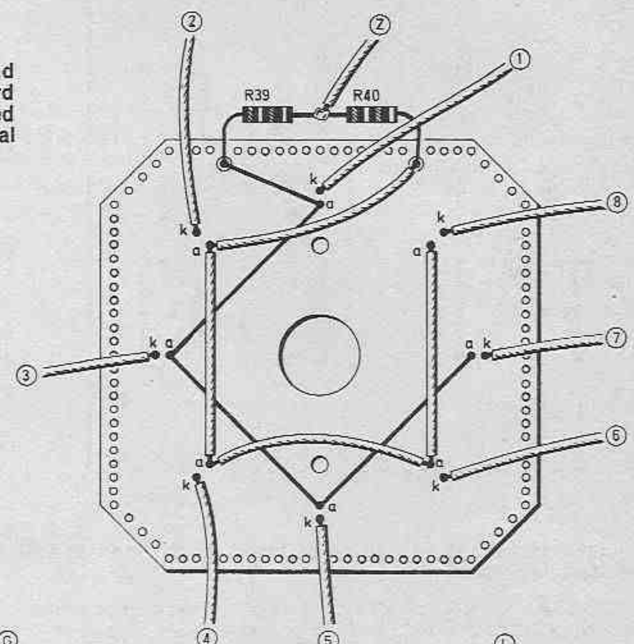




Completed wind direction display assembly in position.

Fig. 4 (above). Cutting details and mechanical construction of wind direction display panel. (below) Layout and wiring of the circuit board section of the wind direction display panel. Note the wires identified by numbers go via the connector block in the display unit to the terminal block location with the same number on the remote sensing unit.





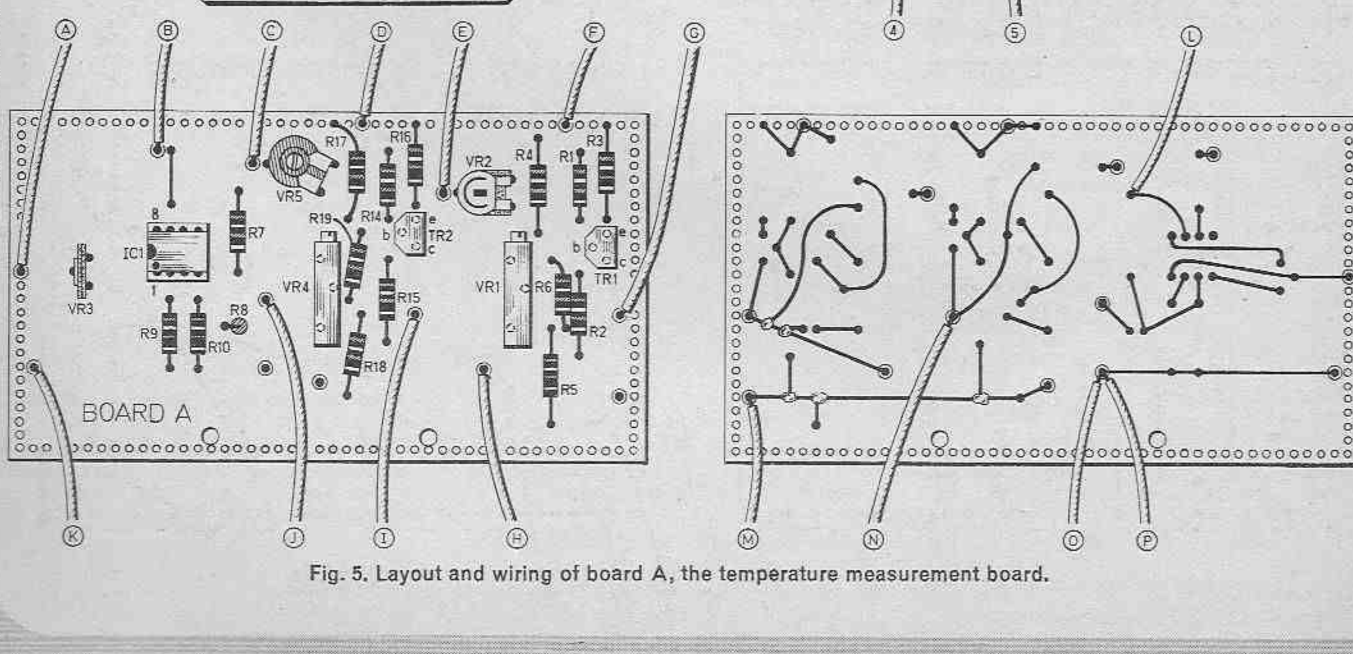
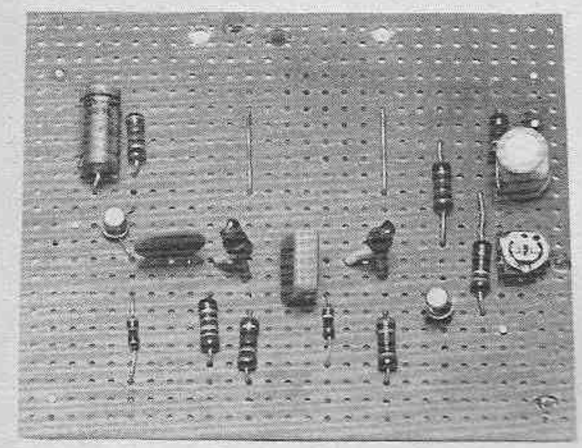
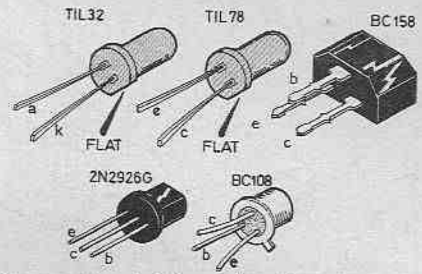


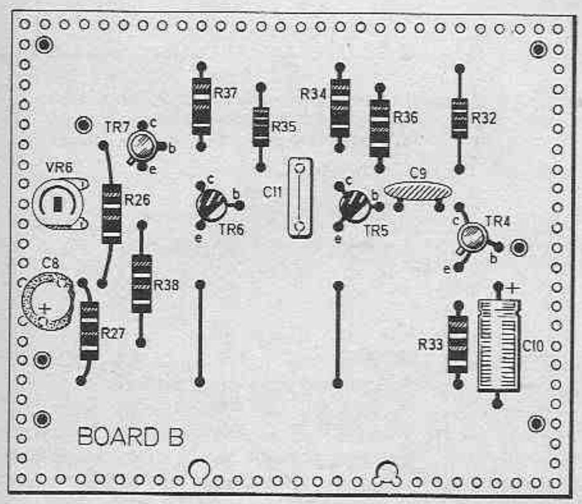
Fig. 5. Layout and wiring of board A, the temperature measurement board.



Topside view of Board B.



Connection details of the discrete semiconductor devices used in this project.



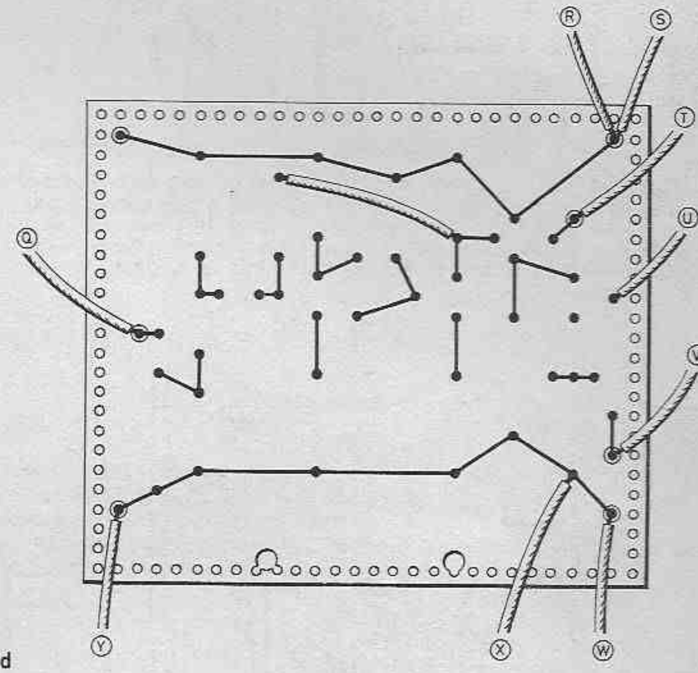
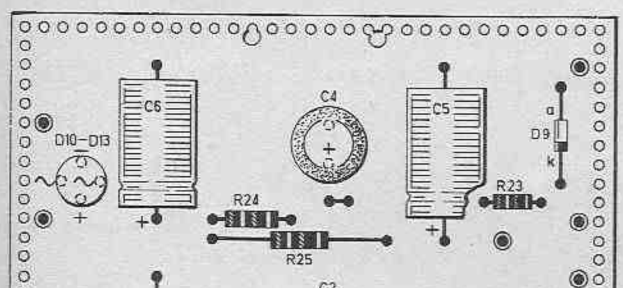
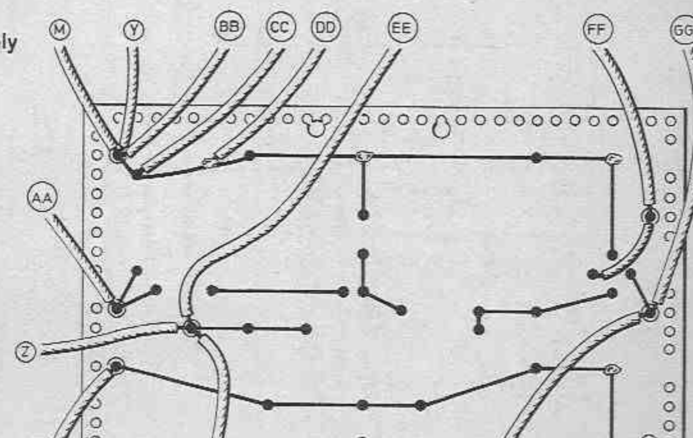


Fig. 6 (above). Layout and wiring of board B, the wind speed measurement board.

Fig. 7 (below). Layout and wiring of board C, the power supply board. Note that this is built on 0·15 inch stripboard.





WEATHER CENTRE

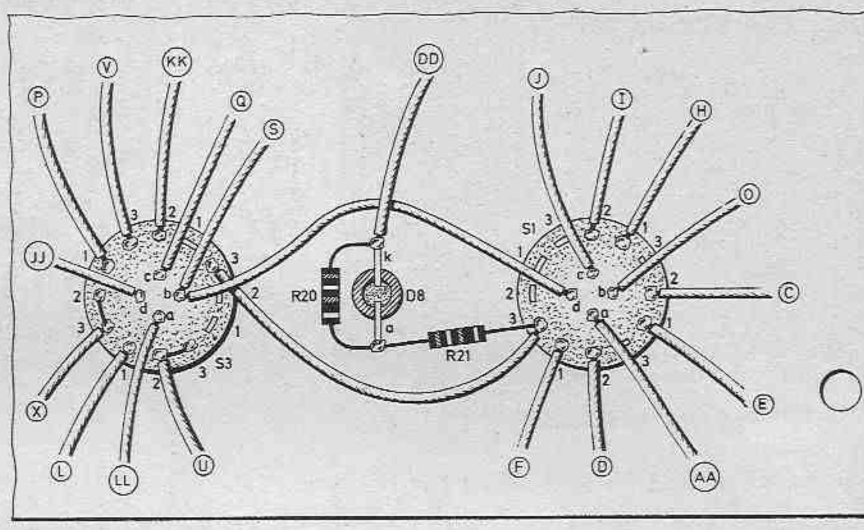


Fig. 8 (above). Wiring details for the selector switches S1 and S2. Note that these are mounted underneath the main chassis. Diode D8 is a flashing l.e.d.

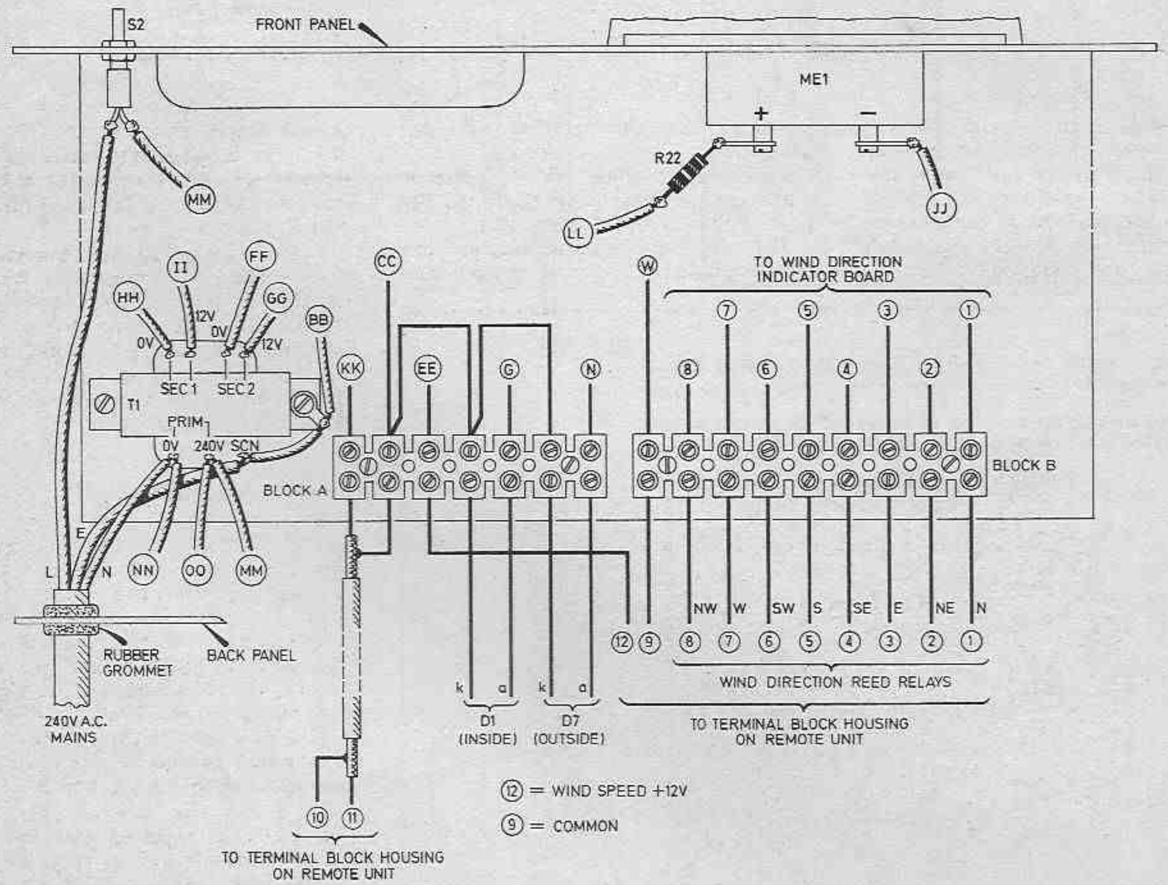
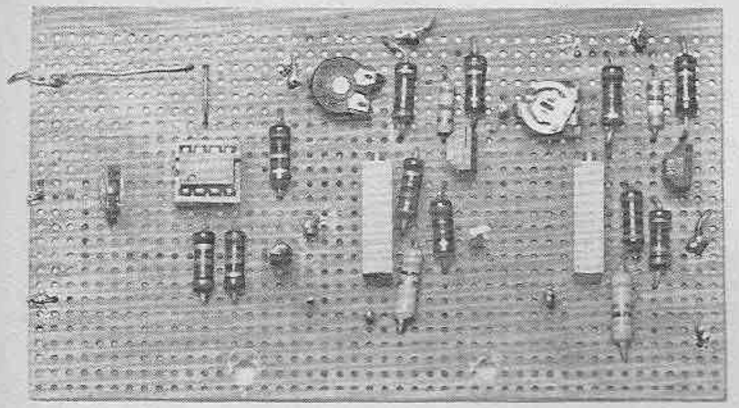
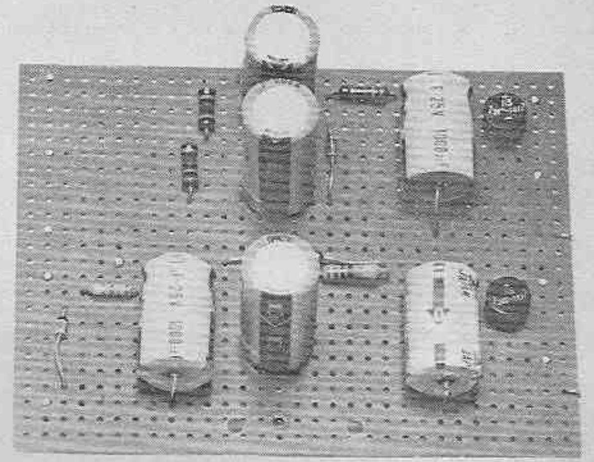


Fig. 9. Layout and wiring details of the chassis mounted components of the Weather Centre. The circuit boards have been omitted for clarity. Note that numbered leads go to the same numbered location at the terminal block on the remote sensor unit.

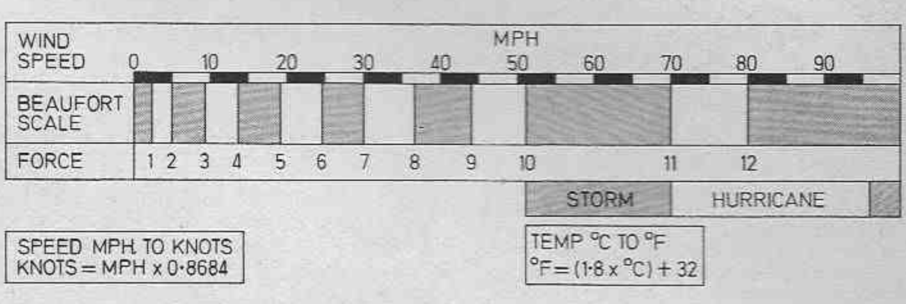


Topside view of Board A.



Topside view of Board C.

Fig. 10. Wind Speed Conversion and information chart. This can be fastened onto the front panel of the completed display unit.

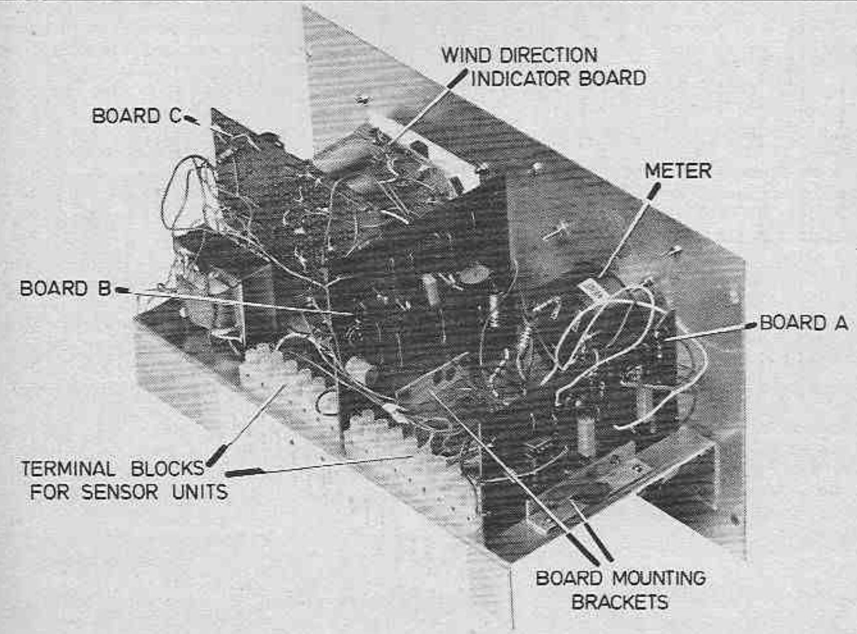


The design and layout of the indicator panel can be clearly seen from the illustrations and the lettering and other finishing is applied directly to the surface of the aluminium sub-panel. As a finishing touch the "mains on" indicator, LP1, is mounted in the centre of this assembly.

Once completed, this indicator panel can be bolted directly onto the front panel of the display unit.

The separate circuit boards can now be made up. Order of construction is not important but at this stage the flying leads should be left off. Full details of component layout and inter-wiring are given in Figs. 5, 6 and 7.

Before mounting the boards onto the chassis, the mounting brackets should be bolted onto the boards themselves. Note that board C has been made up using 0·15 inch matrix board. This is to make it easier to mount the larger components used in this part of the circuit.



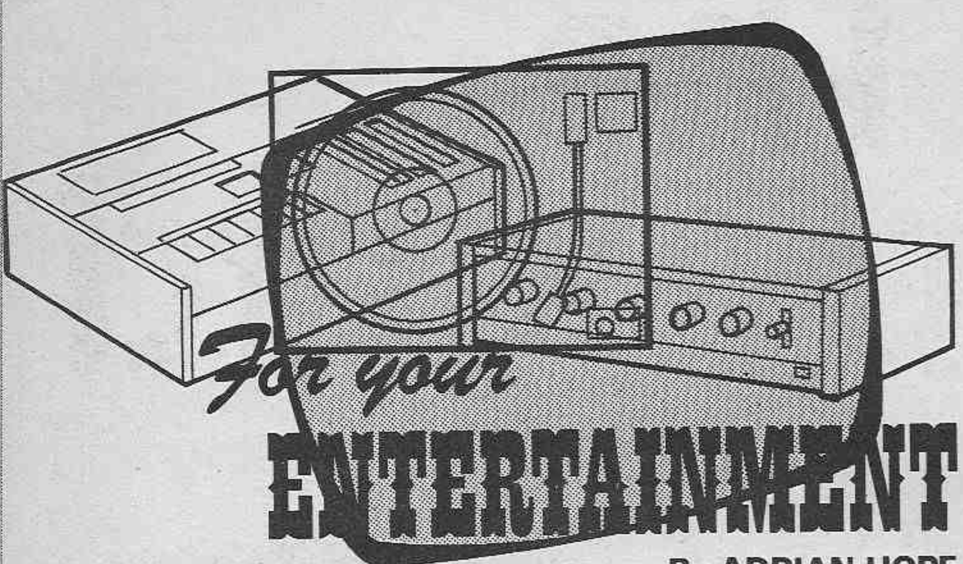
Rear view of completed unit before installing it in its case. The position of each board and other major components is clearly marked.

FINAL ASSEMBLY

Final construction can now begin. Board A should be fixed in position first and wired up to the rest of the chassis mounted components. Other flying leads should also be soldered in position at this stage. Board B is next mounted in position and wired up. Finally, the third board is bolted down and wiring is completed. At this stage it is a good idea to give all the wiring a thorough inspection for errors and bad joints (see Figs. 8 and 9).

To finish the job off, the front panel can be labelled and the wind speed conversion chart (Fig. 10) fixed to the front panel behind a strip of Perspex. This can be cut out of the magazine.

Next month: Building the wind speed/direction and temperature sensors and setting up and using the Weather Centre.



For your ENTERTAINMENT

By ADRIAN HOPE

Digital Radio Service

Despite the much publicised financial problems facing the BBC, the Corporation has very wisely not cut down on research and publicity for its technical achievements. If anything the BBC has recently stepped up the amount of outgoing research information.

The BBC plans to replace Electricity Board "white meters" by switching signals transmitted with radio programmes on the medium and long wave bands have been much publicised. But the system proposed by the BBC for carrying inaudible digital data "piggyback" on v.h.f./f.m. broadcasts has tended to attract very little public interest.

Just such a system is already in use in Sweden, as I found out when I visited the Swedish national radio and TV stations in Stockholm recently. The Swedish system, called PI for Public Information, was developed by the Swedish Telecommunications Administration (Post Office) and makes it possible to transmit an extraordinary amount of data along with a conventional v.h.f./f.m. broadcast.

This data can be used to provide a visual readout on an l.c.d. or l.e.d. display, or to physically control a receiver or tape recorder so that it switches on and off at the beginning and end of a pre-selected programme. The data can also be used to send short text messages, such as traffic information, and even to page citizens anywhere within reasonable reception distance of a v.h.f. transmitter broadcasting ordinary radio.

The data, whether programme identification, text or paging signals, is binary coded, i.e. into "ones and zeros". These one/zero pulses are then used to phase shift a 1·2kHz signal on an extra subcarrier (57kHz) transmitted along with the main mono carrier and stereo sub-carrier.

Quite simply a "one" phase shifts the signal by 180 degrees, while a "zero" pulse leaves its phase unaltered. The bit rate is thus 1200 Baud or bits per second.

In other words it's fairly slow but this doesn't matter because only simple messages need be carried, for instance the name of the station being received, the frequency and perhaps the time of day. Even the paging system relies on very simple messages and since Autumn 1978 Swedish Radio and the Post Office have actually been operating a scheme which has a capacity of a third of a million subscribers.

How it Works

The subscriber to the paging network carries a small receiver, with an l.c.d. or l.e.d. display, which is permanently tuned to the national radio station. But it only responds when a paging message is transmitted on the PI subcarrier which carries an address code that matches a similar code built into the receiver.

Every receiver has a different code so each paging message only triggers the receiver for which it is intended. On receipt of the intended message the receiver bleeps and the display shows either a pre-arranged code, or a specific telephone number which the paged subscriber must call. The whole system is automatic and paging messages can be dialled in from any telephone in Sweden.

If Mr. A wants to get in touch with Mr. B but doesn't know where he is, he goes to the nearest telephone and dials the paging service computer. He then dials the number of Mr B's paging receiver and finally dials either a pre-arranged code (like 1234 to designate "please call your wife") or a telephone number. Provided Mr. B is anywhere in Sweden that can receive ordinary v.h.f. radio programmes his paging receiver will emit bleep tones and he will then proceed to the nearest telephone to answer the paged message.

All this happens while the rest of Sweden simply listens to their v.h.f. radios, completely unaware of the data signals which are being simultaneously transmitted.

Dial-a-Disc Library

As the 70's ended and the 80's began, everyone and their dog had a stab at predicting technology trends over the next decade.

Most long term predictions centred round the high density solid state storage of audio and video material, or the so called "sugar lump" dream. According to this dream all the works of Shakespeare or Beethoven are stored, either magnetically, holographically or in some other unspecified fashion, in a solid state block the size of a sugar lump.

This may one day be possible, but not in the eighties. Much more realistic in the short term is an idea voiced by a European visitor to the Audio Engineering Society convention held earlier this year in London.

Until sugar lump storage, and ready replay access, is feasible, why not keep all pre-recorded programme material in a central or even local library store which the user can dial up by high quality telephone line? That way no one need store any programme material in their own home.

In many respects the idea is an extension of Viewdata, whereby telephone subscribers with a Viewdata TV set can interrogate the Post Office Prestel computer. Of course one obvious objection springs immediately to mind. What happens if two people want the same programme at almost, but not quite, the same time, i.e. you dial up Boulez conducting *The Firebird* five minutes before I do—what happens, do I miss the first five minutes? No because here is the clever part.

All over the world, Post Offices are developing the use of cheap optical fibres instead of expensive copper wires to carry telephone calls. By beaming laser lights down an optical fibre link it's possible to carry a large number of telephone calls at the same time. And this is possible because the optical link has a very wide bandwidth capability, of many megahertz.

Floppy Recording

Imagine the library copy of the *Firebird* recording, probably stored on digital tape or disc. When the recording is dialled up by a subscriber it is automatically replayed in the library at very high speed. So the entire musical performance is fed down the line in just a few seconds.

The optical fibre link has sufficient bandwidth to accept the very high frequency signals created by such rapid replay. At the receiving end, in the home, a high density magnetic recording medium such as a modified computer floppy disc, captures all the incoming information as it arrives at high speed. The disc then replays at much lower speed to produce the *Firebird* at the correct speed in "real time".

There seems no reason why this system shouldn't work or indeed why it shouldn't be commercially viable. All the technology is already available. What's more it could offer the answer to several problems currently suffered by the record industry.

Record buyers would no longer need to suffer with bad pressings or bad quality tapes, because they would no longer actually be buying a record. Instead they would buy the temporary use of an incoming signal from a technically perfect library copy.

The record industry currently claims that it is losing sales through unauthorized copying of commercial recordings. If each subscriber dialling a programme had to pay a royalty for the service, then the record industry would be assured a constant source of revenue.

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RADIO WORLD

By Pat Hawker, G3VA

Power and broadcasting

Broadcasters today make use of an extraordinary wide range of transmitter powers: from under 0·0005kW to over 1000kW. The lowest power units are mostly those for the local u.h.f. relays, many of which have a peak output of only 0·5 watts, with an effective radiated power of from about 6 to 10 watts depending on the gain of the aerial.

The highest power transmitters currently being used for British television are the two paralleled 40kW transmitters installed for each channel radiated from the Crystal Palace. Local radio stations are mostly under 1kW, while the highest power medium-wave transmitter in the UK has been, for many years, the old wartime 600kW "Aspidistra" transmitter at Crowborough, Sussex.

Overseas there are 110kW u.h.f. television transmitters in the United States and some medium and long-wave transmitters in Europe and the Middle East of between about 1000 and 2000kW.

Solid-state transmitters

Most of the modern radio and television transmitters now being installed for local services are of "all-solid-state" design, using modular multi-unit final power amplifier stages. Currently, for ILR services, the IBA are installing Redifon solid-state m.f. transmitters suitable for powers up to 1kW (or 2kW by using two in parallel) and Harris 0·3kW v.h.f./f.m. solid-state transmitters. Last year they put on the Hebrides the highest power all-solid-state u.h.f. television transmitter so far used in the UK—200 watts peak.

But I see that in Japan manufacturers are now developing all-solid-state designs of 5—10kW (m.f. and v.h.f. radio) and 3kW (u.h.f. television).

Experience since about 1974 has shown that the all-solid-state approach offers useful advantages for "unattended" operation since such equipment can almost be considered "fit and forget"—at least for many months at a time. The same trend is beginning to show up also in h.f. amateur radio transceivers.

A number of recent h.f. designs provide up to about 100 watts output from transistors, often incorporating broadband techniques that eliminate the need for any retuning of the power amplifier when changing bands. It also seems that in future we are likely to see similar powers from the more recent VMOS power field effect devices which should prove less vulnerable to mismatched loads, etc. Circuits providing 100 watts from two VMOS devices in push-pull have already appeared.

Power race

Recently the Prime Minister hinted at a big increase in British "propaganda" to be directed at the USSR. A few weeks earlier it had been announced that BBC External Services are to be re-equipped with a number of 500kW h.f. transmitters—double the power of some earlier 250kW units, and many times more powerful than the bulk of the older transmitters.

While this may be necessary politically, it is rather sad news for those concerned with the poor state of the h.f. broadcasting bands and reflects the fact that the recent World Administrative Radio Conference did not produce any firm guidlines on the maximum power of h.f. broadcast transmitters. In an ideal world nobody would need 500kW on h.f.

Much of the present band congestion has been brought about by the "power race", by the many channels carrying the same programme directed at the same targets in the hope that at least one will get through the interference and "jammers" and the general overcrowding. Another conference is to be held in a few years time to try and plan the additional frequencies that have been allotted to h.f. broadcasting, but the chances that this will prove successful must be regarded as slim.

The BBC would, of course, deny that they are engaged in "propaganda" broadcasts but endeavour (with considerable success) to reflect the British "way of life". But then has it not been said that "propaganda is that branch of lying which consists in very nearly deceiving your friends without quite deceiving your enemies"?

Curiously enough, I once had a good reason to be grateful to BBC News for getting things wrong. About August 22, 1944 they announced that Paris had been "liberated" by the French Resistance; in fact this did not happen until August 25.

For rather complicated reasons, this resulted in my arrival in the city very soon after the real liberation, a privilege not accorded to many British service personnel—and I spent six interesting weeks there as a radio operator. Indeed on August 29, while in the Champs d'Elysee, I actually watched a very controversial American-French "victory parade" that afterwards was formally denied (on BBC and in the British and American press) as having ever taken place! It was clearly one of those occasions that merited Churchill's famous phrase that, in wartime, "Truth is so precious she should always be attended by a bodyguard of lies."

Space television

There has been a remarkable growth of public interest in the idea of direct-broadcast satellites since the Home Office announcement that serious consideration is to be given to the implementation by the UK of the 1977 ITU Plan which permits the British to operate up to five channels of television in the 12GHz band from an orbital position of 31 degrees West. France and West Germany are currently planning two three-channel direct-broadcast satellites for a "pre-operational" phase starting in 1983-84.

Comsat in the USA have stated their wish to put up a direct-broadcast satellite (although so far have not filed a formal plan with the FCC) to join the massive use of the 4/6GHz 5 to 10 watt satellites as "distribution links" for cable networks. These are already in full swing throughout North America with some 2000 receive-only terminals and a sprinkling of enthusiasts with equipment capable of receiving directly from these satellites.

Several years ago it was noted that the television situation in the UK is different to that found elsewhere. This is mainly because of our very sophisticated (and unique) u.h.f. terrestrial system which has been designed to provide four different programme channels to over 99 per cent of the population. The American aim of providing cable systems carrying 24 or even 48 programme channels could not easily be met in Europe by direct-broadcast satellites, even if a satisfactory way of paying for such enormous programme choice could be devised.

As others have pointed out: "The question of broadcasting from spacecraft (in the UK) will be one of need, desire or choice, rather than technological possibility or timescale". In other words, with our four-channel u.h.f. system due to be fully implemented in the course of the next five years or so, will we need to rush into orbit before say 1990 or so? The aerospace and electronics industry, however, may feel their future depends on space.

Footprints

There is, of course, the argument that if we don't then British audiences will be won away from the BBC and IBA by the space sirens of France, Germany and Luxembourg, although this argument seems less convincing than it is sometimes made out to be. Still, I suspect that in the months ahead we shall all be hearing a good deal about "footprints" (areas covered from satellites), "overspill" (areas of neighbouring countries that a satellite is virtually bound to cover even if fully conforming to the ITU 1977 Plan), and the European Space Agency's "L-Sat" (the large space platform which, with the help of the later Ariane launchers, could put a fully-equipped direct-broadcast satellite into geostationary orbit).

Meanwhile, by the time these notes appear, the Second *Ariane* launch from French Guiana, on or about May 23, may have put the first of the Phase 3A *Oscar* amateur radio satellites into a highly elliptical orbit taking it up to almost 36,000km above Earth (perigee 200km). If all goes well it will be able to provide long-distance two-way contacts on s.s.b. telephony or morse.

Amateurs will be able to transmit "up" on or about 435·2MHz, with the "down" signals on or about 145MHz. By comparison, all the previous eight *Oscar* amateur radio satellites have been in relatively low orbits, limiting the distance covered and also the time during which the satellite is available on each orbit.

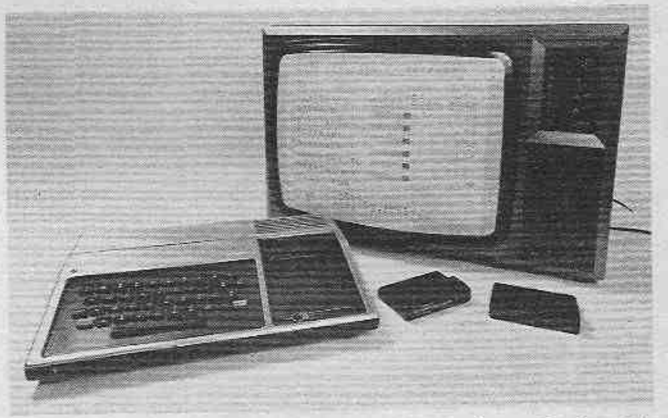
However, it will need a transmitter of medium power and a fairly sensitive receiver. Beacons will operate on frequencies of 145·810 and 145·990MHz.

Everyday News

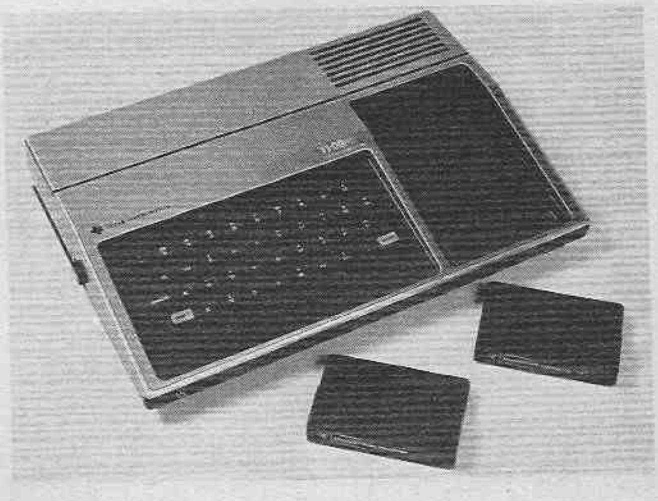
COMPUTER THAT TALKS

A LEADING micro-chip manufacturer, Texas Instruments, announced recently the availability in the UK of a new computer called the TI-99/4 Home Computer. The system is based on the 9900 Family microprocessor, and is the first 16-bit machine to be aimed at the UK domestic market.

Primarily intended for use in the home by *all* the family, this powerful and versatile device will also find many uses and applications in the office, at schools and colleges and in the laboratory.



Shown here is the first talking computer for the home. Designed by Texas Instruments, it brings push-button computing power into the home for education, personal finance, record keeping and entertainment.



The brain of the unit is located in a streamlined main Console fitted with a staggered Qwerty keyboard. Total on-board memory supplied is 42 kbytes divided up as 16 kbytes of RAM and 26 kbytes of ROM; 14 kbytes of the latter are devoted to an extremely powerful TI BASIC interpreter. Additional memory can be added.

Basic/Graphics

The in-built TI-BASIC has full floating point 13-digit expanded BASIC fully compatible with ASCII and the basic specifications of ANSI, has 33 statements, 19 system functions and 14 commands. There are powerful editing facilities incorporated, colour graphics, sound and music, and an equation calculator for maths and complex scientific calculations.

The graphical capabilities need to be seen to be believed. The user is able to specify the colour of graphic characters and screen background from a choice of 16 different colours. All 16 colours can be used on the screen at one time. Video resolution is 192 x 256 producing very clearcut displays and this with the colour abilities makes charts and graphs much easier to read and games more exciting and realistic.

Graphic "priority" facility allows graphics to pass behind or in front of others. Most effective for games.

If your graphical requirements are not met by those contained in in-built ROM, you can easily "paint" your own shapes, drawings, pictures and gameboards by calling a special in-built subprogram.

The in-built sound generator permits tunes to be "composed" when a CALL SOUND program is called up. The notes can cover a five octave range (within 110Hz to 40kHz) with simultaneous 3-note generation to allow chords. A noise source is also included to produce sound effects. All these sounds can be heard through the speaker in the Console.

Even those without programming experience can immediately use the computer to solve problems, use it for personal finance, record keeping, education for the children and entertainment for all the family by using the TI Solid State Software Command Modules. These contain programs in ROM (up to 30 kbytes) and are contained in a cassette-like box which plugs into a slot on the Console. This is not a tape and has no moving parts. The program is available immediately the module is inserted and instructs you what to do. Modules are available for Personal Record Keeping, Statistics, Household Money Management, Pre-school Early Learning Fun, Number Magic, Beginning Grammar, Video Games, and Video Chess. TI are committed to continuing development of "module" programs to meet many needs and interests.

Audio/Visual

The Educational programs for children are of particular interest, where colourful displays are supplemented by sounds and tunes. Even young children after initial instruction can use the machine for learning number, the alphabet and grammar by an audio/visual method.

Accessories for the 99/4 are a pair of 8-position joysticks with action button—ideal for games; a 32-column thermal printer with upper and lower case characters, graphics including user defined; floppy disc storage system; a peripheral adaptor for industry standard printers, remote keyboards, acoustic couplers etc; and last but by no means least, a speech synthesizer.

Speech

The speech synthesiser allows your computer to literally speak by simulating the human voice, in a very clear and precise manner. It has a vocabulary of 373 words which can be used as verbal instructions and prompts within programs, and for message purposes, from typed in material. Plug-in word modules will allow, e.g., medical, legal, technical and other specialised vocabularies to be handled as well as foreign languages.

A noteworthy design feature of the TI peripherals is the elimination of interconnecting cables. Peripherals simply plug into the side of an adjoining one.

The computer can be connected to a video colour monitor or a colour TV set equipped with an NTSC video input connector. These will be available from 99/4 stockists.

The Home Computer Console is guaranteed for a period of 12 months and will cost from £990 including the TV set. The unit can be purchased separately for £650.

... from the World of Electronics

ANALYSIS

JUST LIKE REAL

One of the big boom activities in electronics is the simulator, a faked-up but realistic version of an operational equipment and its functions. The idea is not new. The Link trainer for teaching blind-flying to pilots was popular over 40 years ago. You sat in a hooded cockpit and "flew" entirely by instruments under the supervision of an instructor. If you "crashed" it might cost you the price of a drink for the instructor. But you lived to try again.

Today, with the ready availability of cheap computing power and other electronic aids the flight simulator is virtually indistinguishable from the real thing. Climb into the British Airways simulator in Aberdeen, for example, and you can fly a complete mission by S-61N helicopter to a North Sea oil rig without leaving the ground.

Open the throttles and the engine noise increases. Lift off and watch the ground recede. Six hydraulic jacks provide the sensations of pitch and roll, surge and sway. All the instruments and navigational aids operate as in real life.

Approach to the oil rig platform may be in daylight, twilight or darkness and practice landings made in wind speeds of 50 or 60 knots, typical of tough North Sea conditions. This particular simulator cost £1·8 million and is worth every penny in fuel saved and real aircraft released for revenue earning operations.

You can buy a simulator for almost any activity, both civil and military. Trains, cars, ships, power stations, weapons of all sorts. Mostly they are used for training.

The British Army uses Marconi's Master Gunner for classroom training of forward observation officers. A full colour panoramic view of the battlefield is projected and computer-generated animated targets, shell-bursts, rising dust and smoke are superimposed. Four loudspeakers provide noise effects of own and enemy gunfire. It is highly realistic and recovers its cost many times over in saving on live ammunition.

But so realistic and flexible is the modern simulator that it can also be used for operational research. In an electronic warfare scenario the effects of various types of jamming on one's own or on enemy radars can be assessed and suitable countermeasures developed.

Brian G. Peck

Dental History

A dental management system designed by Racal Information Systems gives dentists instant access on a c.r.t. display to a patient's clinical notes and a graphical reproduction of his or her tooth chart.

The largest system can accommodate 64,000 patient records. A keyboard entry up-dates the record after each treatment.

UK Trinitrons

Production of Sony Trinitron colour TV tubes will start next year in a new plant at Bridgend, South Wales. The new factory will be complementary to the present TV assembly plant and an annual production rate of 150,000 sets is planned.

Sony, although Japanese owned, received a Queen's Award for export achievement this year with over 50 percent of production sent overseas. Sony is expected to employ 1,000 people at Bridgend by 1981.

CHIPS AT WORK

At a recent conference in Birmingham organised by the University of Aston most specialist speakers agreed that unemployment predictions following widespread introduction of the "chip" were grossly exaggerated.

FOUR-COLOUR LED

A light emitting diode that can emit red, yellow, orange or green light has been developed by Sanyo. It uses four layers of gallium phosphate, the colour required being determined by the current through the device.

No Lead Guitar

No trailing leads are needed with electric guitars for users of the Rello TXGT Guitar Radio Transmitter System. The short-range radio is the size of a cigarette packet and can be slipped in a pocket. The equipment is made by Martello Sound, Rye, East Sussex.

Stereo radio on the medium waveband is being made available in the United States following the choice of one of six proposed systems. That chosen was developed by Magnavox, a US subsidiary of the European Philips company.

VHF Up-Date

After 25 years' of service the BBC's first v.h.f. broadcast transmitters at Wrotham, Kent, are being retired and replaced with six new transmitters supplied by Marconi.

Advances in technology over $2\frac{1}{2}$ decades have resulted in the new transmitters being less than one-eighth of the size of the originals and they consume less input power for the same output.

Euro-TV

Europe could have its first commercial TV service by satellite by 1983. Radio Luxembourg is planning a service. So is a Swiss-based consortium in which Britain might have a stake through Thorn-EMI.

Political difficulties could cause delay but few observers doubt that satellite TV giving blanket coverage of large areas of Europe will be with us by the mid-80s—will we need a European TV licence?

SOLAR COOLING

We usually think of solar energy for heating. Now an American company is experimenting with two types of solar-powered air-conditioning cooling units.

These coolers are to be tested in Phoenix, Arizona, where it is anticipated that they will handle 60-70 percent of the building's cooling needs. The experiments are part of a joint US/Saudi Arabian project.

NUCLEAR BODY SCANNING

A new type of medical diagnostic body scanner is under development and will be used experimentally at Hammersmith Hospital, London. If successful it could supplant the conventional X-ray type scanner now in use. Instead of X-rays the new machine exploits nuclear magnetic resonance (NMR) techniques to build up a picture of the condition of body tissues.

The technique of NMR spectroscopy has been used for chemical analysis for years. Now, with advanced super-conducting magnets it can be applied to larger areas such as a human body and will allow better examination of soft tissues as well as being safer for the patient than X-ray techniques.

Audio Millivoltmeter

BY R.A.PENFOLD

FOR SIGNAL MEASUREMENT ON AUDIO EQUIPMENT DOWN TO 10mV R.M.S FULL SCALE

An audio millivoltmeter is really just a form of a.c. voltmeter, and and it only differs from an ordinary multimeter switched to read a.c. volts in that it is much more sensitive.

Whereas the a.c. voltage ranges of a multimeter usually start at a few volts f.s.d. (full scale deflection), the ranges of a millivoltmeter usually start at a few millivolts f.s.d. and often go no higher than a few volts f.s.d. In other words, a millivoltmeter carries on in the high sensitivity direction where a multimeter leaves off.

An a.f. millivoltmeter can be invaluable when dealing with audio equipment, and also when working with many other items of equipment such as electronic musical instruments, radio receivers, ultrasonic systems; in fact any electronic gear which handles small, low frequency signals.

It can be used for such measurements as signal to noise ratio, determining output signal levels, frequency response, and voltage gain. For the last two types of measurement an a.f. signal generator is also required, and these two items of test gear should be regarded as virtually essential for anyone seriously interested in the practical side of audio.

It is not uncommon for audio millivoltmeter designs to be rather complicated, but the design featured here performs quite well despite the fact that it uses only one active component plus a few passive devices.

It has six measuring ranges which are as follows: *Range 1* 0-10mV; *Range 2* 0-20mV; *Range 3* 0-100mV; *Range 4* 0-200mV; *Range 5* 0-1V; *Range 6* 0-2V. The input impedance of the circuit is 1 megohm.

PRECISION RECTIFIERS

A moving-coil meter cannot be used to directly measure a.c. voltages as it will only give a positive deflection if the input signal is of the correct polarity. If an a.c. signal is applied to a moving coil meter, one set of half cycles will produce a positive deflection and the other set will produce a reverse deflection.

In practice the inertia of the meter pointer will prevent it from following each half cycle and it will instead respond to the average input voltage, which is zero since the positive and negative half cycles cancel out one another.

This problem can be overcome by adding a diode in series with the meter, as shown in Fig. 1(a). In theory this is quite acceptable as a theoretically perfect diode will have zero or a fairly low and fixed forward resistance, and an infinite or at least very high reverse resistance.

This would result in the elimination of half cycles of the wrong polarity and would not affect the linearity of the circuit.

DIODE LINEARITY

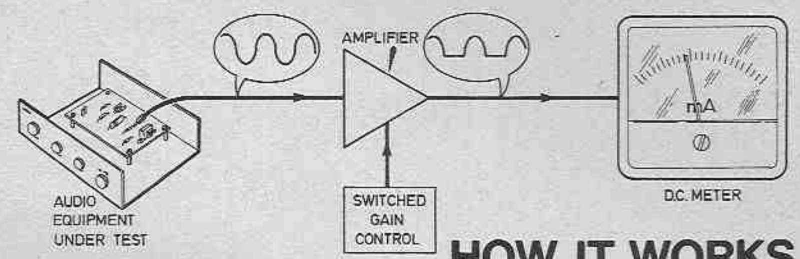
Unfortunately, practical diodes tend to have a resistance which varies with the applied forward bias. At most voltages the forward resistance is quite low, but with only a small forward bias (say a few hundred millivolts or less) this resistance increases considerably.

When measuring fairly high voltages this does not really affect linearity much since there is a reasonably high voltage applied to the circuit for a large proportion of the time. However, when measuring small voltages the non-linearity of the diode will obviously have a profound effect on results.

It is for this reason that some multimeters do not have very low a.c. voltage ranges, and those that do have a separate non-linear scale for the lowest range(s).

The conventional way of overcoming this problem in an audio millivoltmeter circuit is to use the basic configuration shown in Fig. 1(b). Here the diode is included in the negative feedback loop of an amplifier.

The gain of the amplifier without any feedback applied, or open loop gain as it is termed, must be very high. The voltage gain of the circuit with feedback applied, or closed loop gain, is controlled by the resistances of *D1*, *R2* and *R1*. The higher the resistance of *D1* and *R2* in series compared with that of *R1*, the higher the closed loop gain of the circuit.



HOW IT WORKS

The test probes are attached to the appropriate point in the equipment under test and the signal to be measured is fed into the unit. This consists basically of a switched gain amplifier.

Because we are using a moving coil meter, the output signal must also be rectified to d.c. and the amplifier does this internally by chopping off the negative half cycles.

The required gain can be selected using a rotary switch and the output of the amplifier fed to the meter. The amplitude of the signal can then be read off on the correct scale in millivolts.

PRINCIPLE OF OPERATION

The action of the circuit is quite simple. Negative input half cycles have no effect on the circuit as *D1* will block negative output signals from the meter. On positive input half cycles the gain of the circuit will initially be very high because the forward resistance of *D1* will be high, and little feedback will be applied to the circuit.

This results in quite a large rise in the output voltage, and this compensates for the high resistance of *D1*. Once the initial high resistance of *D1* has been overcome, the gain of the circuit falls to a level set by *R1* and *R2*.

Therefore, the higher the resistance of *D1*, the higher the gain of the circuit, and thus a linear relationship between input voltage and meter reading is obtained.

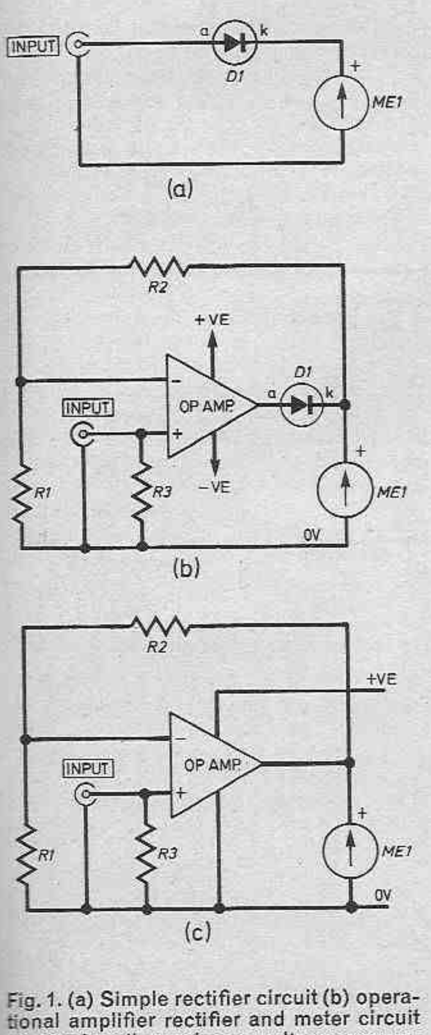


Fig. 1. (a) Simple rectifier circuit (b) operational amplifier rectifier and meter circuit (c) single rail supply a.c. voltage measuring circuit.

SLEW RATE

One problem with this circuit is that because the amplifier has a very high level of gain at the beginning and end of each output half cycle when the resistance of *D1* will be high, the output voltage is called upon to change very rapidly on these occasions, far more rapidly than if it was used as a straight forward amplifier.

The maximum rate at which the output potential of an amplifier can change is known as the slew rate, and is normally expressed in terms of the maximum voltage change that can occur in one microsecond.

Modern operational amplifiers have quite high slew rates, but even so, they usually prove inadequate in this type of circuit at high input frequencies with a resultant loss of linearity.

OP-AMP RECTIFIER

In theory it is possible to use an operational amplifier itself as a precision rectifier using the configuration given in Fig. 1(c). Here the device is used in what is basically a straight forward amplifier, but the usual (for op-amp circuits) dual balanced positive an negative supplies have been replaced by a single positive supply.

On positive input half cycles the circuit operates in the normal way, but on negative going half cycles there is no effect on the circuit. The output cannot go negative of the 0V rail as there is no negative supply.

Thus the circuit operates as a precision halfwave rectifier, and it is this configuration which is used in the audio millivoltmeter described in this article.

THE CIRCUIT

The complete circuit diagram of the Audio Millivoltmeter appears in Fig. 2. The non-inverting (+) input of IC1 is biased by R1 to the earth rail voltage, and this component sets the input impedance of the circuit at about 1 megohm.

It is normal for equipment of this type to have a high input impedance so that it has little loading effect on any circuit to which it is connected. C1 provides d.c. blocking at the input.

The output of IC1 connects to the meter via VR2, R11 and S2, and VR2 enables the sensitivity of the circuit to be set to the correct level. When S2 is in the BATTERY CHECK position the meter is connected across the supply lines via R12, and the latter converts the meter to a 10 volt f.s.d. d.c. voltmeter. This enables the battery condition to be checked.

VOLTAGE GAIN

The voltage gain of IC1 (closed loop) is determined by the feedback resistors, and is equal to the resistance

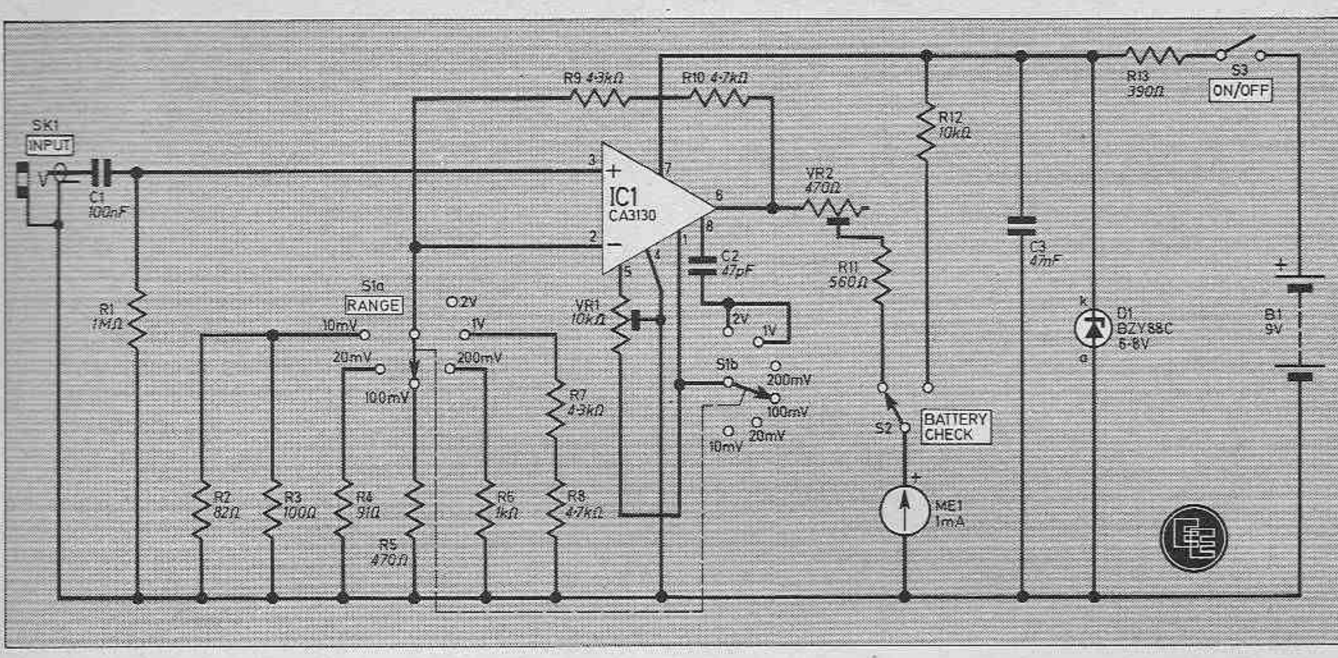


Fig. 2. Complete circuit diagram of the Audio Millivoltmeter.

between the output and inverting input plus the resistance between this input and earth, divided by the resistance between the inverting input and earth.

Thus in the 1V position of S1 the circuit has a gain of two. In the 200mV position the gain is ten times, the gain being increased by a factor of five, and the sensitivity being similarly increased. By having six switched gain levels the six measuring ranges are produced.

Capacitor C2 is a compensation device and this is needed in order to aid the stability of the circuit. This is only needed on the 2 and 1 volt ranges, and is switched out of circuit by S1b on the other ranges. Leaving it in circuit on these ranges would result in a comparatively poor high frequency response.

The frequency response of the unit is flat over the audio frequency spectrum on any range, and on most ranges it extends well beyond the upper audio limit (about 20kHz).

Capacitor C3 is needed in order to aid stability and decouple the power supply.

OFFSET VOLTAGE

Theoretically, under quiescent conditions the output will be at the 0V supply potential, but in a practical circuit a small output voltage or 'offset' voltage is produced.

This voltage is only a few millivolts at most, but is multiplied by the voltage gain of the circuit and is therefore quite substantial on the most sensitive ranges. This would obviously produce a strong indication on the meter unless steps were taken to compensate for the offset voltage.

Preset VR1 is what is known as an "offset null control", and this can be used to remove the offset voltage and zero the meter. The offset null circuitry is affected to some degree by variations in the supply voltage, and so a simple zener regulator circuit consisting of R13 and D1 is used to stabilise the supply voltage.

It should perhaps be pointed out that most operational amplifiers will not operate in this circuit since they cannot operate with their input and output terminals at and very close to the negative supply rail. Do not use a substitute for the CA3130T.

COMPONENTS

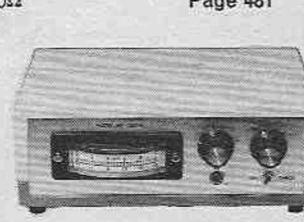
Resistors

R1 1MΩ
R2 82Ω
R3 100Ω
R4 91Ω
R5 470Ω
R6 1kΩ
R7 4·3kΩ
R8 4·7kΩ
R9 4·3kΩ
R10 4·7kΩ
R11 560Ω
R12 10kΩ
R13 390Ω
All ¼W carbon ± 2% or better

See Shop Talk Page 481

Potentiometers

VR1 10kΩ subminiature horizontal preset
VR2 470Ω subminiature horizontal preset



Capacitors

C1 100nF polyester
C2 47pF ceramic
C3 47nF ceramic

Semiconductors

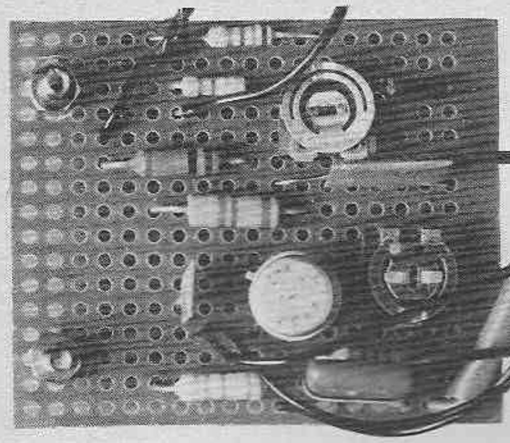
IC1 CA3130T operational amplifier
D1 BZY88C6V8 6·8V 400mW Zener diode

COMPONENTS approximate cost £14

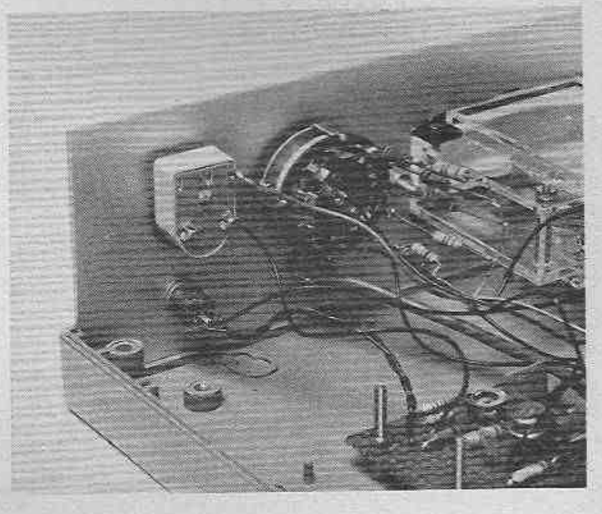
Miscellaneous

ME1 1mA f.s.d. moving coil meter (see text)
S1 2-pole, 6-way rotary switch
S2 s.p.d.t. miniature toggle
S3 rotary on/off
SK1 3·5mm jack socket
B1 9V type PP3
Case, 205 × 140 × 75mm, Verocase 75-1411-D or similar; plain 0·1 inch matrix s.r.b.p. board, 16 × 18 holes; control knobs (2 off); PP3 battery connector; connecting wire; screened cable.

Audio Millivoltmeter



Top view of circuit board.



Close-up of front panel switches.

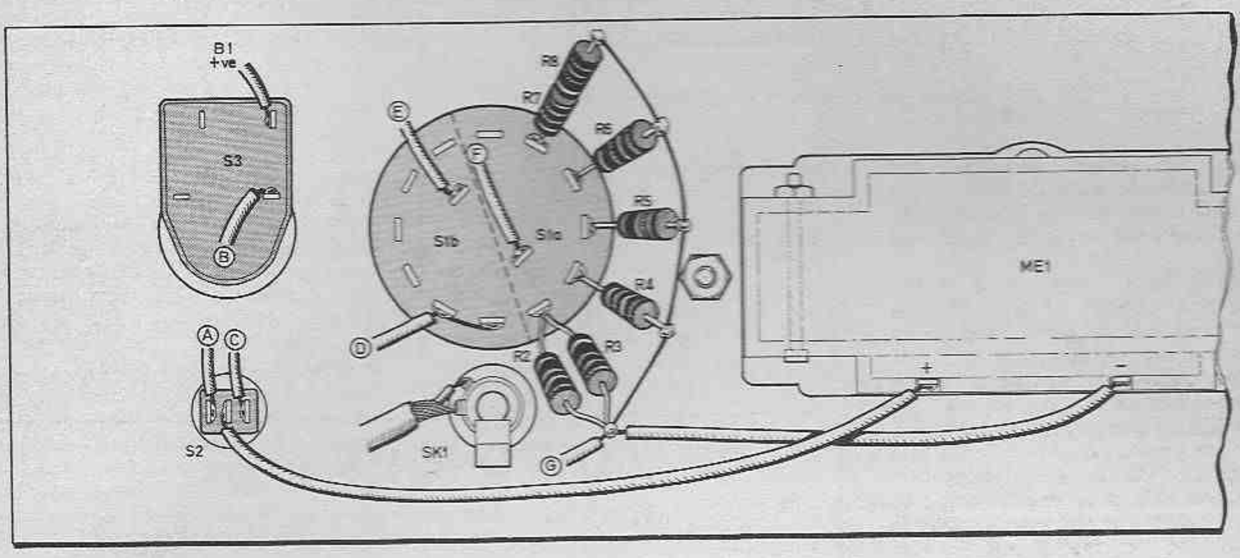
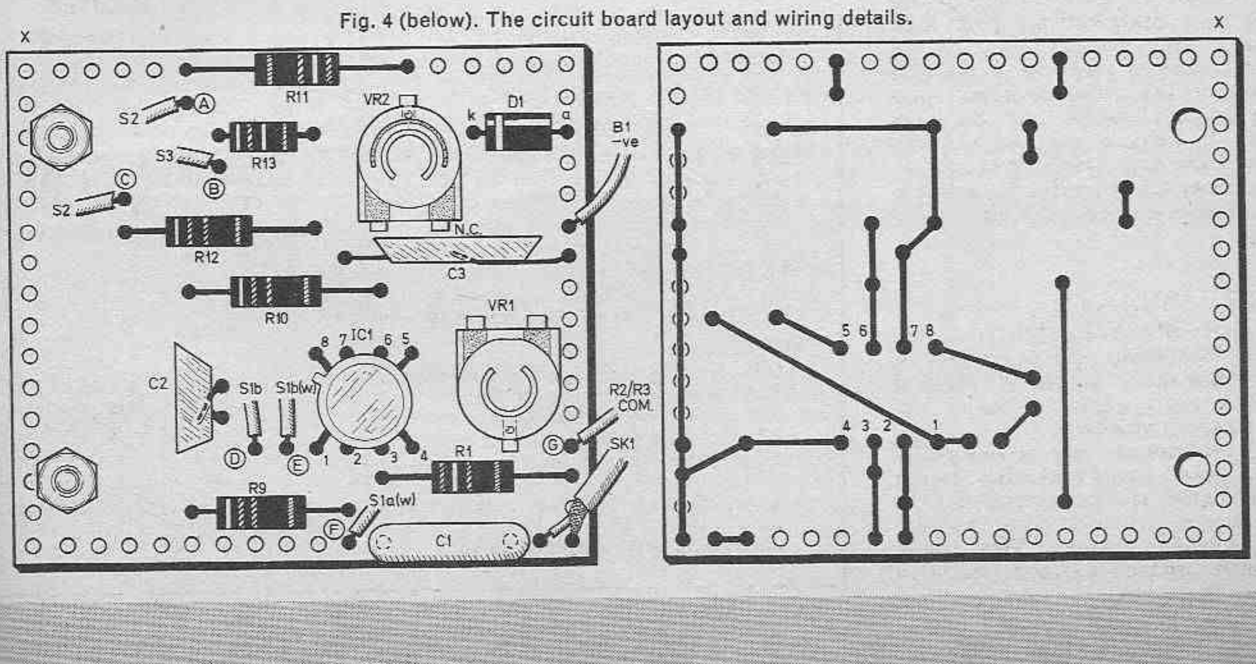


Fig. 3 (above). Wiring details of the front panel.

Fig. 4 (below). The circuit board layout and wiring details.



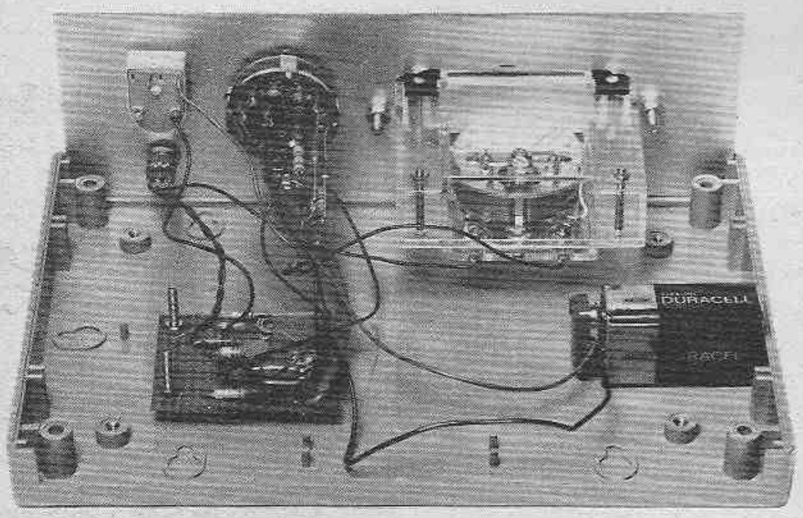
CONSTRUCTION starts here

CASE

A Verocase type I (205×140×75mm) or similar cabinet will provide a suitable housing for this project. A case of all metal construction would have the advantage of screening the circuitry, but this is by no means essential.

Start by cutting out a panel having 16×18 holes using a hacksaw and then drill the two 3·2mm diameter mounting holes. Next begin to mount the components in the positions indicated in the diagram. Bend their lead-out wires and tags flat against the underside of the panel, cut the lead-outs to length, and solder them together to conform to the underside view of Fig. 4. Continue this process until the panel is completed.

Resistors R2 to R8 are not mounted on the panel, but are wired direct to S1, as shown in Fig. 3. Next the point to point wiring is completed, as detailed in Figs. 3 and 4 and finally, the component panel is mounted on the base of the cabinet to the rear of the controls using 6BA or M3 nuts and bolts. Note that a screened lead should be used to connect the input socket to the component panel.



Interior view of the unit from the rear.

The front panel layout can be seen from the accompanying photographs, but is not critical. An edgewise panel meter is used on the prototype, but any moving coil meter of the correct sensitivity should be suitable, provided it is physically small enough to fit the case selected of course.

Whatever type of meter is chosen, it will require a large cutout which can be made using a fretsaw or a needle file. The input socket is a 3·5mm jack type.

CIRCUIT BOARD

Much of the circuitry is wired up on a 0·1 inch plain matrix board, and details of this are given in Fig. 4. It is strongly recommended that this layout should be used as component layout is quite critical, and poor design work here could easily lead to instability in the finished unit. Stripboard is far from ideal for this type of circuit and should not be used.

ADJUSTMENT AND USE

At the outset VR1 should be adjusted in an almost fully anticlockwise position, and VR2 should be put in a fully clockwise setting. An ordinary screened test lead with suitable prods is connected to the input, and initially the two test prods are shorted together. When the unit is switched on there should be no deflection of the meter.

Set S1 to the 10mV range and slowly adjust VR1 in a clockwise direction. At roughly a midpoint setting of VR1 this should begin to produce a positive deflection of the meter pointer. The potentiometer should be adjusted as far as possible in a clockwise direction without any significant deflection of the pointer being produced.

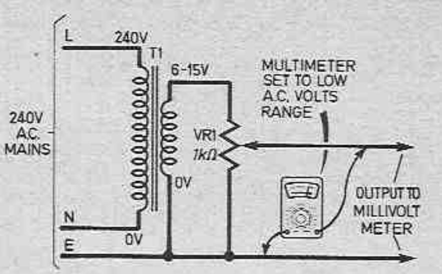


Fig. 5. The circuit for obtaining a calibration signal from the mains.

In order to calibrate the unit an a.c. signal of known amplitude (and which falls within the coverage of the millivoltmeter) is required.

Such a signal could, for example, be obtained from an a.f. signal generator set for sinewave output at a frequency of a few hundred hertz. If the signal generator has some form of accurate output level calibration, it is simply a matter of adjusting it to produce an output of say 1 or 2 volts r.m.s., switching S1 to the appropriate range, coupling the signal generator to the millivoltmeter, and finally adjusting VR2 for a full scale reading on the meter.

If the signal generator does not have suitable calibration, the output amplitude can be set to the required level with in aid of a multimeter set to a low a.c. volts range and used to monitor the output from the signal generator.

If a suitable signal generator is not available it is possible to use some other signal source. For instance, a mains transformer having a secondary voltage of something in the region of 6 to 15 volts can be used in the manner illustrated in Fig. 5, where VR1 is used to set the required output voltage.

Do *not* try to obtain a calibration signal direct from the mains. This can be very dangerous.

On the prototype a 0 to 20 scale was added to the meter for greater convenience when taking readings on the 20mV, 200mV, and 2V ranges, but as it is quite easy to convert the meter reading into terms of actual voltage anyway, this is not essential. ⌑

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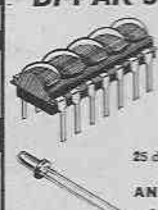
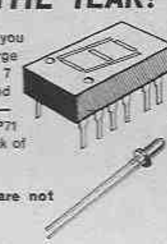
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OHM'S LAW

THE current that flows through a circuit is proportional to the voltage applied to that circuit and inversely proportional to the total resistance in that circuit—as contributed by components and wires.

This is a most important fundamental law governing all electric and electronic circuit theory. It is known as **Ohm's Law.**

Voltage is measured in volts (V).

Current is measured in amperes (A).

Resistance is measured in ohms (Ω).

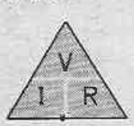
Voltage is a term that expresses potential difference. The potential difference (p.d.) existing between the terminals of a battery is measured in volts.

When a current is flowing through a circuit, a p.d. is developed across any component that has resistance, and this is measured in volts.

If a 2 ohm resistor is connected across a 9 volt battery the current flowing through the circuit will be $9 \div 2 = 4 \cdot 5$ amperes.

(A resistor is a component that has a definite known value of resistance. It is the most widely-used type of electronic component.)

The relationship between volts, amperes and ohms is clearly seen if we draw a triangle:



These capital letters are the **symbols** for voltage (V), current (I) and resistance (R). Note: the **units** in which these quantities are measured are as detailed after the second paragraph of this article.

If two quantities are known the third can be easily calculated. Cover the symbol of the unknown quantity with the finger and then the required formula will be exposed in the triangle:

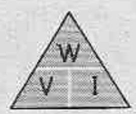
$$V = I \times R$$
$$I = V \div R$$
$$R = V \div I$$

POWER

The power developed in any circuit is measured in watts (W), and is the product of the voltage and the current.

So $9 \times 4 \cdot 5$ equals $40 \cdot 5$ watts.

A similar triangle can be drawn for watts, volts and current:



$$W = V \times I$$
$$V = W \div I$$
$$I = W \div V$$

PRACTICAL VALUES

A 9 volt battery is commonly used to provide power for electronic circuits. Typical resistor values are, however, much larger than the 2 ohms used in the example above. Values generally range from several hundred ohms to tens of thousands of ohms.

Some typical values are: 100, 220, 330, 680, 1,000, 1,500, 47,000, 100,000, 1,000,000 ohms. This is only a small selection from the large range of "preferred" values which are readily available.

The currents flowing through typical electronic circuits are thus very small, and sub-units of the ampere are used, such as milliamp (mA) which is one-thousandth of an ampere.

Sometimes it is necessary to employ an even smaller sub-unit, like the microamp (μA) which is one-thousandth of a milliamp.

TABLE 1

Ohms	Current	
	mA	μA
100	90	90,000
1,000	9	9,000
10,000	0·9	900
100,000	0·09	90
1,000,000	0·009	9

Table 1 shows the ohms-current relationship with the current from a 9V battery expressed both in mA and μA.

In practical circuits there will usually be several resistors or other circuit devices with ohmic properties, all of which influence or determine the actual current flowing.

MULTIPLES AND SUBMULTIPLES

Like current, voltages and wattages are sometimes expressed as submultiples of the Unit:

millivolt (mV) one-thousandth of a volt

milliwatt (mW) one-thousandth of a watt.

Resistance values are frequently expressed as *multiples* of the Unit:

kilohm (kΩ) 1,000 ohms

megohm (MΩ) 1,000,000 ohms

WORKSHOP MATTERS

By Harry T. Kitchen

Good Practice

During constructional work most of us will have sat and stared at the work and wondered what to do next; except with the very simplest of circuits we will run out of inspiration. Or, perhaps, we have built up a circuit and have failed to get it to work.

Sometimes the cause is obvious; at others it is not. This month I intend to deal with a few dodges that can be most useful.

Shock Treatment

You have a circuit board in front of you, it little matters what sort. You slip component wires into the holes provided and you snip them off to the requisite lengths.

You may well think that that is the end of the matter. But is it? Where did the surplus bits fly off to? They can travel surprising distances and at surprisingly high speeds. They required, in comparative terms, large amounts of energy to propel them so far and so fast.

What of the other ends, those left on the components? They, too, were subjected to the same amount of energy, but in the opposite direction. They couldn't move—well, perhaps not much—and so had to absorb that energy.

Frequently, and most fortunately, absorbing that energy does the component no harm. But what if the component cannot safely absorb that energy and is damaged? You will be left wondering why your circuit does not work; perhaps immediately; perhaps some time in the future.

Components most at risk are those having glass/metal junctions or seals, and the shock of the wires being snipped may fracture these seals. Circuit failure depends upon the rate of ingress of air into the device—remember these are either evacuated or are filled with an inert gas. A pair of pliers interposed between the device and the wire cutters will absorb the energy, and should always be used with semiconductor devices, or wherever there is doubt.

Heat Shunts

From shock shunts we come to heat shunts. True, the use of these is fairly well known, but are they widely used? I believe not.

Silicon devices, with their high operating and storage temperatures have lulled many into a false sense of security. Why use a heat shunt when the junction can operate at 180°C, and the device can be safely stored at 200°C?

If you have an iron operating at the correct temperature, and your soldering technique is impeccable, then I believe you can probably dispense with a heat shunt. By "impeccable" I mean that the iron is applied to the component for the absolute minimum amount of time, with the minimum amount of soldier required for a good clean immaculate joint.

If your iron is "cold", i.e. takes an appreciable amount of time to melt solder, or your joints are dirty or greasy so that the solder does not take, then you stand an excellent chance of ruining your component through excess temperature applied for an excessive length of time.

Silicon devices are not alone in requiring protection from soldering irons. Almost anything used in constructing an electronic circuit can be damaged by excess heat applied too long. Copper pads will lift off p.c.b.s, resistors values will change, capacitors may become open circuit or short circuit. It behoves us, then, to take care whilst soldering, and the use of a heat shunt is I believe good practice at all times.

Boards and Sub-assemblies

Most circuit boards require attachment to something; so there will be holes in them. If not, it is simple to drill three or four holes where they will not interfere with the circuit, nor appear too unsightly.

Drill these holes, say, 6BA clearance. Then insert bolts from the copper, or conducting side, and add the nuts from the component side.

If the bolts are longer than the deepest component, the board can be manipulated in all directions and will be protected by the bolts. When the board is complete, these bolts can be removed.

Sub-assemblies are much used in industry, and with good reason. They can be built up where convenient, tested, and finally joined together to produce the whole—whatever that may be. In our case it means that it is safer to build up a complex circuit on separate boards, and then to join these together to form the complete circuit. Not only can individual circuits be tested more easily, but rectification or modification is more easily effected.

If you adopt this philosophy, try to achieve a situation where the individual boards can be joined together for final testing before assembly into its final cabinet, as there is nothing so annoying as connecting a number of boards into a cabinet, perhaps requiring considerable manipulative skill in the process, only to find that something does not work as planned. Taking this a stage further, the ideal situation would be one where the circuit boards could be connected up, tested, and then assembled into the cabinet en bloc.

This is one of those areas where, if you are doing all your own work, it pays to take your time, to think it out on paper. An error on paper is easily erased; on hardware it is not so easy.

Static Charge

I recently saw a colleague, one whom I had expected to know better, remove a chip from its protective conductive foam and pass it round for examination.

He was surprised when his circuit didn't work; I was not, for it was one of those that contained an input stage utilising IGFET'S (Insulated Gate Field Effect Transistors).

Some chips are as tough as old boots, others are not. Amongst these are the IGFET family.

Man-made fibres abound in our world and as a consequence we carry around with us static charges, charges that will easily puncture gates of such devices and render them quite useless. If you come across these devices, leave them in their protective conductive foam packing until the very last moment.

Pick each device up by the ends, being careful not to touch any pins, and insert it into its sockets—being wise you will, of course, use one, for to solder such a device is to compound your error. It is possible to purchase special insert tools, but unless you are into such devices in a big way they are hardly worth while.

It is a wise precaution when handling any such devices to ensure that your soldering iron is a low leakage type, well bonded to a good earth. Similarly, you yourself should be bonded to earth. You are not expected to strap your ankle to earth! but you can, and should, frequently touch a good earth to enable static charges to leak harmlessly away.

Use Sockets

It is good practice, to use sockets into which i.c.s can be plugged, rather than soldering them into position. It enables suspect i.c.s to be easily changed, whilst the i.c. itself is not subjected to soldering iron temperatures, for heat shunting can be very fiddling if not impossible.

Suspect i.c.s are not rare; it is quite possible that an i.c. will function well in one application, but not in another. Replace it with an identical i.c. and all is well. Manufacturing tolerances are largely to blame, but a "brand X" 741 can be superior to a "brand Y" 741, though ostensibly identical.

PLEASE TAKE NOTE

Dual-Line Game May 1980

The TIL209 l.e.d.s on the circuit diagram are incorrect and should be TIL220 types.

Similarly the correct Zener diode is the BZX85, as published in the components list.

Kitchen Timer March 1980

The values of C3 and C4 have been transposed in the components list. They are correct on the circuit diagram. Some readers have experienced problems with the turn-on reset. Capacitor C2 may be increased to 10nF to overcome this.

George Hylton brings it DOWN TO EARTH

A READER from Malaysia asks about making mains transformers. How can you ensure that a transformer is capable of handling the required power? How many turns do you put on to obtain the desired voltages? Can you rewind an existing transformer to give a new output voltage?

I don't know if it was ever possible to walk into a shop and buy the parts needed for a power transformer. But I'm quite sure that it isn't possible now—not in the UK, anyway.

In any case, the cost of wire in small quantities is so high nowadays that it is probably quite uneconomic to make your own transformers from scratch. For this reason I'll concentrate on the possiblities of modifying an existing transformer.

Before discussing this, let me give my usual reminder that the *mains can be lethal*. Don't take chances.

Power Drive

Common sense tells you that the more power a component has to handle the bigger that component is likely to be. Mains transformers are no exception. The smallest ones in general use can handle about one watt. It is not very sensible to try to use such a miniature component to power a ten-watt amplifier.

Attempts to squeeze more power out of a transformer than it can really handle are sometimes made by professional engineers in cases where the power is extracted only for brief periods, with ample time for cooling off between uses. If a transformer were needed for a piece of equipment which gave a short time signal—sounding a hooter, say—once an hour it would be reasonable to work it fairly hard.

In the majority of applications of interest to readers of the magazine it will not be possible to use a short-time rating; we must assume that our transformers will have to work all the time and must be "continuously rated". So if you do salvage a transformer from equipment which operates only intermittently be sure to allow for this by down-rating its power handling by at least half.

Watt Power

To find out the power handling capacity of a transformer multiply the output voltage by the rated output current. A transformer rated at 10V 2A is a 20 watt transformer.

If a transformer has several windings, all intended to be used simultaneously, the power handling capacity is found by working out the rated output power of each winding and adding them all together. Thus, a mains transformer from an old valve operated radio might have windings of 300-0-300V 100mA, 6·3V 3A, and 5V 2A.

A conservative estimate for the power from the 300-0-300V winding (designed to drive a push-pull rectifier) is obtained by taking the 300V of the half-winding rather than the 600V of the full winding; this gives a rating of $300\text{V} \times 0{\cdot}1\text{A} = 30\text{W}$. To this is added the 18·9W of the 6·3V winding and the 10W of the 5V winding, making a total of 58·9W. This is the upper limit of power which can safely be drawn.

Turns Per Volt

Such a transformer is only capable of easy rewinding if the existing mains primary can be left intact on the bobbin with all its insulation undamaged.

For this to be possible requires two things. First it must be possible to remove the bobbin. This calls for dismantling the "stack" of core laminations; if they are stuck together with pitch etc. this may not be possible. Secondly it is only possible to leave the mains primary in situ if the secondary is wound on top of it so that the secondary can be stripped off without disturbing the primary; or if primary and secondary occupy different "slots" of a segmented bobbin, i.e. they lie side by side instead of one on top of the other.

Assuming that the bobbin is indeed accessible and the secondary strippable it is useful, before stripping, to make provision for counting the turns as they are unwound. A vital design parameter is the number of turns which would give an output of one volt. Armed with this information you can easily calculate how many turns to put on to give the output voltage you need.

If there is a low-voltage secondary the number of turns is easily counted as you unwind. For example, if the 5V winding on the transformer I just used as an example has 50 turns then you know that your transformer has ten turns per volt.

Large transformers have smaller turns per volt than small transformers. If your transformer has no convenient low-voltage secondary you are faced with the tedious problem of counting large numbers of turns. Do it in batches of say fifty, making a mark on a piece of paper for each batch.

Alternatively, if there is enough room between the bobbin and the core of the intact transformer you can put on an extra winding with a known number of turns, measure the voltage and work out the turns per volt figure from that.

If for example you manage to put on twelve turns and an a.c. voltmeter connected to this temporary winding reads 0·5V then your transformer has 24 turns per volt. If you want to get 10 volts from it you must use 240 turns when you rewind the secondary.

Wire Size

To work efficiently, the secondary winding you put on to replace the original secondary must occupy all the available space. That is you must use the thickest wire possible.

In theory the primary and secondary should each occupy half the available winding space. In practice the primary, which has to withstand the main voltage and needs good insulation often occupies rather more than half.

If the secondary has to deliver only a low voltage it is usually sufficient to wind it with enamelled wire, the enamel providing the insulation between turns and layers. (Nowadays primaries are also often wound this way too but the precision winding techniques needed make it impossible to hand-wind high-voltage windings safely without using insulation between layers).

If a winding does not fill the available space it will have a higher resistance than it should and this will cause the voltage to fall too much as the current taken is increased. Wire tables exist which show how many turns of different gauges of wire and different insulations can be packed into a given cross sectional area.

These tables assume perfect packing and in practice you will get rather fewer turns into the space than the tables suggest.

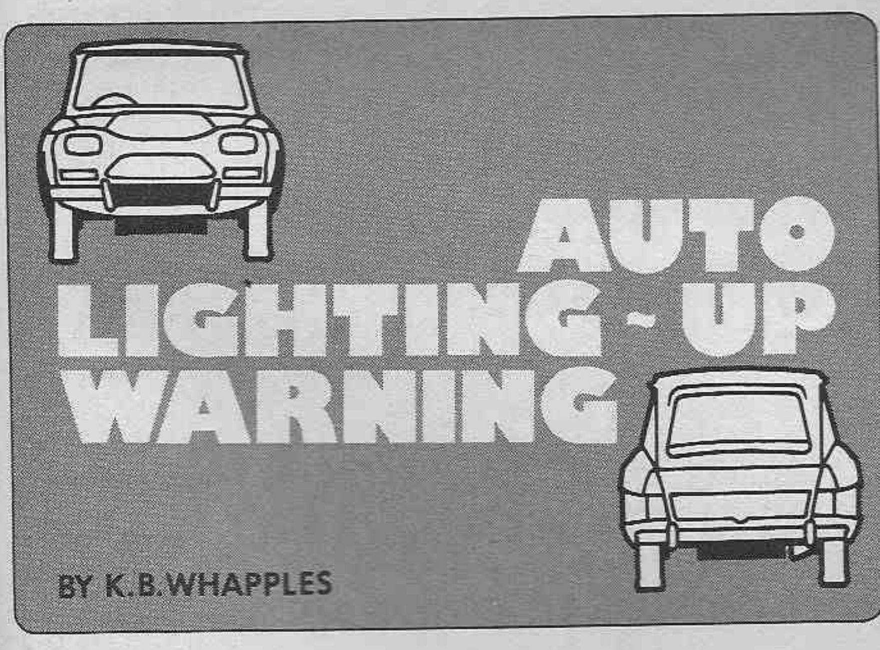
Laminations

Laminations are insulated on one by side an oxide coating. When the core is reassembled the laminations must be stacked so that there is a layer of oxide between adjacent laminations.

Also the laminations must be interleaved. If, as is usual, they are in the form of *E*s and *I*s, this means putting in an *E*, then an *I*, then an *E* and so on. If the stack of laminations is not packed tight and firmly clamped it will buzz.

Tricky Business

You may conclude from all this that rewinding and reassembling a mains transformer is a tricky business, not to be lightly undertaken. You are right. I gave up doing it many years ago when I realised it is usually just not worth the trouble.



AUTO LIGHTING-UP WARNING

BY K.B.WHAPPLES

RECENT police campaigns over vehicle lighting have highlighted the growing concern about motorists who have defective lights or who fail to display lights early enough or during periods of poor daylight.

The human eye adapts itself automatically to slow variations in ambient light intensity but as individuals our subjective judgement of absolute light level is inconsistent and dependant on many psychological factors.

The unit described here indicates that the ambient light level has fallen below a preset level and the driver has failed to turn his lights on.

CIRCUIT

The complete circuit is shown in Fig. 1. In normal operation, with the ignition switch on, and the sidelight switch off, the circuit is effectively connected across the battery, the negative rail of the unit being connected to the chassis via the low resistance of the sidelamps.

Resistor R1 limits the current flowing through the Zener diode D1 to approximately 8mA, more than sufficient for the light sensing circuitry and low enough to have negligible current drain on the car battery.

The Zener diode provides 5·6 volts, stabilised against supply changes, for the light sensor, PCC1, which is an ORP12 light dependent resistor, or l.d.r. for short. The resistance of the l.d.r. increases as the level of light falling on its sensitised surface reduces.

TRIP LEVEL

In series with PCC1 are the resistor R2 and variable resistor VR1, whose values have been chosen to enable adjustment of the "trip level" between "dull" and "quite dark" light levels.

When the voltage across the l.d.r. reaches approximately 0·6 volts, the silicon controlled switch, SCS1, switches on and illuminates the warning display l.e.d. D3. The l.d.r. derived voltage is applied to the cathode gate of SCS1 via a low-pass filter with a 30 second time constant comprising R3 and C1.

This ensures that random fluctuations in light level, such as driving through a tunnel or inadvertently obscuring the sensor with the hands, do not trigger the warning device, whilst also decoupling the very sensitive gate from transients which would otherwise cause false triggering.

Resistor R4 also avoids false triggering at switch on and R5 limits current through D3 to about 20mA.

LIGHTS ON

When the vehicle lights are switched on, the negative rail is switched to the positive supply rail of the vehicle meaning that the unit is now short circuited and receives no supply voltage.

The purpose of D2 is two-fold. As the light level decreases and the l.d.r. voltage approaches 0·6 volts certain conditions, for example low sun shining through a row of roadside trees, with a lower "mean" level than the threshold setting may cause early triggering. However, each "bright" interval causes the l.d.r. voltage to fall thus forward biasing D2 and restoring the voltage on C1 to the "bright" or true light level quickly.

The unit therefore responds to increases in light level far more quickly than reductions, further reducing the possibility of undesirable warnings. Also, when the lights are switched on and the unit is short circuited any voltage on C1 forward biases D2 and discharges C1. The shorting action of the switches also removes the supply from SCS1 which in turn resets it.

In the event of the warning lamp coming on when the driver feels that lights are not required, the unit is simply reset by switching the sidelights on and off. This extinguishes the warning l.e.d. D3.

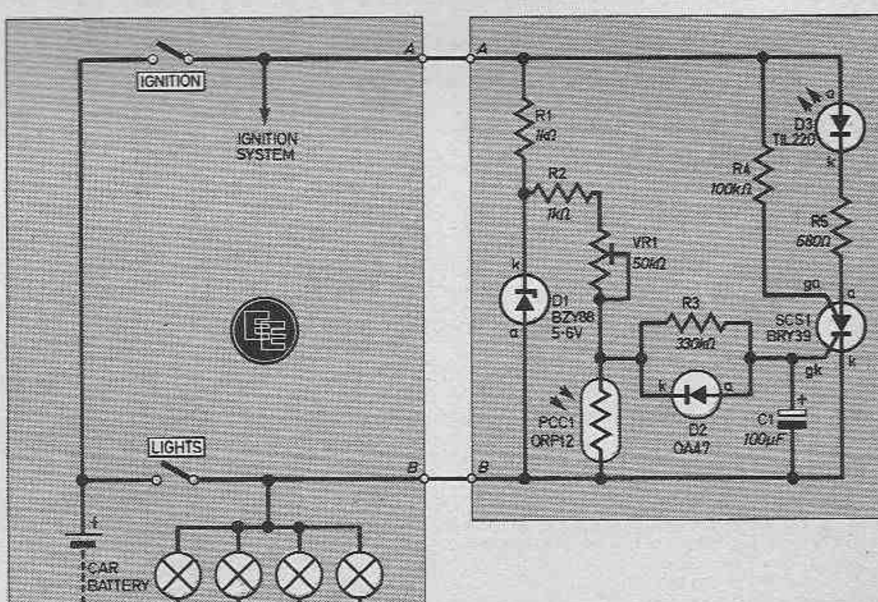
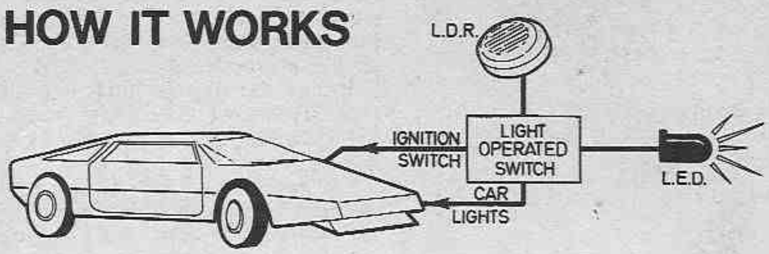


Fig. 1. Complete circuit of the Auto Lighting-Up Warning. Note that this version is for negative earth. See text for modifications for positive earth.

CONSTRUCTION starts here

HOW IT WORKS



A light operated switch is connected to the ignition switch and the non-earthed side of the vehicle lighting circuit.

When the ignition is switched on, power is applied to the unit but in daylight the resistance of the light dependant resistor is such that the electrical switch is not activated and the warning l.e.d. is kept unlit.

If darkness falls or visibility becomes poor and the unit is not disenabled by switching the vehicle lights on, then the change in resistance of the l.d.r. caused by the change in light level activates the electrical switch and lights up the warning l.e.d.

CIRCUIT BOARD

Component layout is not critical and the unit can be constructed on any small off-cut of 0·1 inch matrix stripboard. However, in the prototype a small printed circuit board was used and the foil pattern and component mounting details are shown in Fig. 2. When considering how to mount the l.e.d. and the l.d.r. there are two approaches. The first is to mount them separately at strategic points on the dashboard. The second is to build the complete unit in a small box that can be mounted in a suitable position.

Whichever approach is used the constructor should observe the following. The l.d.r. performs better if it is mounted horizontally and in a position where daylight from the windscreen falls on its face as vertically as possible, as opposed to pointing it through the windscreen.

All soldering should be clean and strong in view of the high vibration environment. P.V.C. covered stranded wire is strongly advised. The p.c.b. may be used even if the sensor and/or warning l.e.d.s are mounted remotely, the p.c.b. positions of these components simply being used to connect the wires to these components.

CASE

If you take the option to build the complete unit into a box, then a small ABS plastic container 30 × 45 × 15mm in size will be required. Also a hole will have to be made in a suitable position in the box for the l.e.d. D3. above the circuit board.

The circuit board can be held in place with a piece of double sided self adhesive foam strip. A good method of mounting PCC1 in a remote position is to solder it to a small piece of stripboard and attach the leads to the stripboard. This assembly can then be pushed through a suitable hole in the vehicle dashboard from behind and held in place by means of screws or epoxy resin glue.

Flexible stranded wire can be used for all leads and when all the components are wired in it is a good idea to test the unit before installing it in the vehicle.

COMPONENTS

Resistors
- R1 1kΩ
- R2 1kΩ
- R3 330kΩ
- R4 100kΩ
- R5 680Ω
- *R6 470Ω

All ¼W carbon ± 5%

Capacitor
- C1 100μF 16V elect.

Semiconductors
- SCS1 BRY39 silicon controlled switch
- D1 BZY88C5V6 5·6V 400mW Zener diode
- D2 OA47 small signal germanium diode
- D3 TIL220 red l.e.d.
- *TR1 BD132 *pnp* silicon

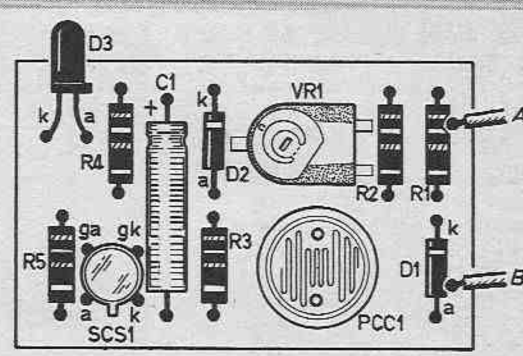
Miscellaneous
- VR1 50kΩ miniature horizontal preset
- PCC1 ORP 12 light dependent resistor
- *WD1 12V warning device or incandescent bulb, 1·5A maximum

Case, ABS plastic size 30 × 45 × 15mm or similar; printed circuit board or 0·1 inch matrix stripboard as above; stranded wire for off-board connections; bulb holder*.

* components only required if larger warning device used (see text).

COMPONENTS approximate cost £3·50 excluding case

See Shop Talk page 481



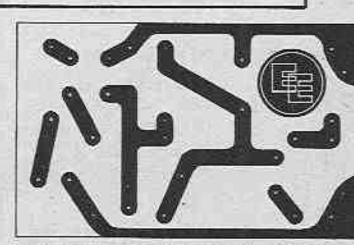
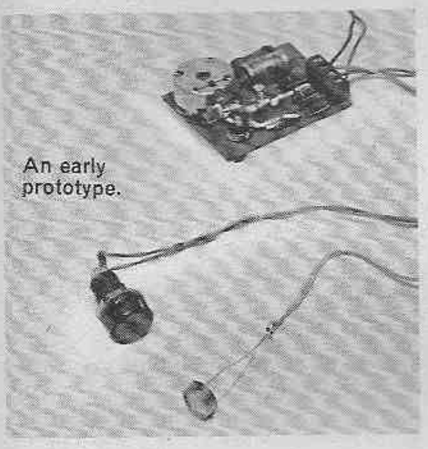


Fig. 2. Suggested p.c.b. layout of the unit. Note that modifications for high current warning device are not included on the board.



An early prototype.

Connect it up to a 12 volt supply and cover up PCC1 with your hand. If the warning l.e.d. comes on after about 15 to 20 seconds, then all is well.

INSTALLATION

The wiring of the unit is straightforward. The positive lead can be connected to any service on the vehicle that is only powered when the ignition is switched on, for example the car radio or cigarette lighter or alternatively direct to the ignition switch.

The negative lead must be connected to the light switch so that when the light switch is off the lead must be connected to the switch contact that is connected to the sidelamp bulbs and not to the contact that goes straight to the battery. This provides the earth return for the unit; Fig. 1 should make this clear.

Mount the unit in such a position that it is unlikely that any items are going to be laid across the face of the l.d.r.

For negative earth vehicles the connections are as detailed above, and as in Fig. 1. For positive earth vehicles the connections are simply reversed, that is the positive lead of the unit goes to the lights and the negative lead to the ignition switch.

When installed in the unit, the variable resistor VR1 can be slowly adjusted to enable the warning indicator to trip at the required light level.

CONCLUSION

To reduce or increase the delay period, the value of R3 is altered accordingly and can be replaced by a 500 kilohm variable resistor if desired. Alternatively the value of C1 may be altered.

If an alternative type of l.d.r. is available then R2 and VR1 can be replaced with a single 100 kilohm variable resistor to give a wider range.

If you wish to incorporate a lamp or buzzer or other form of warning device in place of the l.e.d. then the circuit must be modified as in Fig. 3. Although the BRY39 controlled silicon switch will sink up to 150mA the cold resistance of virtually all incandescent lamps will allow a current in excess of this to pass at switch on and so destroy the device. This is true even of a 12 volt 1 watt Lilliput lamp. Therefore, the suggested output modification is necessary for virtually all sorts of lamp. ⌑

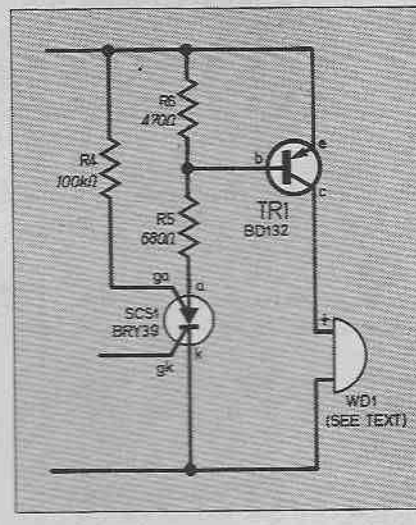


Fig. 3. Circuit modification for high current consumption warning devices

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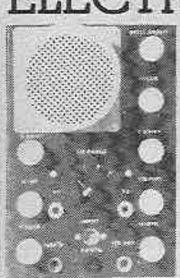

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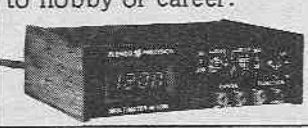

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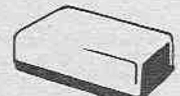

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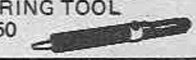

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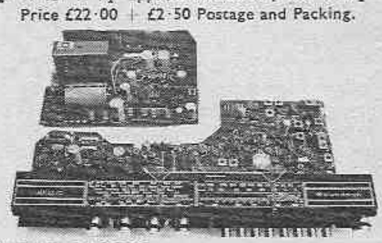

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