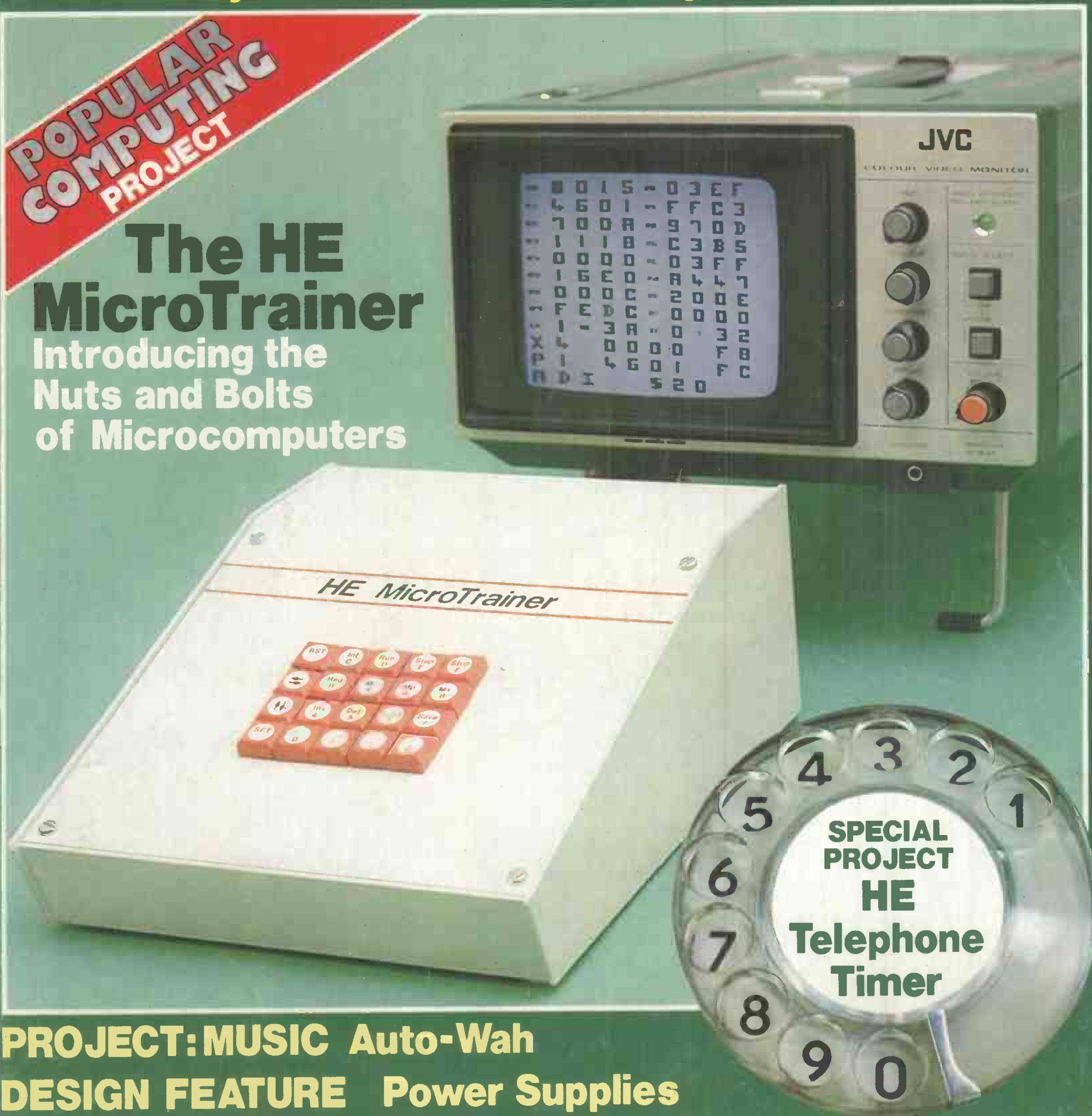
Hobby Electronics

JUNE '82
ISSN 0142-6192
70p

Project Electronics For Everyone



POPULAR COMPUTING PROJECT

The HE MicroTrainer

Introducing the Nuts and Bolts of Microcomputers

SPECIAL PROJECT
HE Telephone Timer

PROJECT: MUSIC Auto-Wah

DESIGN FEATURE Power Supplies

SUMMER SPECIAL Auto Greenhouse Sprinkler

NICADS : UK's LOWEST PRICES

AMBIT'S NEW CONCISE COMPONENT CATALOGUE IS OUT NOW –

Available at your newsagent or direct, for 70p inc.

Ambit's new style catalogue continues to lead the market with low prices, new items, info, 3 £1 discount vouchers. In a recent supplier survey, we were one of only two suppliers listed in all categories!

There's a few examples of some super low prices

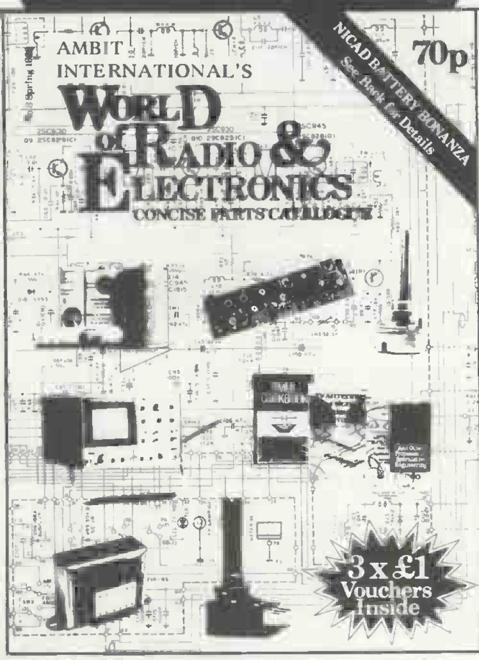
78XX 1A	37p
BC237/8/9	8p
3SK51	54p
10MHz XTALS	£2
8 Pole 10.7MHz XTAL filters	£14.50
2GHz coax relay 150W	£10.95

All the "usual" stuff at rock bottom prices + Toko coils, crystal and ceramic filters, micrometals toroids, Fairite ferrites, Alps switches, OKI LSI, Piezo sounders, RF, IF Modules + Kits etc.

RECHARGEABLE UP TO 400 TIMES PER CELL!

CAPACITY	TYPE	1-9	10-49
500 mAh	AA	80	74
2200 mAh	C	2.35	1.99
1200 mAh	D	2.14	2.06
4000 mAh	D	3.05	2.85
110 mAh	PP3	3.70	3.50

Price on the page



CMOS

4000	0.11
4001	0.11
4002	0.12
4007	0.13
4008	0.50
4008AE	0.80
4009	0.25
4010	0.30
4011AE	0.24
4011	0.11
4013	0.25
4015	0.50
4016	0.22
4017	0.40
4019	0.38
4020	0.55
4021	0.55
4022	0.55
4023	0.15
4024	0.33
4025	0.15
4026	1.05
4027	0.26
4028	0.50
4029	0.55
4030	0.35
4035	0.67
4040	0.50
4042	0.50
4043	0.50
4043AE	0.93
4044	0.60
4046	0.60
4047	0.68
4049	0.24
4050	0.24
4051	0.55
4052	0.55
4053	0.55
4054	1 30
4055	1 30
4056	1 30
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4060	0.75
4063	1.15
4066	0.30
4067	4.30
4068	0.16
4069AE	0.14
4070	0.16
4071	0 16
4072	0.16
4073	0.16
4075	0.16
4076	0.55
4077	0.18
4078	0.18
4081	0.12
4082	0.18
4093	0.30
4099	0.80
4175	0.80
4502	0.60
4503	0.50
4506	0.70
4507	0.37
4508	1.50
4510	0.55
4511	0.45
4512	0.55

4514	1.25
4515	1.25
4516	0.60
4518	0.35
4520	0.60
4521	1.30
4522	0.89
4527	0.80
4528	0.65
4529	0.70
4531	0.65
4532	0.80
4534	4.00
4536	2.50
4538	0.85
4539	0.80
4543	0.80
4549	3.50
4553	2.70
4554	1.20
4555	0.35
4556	0.40
4557	2.30
4558	0.80
4559	3.50
4560	2.50
4561	1.00
4562	2.50
4566	1.20
4568	1.45
4569	1.70
4572	0.22
4580	3.25
4581	1.40
4582	0.70
4583	0.80
4584	0.27
4585	0.45
4702	4.50
4703	4.48
4704	4.24
4705	4.24
4706	4.50
4720	4.00
4723	0 95
4724	0.95
4725	2.24
40014	0.54
40085	0.99
40098	0.54
40106	0.69
40160	1.05
40161	1.05
40162	1.05
40163	1.05
40174	1.05
40175	1.05
40192	1.08
40193	1.08
40194	1.08
40195	1.08

TTL N

7400N	0.10
7401N	0.10
7402N	0 20
7403N	0 11
7404N	0.12
7405N	0.12
7406N	0.22
7407N	0.22
7408N	0.15
7409N	0 15
7410N	0 12
7411N	0.18
7412N	0 19
7413N	0.27
7414N	0.51
7416N	0 27
7417N	0.27
7420N	0.13
7421N	0 28
7423N	0.22
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7426N	0.22
7427N	0.22
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7432N	0.23
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7438N	0.22
7440N	0 14
7441N	0 54
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7448N	0.56
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7460N	0.14
7470N	0.28
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7480N	0.26
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74107	0.26
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74110N	0 54
74111N	0 68
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74116N	1 98
74118N	0 85
74119N	1 20
74120N	0 95
74121N	0 34
74122N	0 34
74123N	0 40

Prices shown EXCLUDE VAT. Access/Barclaycard may be used with written or telephone orders, official MA details on application. E & EO.

POSTAGE and PACKING 50p per order

74125N	0.40
74126N	0 40
74128N	0 65
74132N	0 50
74136N	0 65
74141N	0 45
74142N	1 85
74143N	2 50
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74LS447N	1.95
74LS490N	1.10
74LS668N	1.05
74LS669N	1.05
74LS670N	1.70

RAM

2102	1.70
2112	3.40
2114 2	1.49
4027	5.78
4116 2	1.59
4116 3	1.49
4864P	12.50
6116P 3	9.00
6116P 4	11.25
8264	12.50

74CXX

74C00	0.20
74C02	0.20
74C04	0.20
74C08	0.20
74C10	0.20
74C14	0.55
74C20	0.20
74C30	0.20
74C32	0.20
74C42	0.80
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74C73	0.50
74C74	0.50
74C76	0.48
74C83	0.98
74C85	0.98
74C86	0.26
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74C90	0.80
74C93	0.80
74C95	0.94
74C107	0.48
74C151	1.52
74C154	2.26
74C157	1.52
74C160	1.05
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74C162	1.05
74C163	1.05
74C164	0.80
74C165	0.84
74C173	0.72
74C174	1.05
74C175	1.05
74C192	1.08
74C193	1.08
74C195	1.08
74C200	4.52
74C221	1.06
74C901	0.38
74C902	0.38
74C903	0.38
74C904	0.38
74C905	5.64
74C906	0.38
74C907	0.38
74C908	0.84
74C909	1.52
74C910	3.62
74C914	0.86
74C918	0.98
74C925	4.32
74C926	4.32
74C927	4.32

Processors
8080 series

8080AFC/2	£7.30
8212	2.30
8214	3.50
8216	1.95
8224	3.50
8251	6.21
8255	5.40

Z80 series

Z80A	£3.75
Z80ADRT	7.50
Z80APIO	3.50
Z80ASIO 1	11.00
Z80ASIO 2	11.00
Z80ASIO/9	9.95
Z80CTC	4.00
Z80ACTC	4.50
Z8001	65.00

PROM

2708	2.00
2716	£3.00
2532	0A
2732	£4.00

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AMBIT international 200 North Service Road, Brentwood, Essex

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Vol 4 No 6

PROJECTS

FEATURES

SPECIALS

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WATFORD ELECTRONICS

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ALL DEVICES BRAND NEW, FULL SPEC. AND FULLY GUARANTEED. ORDERS DESPATCHED BY RETURN OF POST. TERMS OF BUSINESS: CASH/CHEQUE/P.Os OR BANKERS DRAFT WITH ORDER. GOVERNMENT AND EDUCATIONAL INSTITUTIONS' OFFICIAL ORDERS ACCEPTED. TRADE AND EXPORT INQUIRY WELCOME. P&P ADD 50p TO ALL ORDERS.

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POLYESTER CAPACITORS: Axial Lead Type
400V: 1nF, 1n5, 2n2, 3n3, 4n7, 6n8 11p; 10n, 15n, 18n, 22n 12p; 33n, 47n, 68n 16p; 100n, 150n 20p; 220n 30p; 330n 42p; 470n 52p; 680n 60p; 1μF 68p; 2μ2 82p; 4μ7 85p.
160V: 10nF, 12n, 100n 11p; 150n, 220n 17p; 330n, 470n 30p; 680n, 38p; 1μF 42p; 1μ5 45p; 2μ2 48p.
1000V: 1nF 17p; 10nF 30p; 15n 40p; 22n 36p; 33n 42p; 47n 48p; 100n 50p; 470n 99p.

POLYESTER RADIAL LEAD CAPACITORS: 250V:
10nF, 15n, 22n, 27n 6p; 33n, 47n, 68n, 100n 7p; 150n, 220n 10p. 330n, 470n 13p; 680n 19p; 1μF 23p; 1μ5 40p; 2μ2 46p; 4μ7 60p.

ULTRASONIC TRANSDUCERS
40kHz 395p/pr

ELECTROLYTIC CAPACITORS: (Values are in μF) 500V: 10 52p; 47 78p; 250V: 100 65p; 63V: 0.47, 1.0, 1.5, 2.2, 2.5, 3.3 8p; 4.7 9p; 6.8, 10 10p; 15, 22, 12p; 33 15p; 47 12p; 100, 19p; 1000 70p. 50V: 47 12p; 68 20p; 220 24p; 470 32p; 2200 90p. 40V: 4.7, 15, 22 9p; 3300, 90p; 4700, 120p; 25V: 1.5, 6.8, 10, 22 8p; 33 9p; 47 8p; 100 11p; 150 12p; 220, 15p; 330 22p; 470 25p; 680, 1000, 34p; 2200, 50p; 3300, 76p; 4700 92p; 16V: 40, 47, 100 9p; 125, 12p; 220 13p; 470, 20p; 680 34p; 1000 27p; 1500, 31p; 2200 36p; 3300 74p; 4700 79p.
TAG-END TYPE: 70V: 4700, 245p; 64V: 3300 198p; 2200 139p; 50V: 3300 154p; 2200 110p; 40V: 4700 160p; 25V: 10,000 320p; 15,000 345p

TANTALUM BEAD CAPACITORS
35V: 0.1μF, 0.22, 0.33 15p; 0.47, 0.68, 1.0μF, 1.5 16p; 2.2, 3.3 18p; 4.7, 6.8 22p; 10μF 28p; 16V: 2.2, 3.3 16p; 4.7μF, 6.8, 10 18p; 15, 36p; 22 30p; 33, 47 40p; 100 75p; 220 88p; 10V: 15, 22, 26p; 33 47 35p; 100 55p; 6V: 100 42p.

MYLAR FILM CAPACITORS
100V: 1nF, 2, 4, 4n7, 10 6p; 15nF, 22n, 30n, 40, 47 7p; 56 100n, 200 9p; 470n/50V, 12p.

MINIATURE TYPE TRIMMERS
2-6pF, 2-10pF, 2-25pF, 5-56pF 30p.

COMPRESSION TRIMMERS
3-40pF; 10-80pF 20p; 20-250pF 28p; 100-580pF 38p; 400-1250pF 48p

SILVER MICA (Values in PF)

2, 3.3, 4.7, 6.8, 8.2, 10, 15, 18, 22, 27, 33, 39, 47, 50, 56, 68, 75, 82, 85, 100, 120, 150, 180pF	15p each
200, 220, 250, 270, 300, 330, 360, 390, 470, 600, 800, 820	21p each
1000, 1200, 1800, 2200	30p each
3300, 4700pF	60p each

CERAMIC CAPACITORS 50V: 0-5pF to 10nF 4p; 22n to 47n 5p. 100n 7p.

GAS & SMOKE DETECTORS
TGS812 or TGS813 575p

ACCESS ORDERS
Just phone your order through and we do the rest

POTENTIOMETERS: Rotary, Carbon, Track. 0.25W Log & 0.5W Lin.

500Ω, 1KΩ & 2KΩ (Linear only) Single Gang	30p
5KΩ-2MΩ Single Gang	30p
5KΩ-2MΩ Single Gang 0/P Switch	78p
5KΩ-2MΩ Double Gang	88p

SLIDER POTENTIOMETERS
0-25W log and linear values 60mm

5KΩ-500KΩ single gang	70p
10KΩ-500KΩ dual gang	110p
Self Stick Graduated Bezel	40p

PRESET POTENTIOMETERS
Vertical & Horizontal

0.1W 50 M—5 M M Miniature	7p
0.25W 100 M—3.3 M M horiz.	10p
0.25W 200 M—4.7 M M 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.

RELAYS: Miniature enclosed PCB Mounting
S.P.C.O., 170 M coil, 7V5 to 12V DC, 380V/6A AC
D.P.C.O., 43 M 4V7 to 7V DC, 250V AC/6A £2 each

OPTO ELECTRONICS
LEDs with Clips

TIL209 Red	13
TIL211 Grn.	18
TIL212 Yel.	18
.2" Red	14
.2" Yell or Grn	18
Square LEDs	29
OCP71	120
ORP12	78
2N5777	45
LD271	46
SFH205	91
TIL32	52
TIL78	54
TIL38	65
TIL100	90
7 Segment Displays	
TIL321 .5 CA	115
TIL322 .5 CC	115
DL704 .3 CCth	99
DL707 .3 CA	99
.3 Green CA	120
DL747 .6 CA	180
FND357	120
FND500	90
MAN3640	175
10 Seg Bargraph	225
LCD 3½ Digits	550
Isolators	
IL74	45
ILD74	99

VOLTAGE REGULATORS

		+ve		−ve	
1A	TO3				
5V	7805	145p	7905	220p	
12V	7812	145p	7912	220p	
15V	7815	145p		—	
18V	7818	145p		—	
1A	TO220 Plastic Casing				
5V	7805	45p	7905	55p	
12V	7812	50p	7912	55p	
15V	7815	50p	7915	55p	
18V	7818	50p	7918	55p	
24V	7824	50p	7924	55p	
100mA	TO92 Plastic Casing				
5V	78L05	30p	79L05	60p	
6V	78L62	30p			
8V	78L82	30p			
12V	78L12	30p	79L12	60p	
15V	78L15	30p	79L15	60p	



CA3085	95p	LM317P	99p	TBA625B	75p
LM300H	170p	LM323K	500p	TDA1412	150p
LM305H	140p	LM723	35p	78HO5	550p
LM309K	135p	TAA550	50p	78HG5	550p
LM317K	350p			79HG	785p

SWITCHES

TOGGLE: 2A/250V		**SLIDE: 240V**	
SPST Standard	33	½A SPST	13
DPDT Standard	44	½AA DPDT	13
SUB-MIN TOGGLE		1A DPDT	14
SPST on/off	54	1A DP c/off	15
SPDT (c/over)	60		
DPDT 6 tags	75	**PUSH BUTTON**	
DPDT c/off	80	Push-Make	15
DPDT Biased	145	Push-Break	18

ROCKER: SPST on/off 10A/250V 28
ROCKER: DPDT 10A/250V 70
ROCKER: DPST ILLUMINATED 85
ROTARY: (Adjustable Stop) 1 pole/2 to 12 way; 2 pole/2 to 6 way; 3 pole/2 to 4 way; 4 pole/2 to 3 way 45

DIL SOCKETS

	Low Prof.	Wire wrap
8 way	8p	25p
14 pin	9p	35p
16 pin	10p	42p
18 pin	16p	52p
20 pin	22p	60p
22 pin	25p	70p
24 pin	27p	70p
28 pin	28p	80p
40 pin	30p	99p

PROTO DEC

Euroboard	520
S Dec	450
Bimboard I	500
Veroblock	375

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6:1 Ball Drive 4511/DAF	185p	C804-5pF: 10: 15: 25: 50pF	278p
Dial Drive 4103 6:1/36:1	775p	100, 150pF	350p
Drum 54mm	59p	'L' 3x310pF	725p
0-1.365pF	350p	00-3x25pF	575p
00-2.365pF	435p		

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'DP' VALVE TYPE Range 1 to 5 BL., RD, Tl Wht.	122p	RFC 5 chokes	140p
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'T' type 1 to 5, Bl, Rd. Wht. Yl	150p	18/1.6	135p
B9A Valve Holder	42p	18/465	152p
		TOC 1	124p
		MW5FR	122p
RDT2	145p	MW/LW SFR	154p

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0.1" Pitch	clad	plain
2½ x 3¾	73p	52p
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3¾ x 3¾	83p	–
3¾ x 5	95p	79p
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DIODES

BY126	12
BY127	12
CRO33	250
OA9	40
OA47	12
OA70	12
OA79	15
OA85	15
OA90	8
OA91	8
OA95	8
OA200	8
OA202	8
IN914	4
IN916	5
IN4001/2	5
IN4003	6
IN4004/5	6
IN4006/7	7
IN4148	4
IN5401/2	15
IN5404	16
IN5406	17
IN5408	19
IS44	9
1S921	9
6A/100V	40
6A/400V	50
6A/800V	65

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1A/50V	18
1A/100V	22
1A/400V	29
1A/600V	34
2A/50V	35
2A/200V	46
2A/400V	46
2A/600V	65
6A/100V	83
6A/400V	95
6A/600V	125
10A/200V	215
10A/600V	350
25A/200V	240
25A/600V	395
BY164	56
VM18	50

DIAC
ST2 25

SCRs Thyristors

5A/400V	40
5A/600V	48
8A/300V	60
8A/600V	95
12A/100V	78
12A/400V	95
12A/800V	188
BT106	150
BT116	180
C106D	38
TIC44	24
TIC45	29
TIC47	35
2N5062	32
2N5064	38
2N4444	130

TRIACS

3A100V	48
3A200V	54
3A400V	56
8A100V	60
8A400V	69
8A800V	115
12A100V	78
12A400V	82
12A800V	135
16A100V	103
16A500V	115
25A800V	220
25A1000V	480
T28000D	120

TTL 74

7400	11
7401	11
7402	11
7403	12
7404	13
7405	15
7406	24
7407	25
7408	14
7409	14
7410	14
7411	16
7412	18
7413	18
7414	28
7416	24
7417	25
7420	15
7421	20
7422	20
7425	24
7426	28
7427	22
7428	25
7430	14
7432	22
7433	25
7437	25
7438	25
7440	15
7441	68
7442	32
7443	90
7444	90
7445	55
7446	65
7447	40
7448	45
7450	16
7451	16
7453	16
7454	16
7460	16
7470	35
7472	26
7473	28
7474	24
7475	40
7476	30
7480	48
7481	120
7482	65
7483	40
7484	70
7485	90
7486	24
7489	205
7490	21
7491	35
7492	25
7493	25
7493	35
7495	35
7496	40
7497	95
74100	80
74104	50
74105	55
74107	25
74109	25
74110	35
74111	55
74112	170
74116	55
74118	60
74119	80
74120	60
74121	28
74122	40
74123	50
74123	35
74126	35
74128	38
74135	40
74136	30
74141	60
74142	175
74143	210
74145	50
74147	90
74150	55
74151	40
74153	40
74154	55
74156	40
74157	30
74159	80
74160	60
74161	50
74162	50
74153	50
74163	50
74164	50
74165	50
74166	50
74167	150
74170	125
74172	275
74173	60
74174	60
74175	55
74176	40
74177	45
74178	80
74180	40
74181	115
74182	60
74184	90
74185	95
74186	470
74188	290
74190	50
74191	50
74192	50
74193	45
74194	50
74195	50
74196	50
74197	50
74198	90
74221	60
74246	120
74247	120
74248	120

74LS

LS00	11
LS01	11
LS02	11
LS03	12
LS04	12
LS05	13
LS08	12
LS09	12
LS10	13
LS11	13
LS12	13
LS13	21
LS14	38
LS20	13
LS21	13
LS22	13
LS26	14
LS27	13
LS28	14
LS30	13
LS32	13
LS33	15
LS37	15
LS38	15
LS40	13
LS42	32
LS47	38
LS48	45
LS55	14
LS63	120
LS73	18
LS74	18
LS75	20
LS76	18
LS83	40
LS85	52
LS86	24
LS90	28
LS92	32
LS93	28
LS95	40
LS96	40
LS107	40
LS109	28
LS112	28
LS113	22
LS114	22
LS123	38
LS124	95
LS125	26
LS126	35
LS132	42
LS133	30
LS136	26
LS138	32
LS139	32
LS145	70
LS147	150
LS148	85
LS151	40
LS153	40
LS155	35
LS157	30
LS158	30
LS160	37
LS161	37
LS162	37
LS163	37
LS164	43
LS165	75
LS166	75
LS173	65
LS174	50
LS175	45
LS181	110
LS190	45
LS191	45
LS192	45
LS193	45
LS195	36
LS196	50
LS197	65
LS221	55
LS240	75
LS241	75
LS242	75
LS243	75
LS244	75
LS245	70
LS247	50
LS248	55
LS249	55

CMOS

4000	10
4001	10
4002	12
4006	50
4007	15
4008	48
4009	24
4010	24
4011	11
4012	16
4013	25
4014	50
4015	50
4016	20
4017	42
4018	45
4019	25
4020	50
4021	50
4022	50
4023	16
4024	33
4025	16
4026	80
4027	24
4028	50
4029	60
4030	30
4031	125
4032	85
4033	125
4034	140
4035	65
4036	275
4037	115
4038	110
4039	290
4040	50
4041	60
4042	45
4043	50
4044	50
4045	105
4046	60
4047	60
4048	40
4049	25
4050	25
451	45
4052	60
4053	50
4054	95
4055	95
4056	95
4057	1915
4059	480
4060	65
4061	1195
4062	995
4063	85
4066	30
4067	295
4068	16
4069	16
4070	15
4071	15
4072	15
4073	15
4075	15
4076	50
4077	18
4078	18
4081	16
4082	16
4085	50
4086	50
4089	125
4093	30
4094	120
4095	75
4096	75
4095	290
4098	75
4099	75
4160	75
4161	99
4162	99
4163	99
4163	99
4175	105
4194	105
4408	790
4409	790
4410	725
4411	675
4412	775
4415	480
4419	280
4422	770
4433	770
4435	850
4440	999
4450	350
4451	350
4490	350
4500	675
4501	28
4502	60
4503	40
4504	75
4506	35
4507	35
4508	150
4510	50
4511	50
4512	50
2708	225
2716	210
4116	80

ICs

2114L-3	87
2708	225
2716	210
4116	80
6502	399
6522	350
6800	300
709C 8 pin	35
710	48
733	100
741 8 pin	74
747C	65
748C	36
753	185
810	169
81LS95	90
81LS96	90
81LS97	90
9400CJ	350
AY-1-1313A	660
AY-1-1320	225
AY-1-5050	99
AY-1-5051	160
AY-3-8500	390
AY-3-8910	600
AY-5-1230	450
CA3011	130
CA3018	86
CA3020	210
CA3023	210
CA3028A	95
CA3035	255
CAA3045	365
CA3046	70
CA3048	220
CA3059	285
CAA3075	213
CA3080E	70
CA3081	190
CAAA3085	95
CAA3089E	200
CA3090AQ	375
CA3123E	150
CA3130	90
CA3140	48
CA3160	95
CA3189	295
HA1336W	240
ICL7106E	750
ICL7107	975
ICL8038CC	300
ICM7204	550
ICM7205	1150
ICM7216A	1950
ICM7217A	790
ICM7224	785
ICM7555	80
ICM7556	150
LA3350	250
LAAA4031	340
LA4032	295
LAAA4400	440
LC7120	300
LC7130	340
LF347	160
LF351	48
LF353	50
LF355	85
LF356	90
LF357	110
LF398	475
LM301A	26
LM308	95
LM311	70
LM318	200
LM319	215
LM324	30
LM339	54
LM348	64
LM349	115
LM358	65
LM377	175
LM379	480
LM380	75
LM381	145
LM382	125
LM384	140
LM386	90
LM387	120
LM389	95
LM393	100
LM394	290
LM733	100
LM1458	40
LM2917	195
LM3900	50
LM3302	95
LM3900	50
LM3909	85
LM3911	125
LM3914	210
LM3915	220
LM3916	220
LS7220	280
M252	625
M253AA	1150
MC1303	88
MC1304P	260
MC1310	150
MC1455	150
MC1458	40
MC1488	55
MC1468	40
MC1469	300
MC1488	40
MC1489	56
MC1495	350
MC1496	70
MC1496	70
MC1596	225
MC1648	290
MC1709G	90
MC1710	79
MC3302	150
MC3340P	120
MC3360P	120
MC3401	65
MC3403	65
MC3403	110
MFC6040	75
MK50398	635
ML924	250
MM5303	635
MM5307	1275
MM5387	47
NE529	225
NE531	14
NE543	225
NE544	210
NE555	16
NE556	45
NE560	325
NE561	398
NE562	410
NE564	420
NE565	120
NE566	155
NE567	140
NE570	425
NE571	420
NE5534	15
RC4136	69
S566B	245
SAB3209	425
SAB3210	295
SAB3271	485
SAB4209	595
SN76013	350
SN76023	350
SN76477	175
SN76488	480
SN76660	120
SL490	350
SP8629	299
TAAA621	295
TAA7120	150
TA7130	160
TA7204	225
TA7205A	175
TA7222	175
TAD100	159
TBA120	70
TBA641	275
TBA800	80
TBA810	95
TBA820	80
TCA965	120
TDA1004	290
TDA1008	310
TDA1022	525
TDA1024	105
TDA1490	290
TDA2004	495
TDA2020	320
TLO61	40
TLO63	80
TLO71CP	30
TLO74	100
TLO81	25
TLO82	45
TLO83	75
TLO84	96
UAA170	170
UAA180	170
UA2240	245
XR2206	300
XR2211	575
Z80CPU	350
Z80AACPU	385
Z80AACTC	325
Z80CIC	300
Z80P10	290
Z80AAP10	320
ZN414	80
ZN424E	130
ZN425E	345
ZN426E	300
ZN427	600
ZN428	478
ZN429	210
ZN1034E	200
ZN1040E	675

TRANSISTORS

AC125	35
AC126/7	35
AC128	30
AC141/2	30
AC176/87	30
AC188	30
ACY17/18	70
ACY20/1	75
ACY22	60
AD140	120
AD149	79
AD161/2	62
AF115	60
AF139	40
AF178	75
AF180/6	70
AF239	78
BC107/8	10
BC108B	12
BC108C	12
BC109	10
BC109B	12
BC109C	12
BC117	24
BC119	38
BC137	40
BC140/3	30
BC147/8	9
BC149	9
BC153/4	27
BC157/8	10
BC159	11
BC160	45
BC167A	10
BC168C	10
BC169C	10
BC170	15
BC171/2	11
BC177/8	16
BC179	20
BC182/2L	10
BC183/L	10
BC184	10
BC184L	10
BC187	26
BC212	10
BC212L	10
BC213	10
BC213L	10
BC214	10
BC214L	10
BC307B	14
BC328	95
BC338	15
BC441	34
BC461	34
BC477	40
BC516/7	40
BC547/8	12
BC549	14
BC556/7	15
BC558/9	15
BCY70	16
BCY71	18
BCY72	28
BD131/2	48
BD133	60
BD135	40
BD136/7	40
BD138/9	40
BD140	40
BD695A	85
BD696A	85
BDY17	195
BDY60	160
BDY61	160
BF115	35
BF167	29
BF173	27
BF177	25
BF178	35
BF179	35
BF180	38
BF194/5	12
BF196/7	10
BF198	16
BF200	30
BF224A	25
BF244	28
BF256	35
BF257/8	32
BF259	35
BF594/5	40
BFR39/40	23
BFR41/79	23
BFR80/81	25
BFX29	28
BFX81	45
BFX84	26
BFX85/6	28
BFX87/8	28
BFY50/1	23
BFY52	23
BRY39	40
BSX20	20
BSY65	35
BSY95A	25
BU105	170
BU205	190
BU208	200
E113	45
E176	50
E421	250
MJ2955	90
MJE340	54
MJE370	100
MJE371	100
MJE520/1	95
MJE2955	99
MJE3055	70
MPF102	40
MPF103	30
MPF104	30
MPF105	30
MPF106	40
MPSA05/6	25
MPSA12	30
MPSA55	30
MPSA56	30
MPSU06	55
MRSU56	60
OC35	125
OC36	120
OC41/2	75
OC44	75
OC45/70	40
OC71/2	40
OC76	50
OC81/2	50
OC83/4	40
OC170/1	50
TIP29	34
TIP29C	60
TIP30	48
TIP30A	48
TIP30C	58
TIP31A	45
TIP31C	55
TIP32A	60
TIP32C	66
TIP33A	65
TIP33C	78
TIP34A	74
TIP34C	88
TIP35A	160
TIP35C	185
TIP36A	170
TIP36C	199
TIP41A	55
TIP41B	60
TIP42A	60
TIP42B	75
TIP120	90
TIP121/2	99
TIP142	120
TIP147	120
TIP2955	60
TIP3055	60
TIS43	32
TIS44	45
TIS88A	50
TIS90	30
TIS91	32
VK1010	80
VN10KM	45
VN46AF	78
VN66AF	85
VN88AF	94
ZTX107/8	11
ZTX109	12
ZTX300	13
ZTX301/2	16
ZTX303	25
ZTX304	17
ZTX314	25
ZTX326	30
ZTX341	30
ZTX500	14
ZTX501/2	15
ZTX503	18
ZTX504	25
ZTX531	25
ZTX550	25
2N526	58
2N696	30
2N697	23
2N698	40
2N699	48
2N706	19
2N918	35
2N930	20
2N961	65
2N1131/2	24
2N1304	65
2N1305	60
2N1306/7	65
2N1671B	120
2N2160	350
2N2219A	28
2N2220A	23
2N2222	25
2N2369A	18
2N2476	56
2N2483	27
2N2497	63
2N2646	45
2N2894	30
2N2904	28
2N2905A	26
2N2906/7	26
2N2926G	10
2N3053	26
2N3054	58
2N3055	48
2N3121	30
2N3133	45
2N3135	30
2N3252	46
2N3442	140
2N3568	25
2N3663	15
2N3702/3	10
2N3704/5	10
2N3706/7	10
2N3708/9	10
2N3710/11	10
2N3713	140
2N3771	179
2N3772	195
2N3773	270
2N3819	22
2N3820	38
2N3822/3	50
2N3866	90
2N3903/4	16
2N3905/6	15
2N4037	46
2N4058	10
2N4061/2	10
2N4069	45
2N4859	78
2N4871	55
2N5135/6	20
2N5138	10
2N5179	45
2N5180	45
2N5191	75
2N5305	24
2N5457/8	30
2N5459	30
2N5485	30
2N5777	45
2N6027	32
2SA715	60
2SC495	70
2SC496	70
2SC1096	85
2SC1173	125
2SC1306	100
2SC1307	150
2SC1449	85
2SC1923	50
2SC1945	225
2SC1953	90
2SC1957	90
2SC1969	140
2SC2028	85
2SC2029	210
2SC2078	170
2SC2091	85
2SC2314	85
2SC2166	165
2SC1679	190
3N128	112
3N140	112
40311	60
40313	130
40316	96
40317	80
40324	100
40326	60
40327	70
40347	90
40348	120
40360	60
40361/2	70
4047	60
4048	70
40411	285
40412	90
40467	130
40468	85
40594	105
40595	110
40603	110
40636	175
40673	85

MONITOR

JUST in time for the summer is what may be the first of a new trend in holiday activities — a leisure-learning holiday. The organiser of Britain's first such holiday, a **Computer Holiday Camp** at the University of Southampton, is Dr. Lionel Wardle, of Management and Personal Services.

The Computer Camp will be not only for teenagers, but for anyone interested in computers; beginners, enthusiasts, professional people and even those suffering from "computer- phobia". Computer Campers will have access to a variety of popular microcomputers and can either learn by themselves, taking advantage of expert advice if they get stuck, or attend the tuition sessions, workshops and demonstrations which will be provided, before going on to get hands-on experience. Recognising the obsession that people sometimes develop with computers, machines will be available 20 hours a day, allowing the dedicated computer-phile maximum time at the keyboard.

On particular weeks, specially designed courses can be scheduled for common-interest groups, while an experienced management consultant will be on hand with advice for the small businessman and the self-employed.

The Computer Camps are being organised as family holidays; to help people who might otherwise be prevented from attending because of family arrangements, accommodation will be provided for family or kids at half price. Each participant will have his or her own study-bedroom in a flat or house on the University campus and all its sporting and recreational facilities will be available, free, plus the South Coast and the New Forest thrown in for good measure.

The cost of a week's Computer Camping at the University of Southampton is £115, self-catering; details and bookings from **Dr. Lionel Wardle, Management and Personnel Services**, 37 University Road, Highfield, Southampton SO2 1TL; Tel. 0703 558621.

Finally, just in case it seems like more work than play, a variety of computer games will also be available, but the organisers warn that these can be highly addictive — as if we didn't know!

News on the NiCad front, this month, from Verospeed. Their new 'Combisix' battery charger is a mains-powered unit which can handle up to six rechargeable Ni-Cad cells in AA, C or D sizes. The six individual charging points are located in two banks of three, on either side of the charger, and each bank can be adjusted to accept up to three cells.

Cells of different sizes can be mounted on either side and AA and C cells can be intermixed. A selector switch offers four charging rates; 50, 120, 180 or 400 mA. The Combisix is priced at around £22. Further information is available from Verospeed, Stanstead Road, Boyatt Wood, Eastleigh, Hants SO5 4ZY; Tel. 0703 618525.

Further to our survey of **The Affordable Computer**, in the April '82 issue, we would like to report that **Watford Electronics**, suppliers of everything electronic for the hobbyist, are also distributors of the **Superboard II** computer. Contact them at 35 Cardiff Road, Watford, Herts or 'phone 92 40588.

A soldering iron is probably the single most important tool for an electronics enthusiast, hence a new range of irons **(middle)**, manufactured by **Adcola** for **OK Machine & Tool (UK) Ltd**, look quite interesting for the hobbyist. At the moment the range consists of two thermostatically controlled, thermally balanced instruments plus one temperature controlled iron. They conform to a number of safety standards including BS3456.

Model OK-001 operates from 240 V and has a short element barrel for effective tip control and a handle which remains cool even after hours of continuous use; it weighs just 43 gr and the barrel is only 51 mm. Model OK-002 is similar, but the barrel is 88 mm long and it weighs 50 gr. Temperature ranges of these irons are 380°C and 400°C respectively.

The proportional control iron, Model OK-003, operates from 24 V 50 Hz and has a variable temperature range of 250°C-450°C. Control is by means of a special IC built in to the handle. It can be totally earthed and has a burn-proof siliconised rubber cable. For further information contact **OK Machine & Tool (UK) Ltd**, Dutton Lane, Eastleigh, Hants SO5 4AA or 'phone 0703 610944.

New from **Global Specialities Corporation**, this month, is a new breadboarding system which is ideally suited to microprocessor based projects and applications involving large numbers of IC packages.

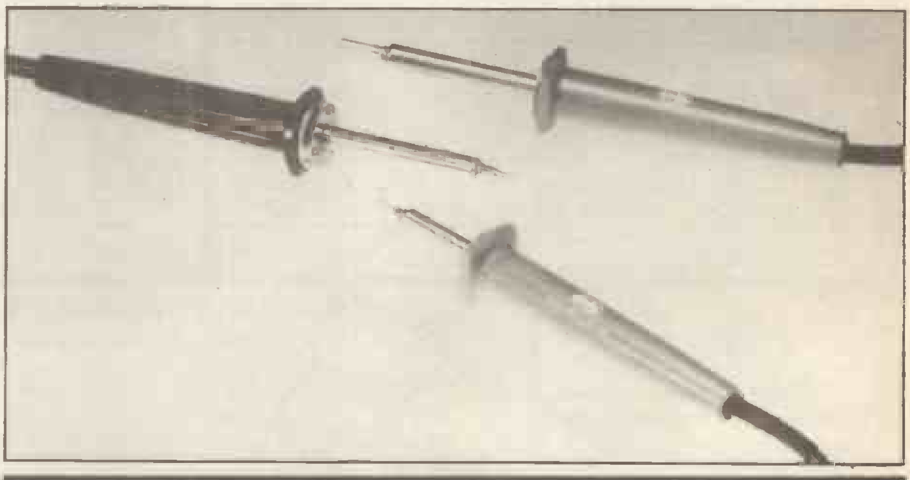
The 'Superboard' PB-105 measures 9.2 x 11.4 inches and can carry up to 48 14-pin DIL packages.

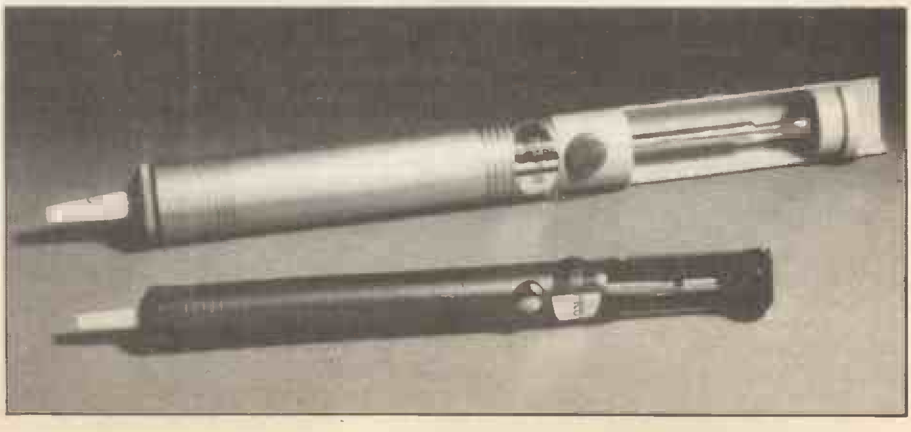
For futher information contact **Global Specialities Corporation**, Shire Hill Industrial Estate, Saffron Walden, Essex GB11 3AQ.

Let's face it, nothing works perfectly, even (or is it especially?) electronic equipment and occasionally it will be necessary to remove components from a PCB. A rather handy tool for the job is a de-soldering tool or solder-sucker, as the Americans call them; the latest additions to the **Tele-Production Tools** range for the electronic enthusiast are two new de-soldering guns **(bottom)**.

The first, 200 mm long and 19 mm in diameter, is intended for most general work while the second, only 165 mm long and 14 mm dia., is a miniature desolder gun for fine work. Both have plunger guards, can be operated one-handed and they have powerful suction action and low recoil, to leave joints clean and tidy; solidified solder is ejected each time the gun is reset.

The guns cost £5.95 each, including VAT and carriage, or £10 the pair. For details contact **Tele-Production Tools**, Stiron House, Electric Avenue, Westcliff-on-Sea, Essex SS0 9NW; Tel. 0702 352719.





MONITOR

For the benefit of our readers who own or rent video cassette machines, we pass on the following warning from **Panasonic**.

Recently, quantities of counterfeit video cassette tapes bearing the brand-name "PANASONIC" have been found circulating throughout the UK. These cassettes copy the Panasonic design and packaging and may not be immediately noticeable as counterfeits. However, the tape is reported to be "substantially inferior" to the genuine article and, besides producing poor picture quality, they could cause damage to the video machine.

Potential customers are urged to buy Panasonic video cassettes only from authorised Panasonic dealers throughout the UK. If in doubt — don't buy; the price may be attractive but the picture and sound quality probably won't be. Official Panasonic dealer lists are available from their Sales Promotion Departments at Slough, Berks (Tel. 75 34522) or Normanton, West Yorks; Tel 0924 890980.

Catalogue Collectors take note: **Clairtronic Ltd**, a specialist distributor of low voltage transformers, have produced an illustrated brochure detailing their stock of **miniature mains transformers** covering powers from 0.2 to 50 VA. The prices listed included p&p within the UK and range from around £1.30 up to £5.98; VAT is not included.

The range comprises four constructions; double bobbin transformers in both chassis and circuit mounting forms, an encapsulated series including the square box 'top hat' type plus a low-profile range with heights as low as 17 mm. The brochures are available from **Clairtronic Ltd**, Churchfield Road, Chalfont St. Peter, Bucks; Tel. 49 87277.

Still on the popular subject of Computing, PET owners everywhere will be interested in the **Third International Commodore Computer Show**, to be held at the Cunard Hotel, Hammersmith, London, between 3rd and 5th June 1982. It will be, we are assured, the "biggest and best" Commodore Show ever, with over 100 exhibitors displaying their wares.

The Show will include many innovatory products from Commodore and a number of original software programs by "approved product suppliers". Hardware will include the Commodore Ultimax, the VIC-20, VIC-40, the Commodore 64, the 4000 and 8000 series and the CBM 128 and 256 machines. Specialist applications demonstrations will cover the needs of specialist businesses, educational users and communications applications. The VIC Colour Computer and a range of VIC software will also be on display while special seminars, with guest speakers, will introduce businessmen and other professional users to the microcomputer. See you there?

Also received from **OK Machine & Tool**, recently, was their new **Electroware** catalogue. The Electroware division supplies tools and accessories for "everyone" (that certainly means us!) involved in building electronic equipment.

The catalogue lists products from OK's bench tool range, wire-wrapping kits, IC tools, PCBs, cases and enclosures, connectors and sockets, plus Ni-Cad battery chargers, soldering equipment and instruments such as multimeters, pH meters and capacitance meters. The Electroware range is available nationally from leading electronic and computer stores or directly from OK, at the address noted earlier. Write for a free catalogue, but send 30p for postage.

One of the greatest attractions of computing is that it can be fun. Of course, when the program has failed for the umpteenth time or the keyboard has locked out for some totally inexplicable reason, fun is replaced by frustration — but then life's like that (to parapharse Alexei Sayle).

Putting greater emphasis on the "fun" aspect, **B&B Ltd**, of Bolton, have launched a new game package for the VIC computer, called VIC 6. The six games on the cassette are designed to challenge the hobbyist — and the professional user. They cover old favourites such as the three-reel fruit machine, Hangman and Roulette and go on to missile game, a wall brick game and a "stay out of trouble under fire" game. The company intends to produce six more packs, enabling the VIC user to build up a library of cassettes; they have set up a mail order operation to handle all enquiries about the VIC 6 and future products. For further information 'phone Beelines on 0204 382741.

A new point-to-point wiring system, just released by **BICC-Vero**, is mainly inteded for circuit prototypes and small-scale production runs. it would also prove useful for the hobbyist who is developing a project too large to be handled by the usual breadboarding methods.

The Speedwire system provides rapid wiring using novel insulation-displacement joints and a special hand wiring tool. Continuous joints are easily made without the need to cut and strip the wire.

The heart of the system is a double-sided push-fit contact and the wiring pen, which pushes the wire between teh terminal's tines. Each double-forked terminal will accept one or two wires; the component side of the contact is gold-plated beyllium copper, designed to give a very low contact resistance.

Full details are available from **BICC-Vero Packaging Ltd.**, Industrial Estate, Chandlers Ford, Eastleigh, Hants. SO5 3ZR: Tel 04215 66300. **HE**

Telephone Timer

Keep Buzby at bay with this money-saving project.

Part 1: The circuit and How It Works.
Part 2, next issue, will cover the construction and wiring details.

TELEPHONE RATES in Britain are based on the number of seconds allowed for a certain charge — which went up to 5p even as this project was being designed (thanks, Buzby). There are three rates, depending on the time of day and three distance rates. The charge system is outlined in your Telephone Directory and also in Table 1. This shows, for example, that for a Local call at the Cheap rate, 5p buys 480 seconds of telephone-time, whereas a long-distance call during Peak time costs 5p for only 12 seconds. Looking at it another way, 5p buys 95 five-second 'units' for a Cheap rate Local call, while the same 5p buys 2.4 'units' for long-distance at the Peak rate.

This method of using five-second intervals has been adopted because it allows a very straightforward circuit — the Telephone Timer may look complicated but in fact it is quite simple, in principle. It just counts a certain number of five-second units — 96, say — and increments the display when this number is 'up', to give a direct read-out in pounds and pence. When the device is reset at the beginning of a call, the display shows '5p' because this is the cost of the first time period — 480 seconds or 96 units, in our example; each subsequent period costs another 5p.

On the front panel, a 10 position rotary switch selects any of the nine possible areas and charge-band times. The final switch position gives direct time readout, ie the display shows seconds rather than pounds and pence. This position is intended for international calls, because there is such a variety of costs and times that it would not be practical to include switch positions for international dialling.

Operation is quite simple. When you want to make a call, first switch the Telephone Timer on and Reset the display. Dial the number and press down the Start Button when the line is ringing. When the call is answered, release the button and the Timer will start. When the call is finished, repeat the process and read off the cost of the call. Place hand into pocket, remove the appropriate amount and place it into telephone box! Should you be making more than one call, area just press the start button again; to zero the display, simply press the Reset button.

The Telephone Timer will never go out of date, either. This is because it can be programmed for any rate! The 'unit table', which is translated into a wired patch-board, is shown in Table 1. Thus, when the cost rises (it isn't getting cheaper) you simply adjust the patches on the board. All the values are rounded up, where necessary, so that your bill is covered.

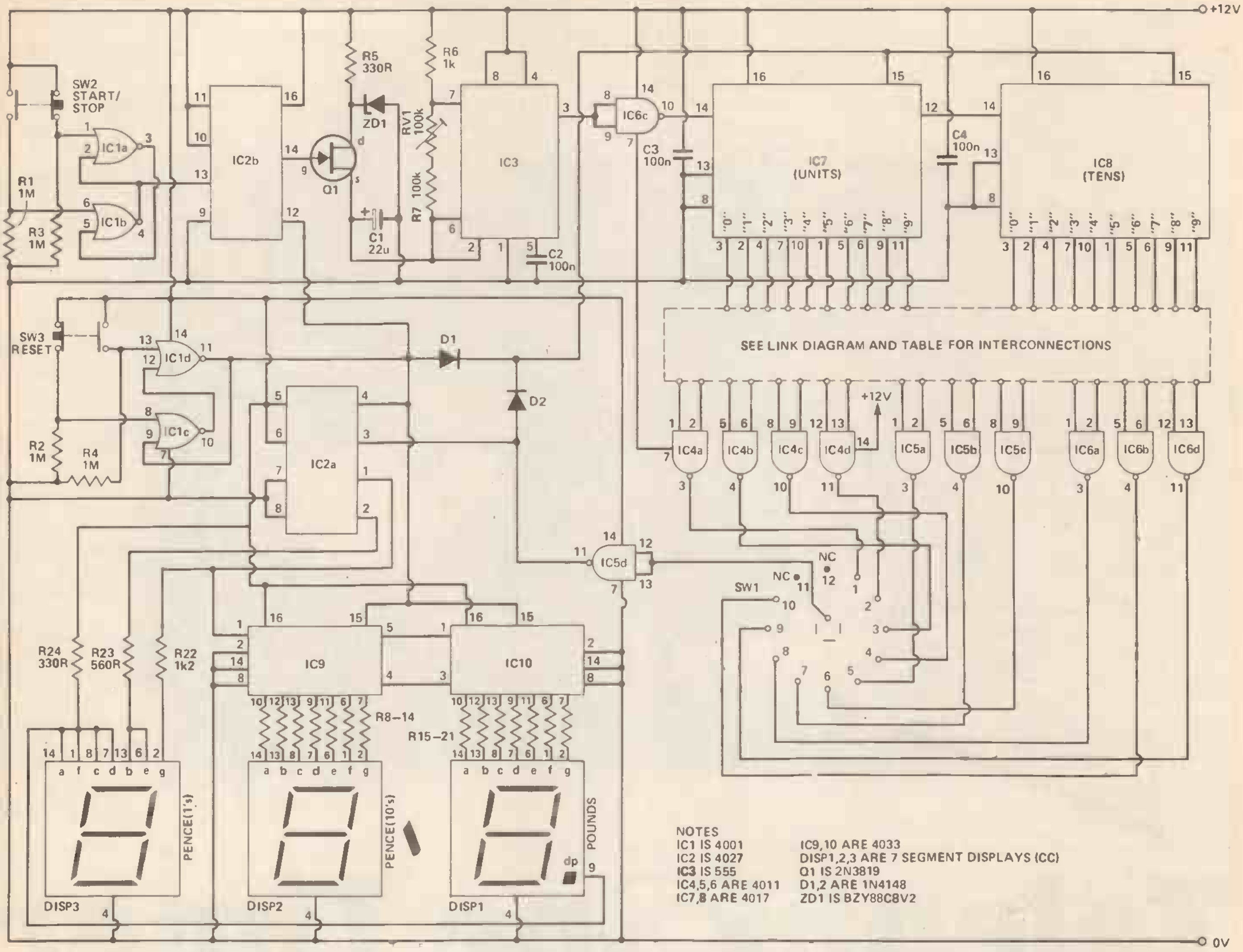


Figure 1. The complete circuit diagram of the Telephone Timer. The Link Diagram, which shows how to program the Timer for the various charge-bands, will be published in the July issue.

TARGET TIME (SECONDS)	TIME RECORDED (SECONDS)	ACCURACY (PERCENT)
480	468.0	−2.5%
120	117.5	−2.1%
90	88	−2.2%
145	141.5	−2.4%
45 (90)	44 (88)	−2.2%
30 (90)	29.5 (88.5)	−1.7%
50 (100)	49 (98)	−2.0%

Figure 2. Tests on our prototype show that the Tmer is accurate to within +0/−2.5%.

The Circuit

The design is based on the fact, mentioned earlier, that the times allowed for a fixed charge (currently 5p) is approximately divisible by five. Therefore, a 555 timer, IC3, is used to supply a square wave with a Period of five seconds (a frequency of 0.2 Hz). This signal is fed to a pair of 4017 decade counters, ICs 7 and 8, which directly count the number of 0.2 Hz clock pulses.

The NAND gates, IC4a, b, c, d, IC5a, b, c and IC6a, b, d, are used to decode the counter inputs. By connecting the relevent counter outputs to the gate inputs, each gate will produce an output pulse when the count corresponds to the preselected number of 5 S intervals. The appropriate output is selected by SW1, a 10-position switch. This pulse is used to reset the decade counters, via IC5d and D2, and also to drive a divide-by-two flip-flop, IC2a. The flip-flop is triggered by a rising edge (ie a transition from 0 to 1).

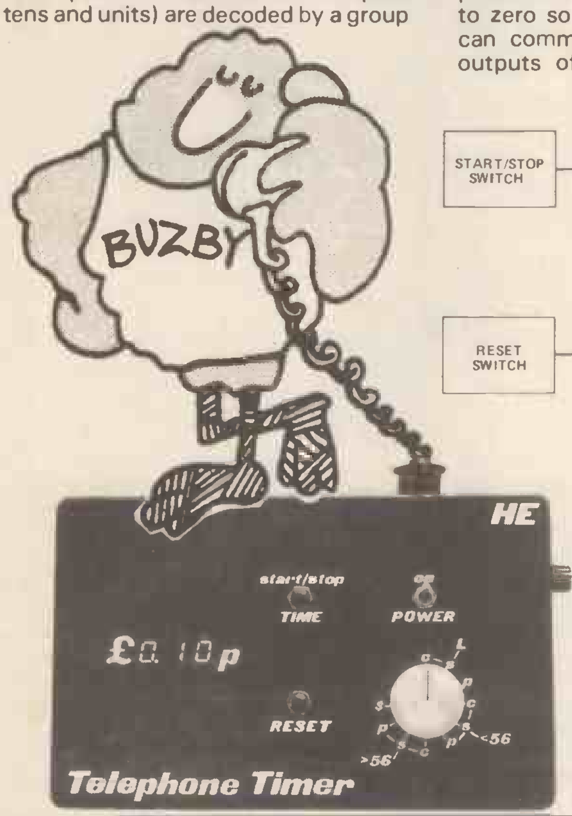
The squarewave produced by IC2a is used as the clock input for the 7-segment display decoder/drivers, ICs 9 and 10, which are the 'pounds' and '10p' display drivers. The third ('pence') display is driven directly by the Q and Q outputs of the flip-flop; since this only ever shows either '0' or '5', no further decoding is necessary.

The system is started and stopped by operating a push-button switch, de-bounced a bistable flip-flop, IC1a, b. When the button is pressed the output is one state — either high or low — and when it is released, the output reverses. The start/stop pulse is fed to another flip-flop, IC2b; when a rising edge appears at its clock input, its output changes state. IC2b controls the 555 (IC3) so that when the start/stop button is first pressed, the 555 starts running and when it is re-pressed, the timer stops, freezing the displays. The frequency of the timer is controlled by the voltage on its trigger pin (pin 2), supplied by a field effect transistor, Q1. The Zener diode is used to supply 8V2 to the trigger pin when the FET is conducting, since an error would arise in the initial time period if the trigger line was simply driven between +12 V and 0 V, due to the time it would take C1 to charge and discharge. The reset push-button simply resets all the devices in the circuit, via bistable IC1c, d and D1, returning the system to the 'start' condition.

Next month, we will give detailed instructions for assembling the Telephone Timer and describe how the device may be programmed for the nine Buzby charge bands. In the meantime, see the **Buylines** page for helpful hints on where to get the components for this money-saving project.

How It Works

The Telephone Timer simply counts a preset number of five-second 'units' and increments the display at the end of each group of units. The display gives a direct read-out, in pounds and pence. The Timer is set up to produce 0.2 Hz clock pulses (ie a Period of 5 S) to drive the decade counter/dividers, which directly count the number of clock pulses. The counter outputs (tens and units) are decoded by a group of NAND gates to select the appropriate number of 5 S intervals corresponding to the telephone charges (see text and Table 1); each gate will produce an output pulse at the end of a certain number of 5 S intervals. The required charge-rate is selected by a 10-position switch which feeds the pulse to a divide-by-two flip-flop. This pulse also resets the decade counters to zero so that another timing period can commence. The complementary outputs of the flip-flop are used to directly drive the 'pence' display (which always alternates between '0' and ''5'') and the '10p' decade counter/7-segment decoder — this increments by one at half the rate of the 'pence' display; the 'pounds' decoder/driver is driven by the Carry output from the '10p' counter. The 5 S interval timer is started and stopped by a de-bounced push-button switch. The Reset switch is also de-bounced and resets all counters to zero — the display shows ''5'' at this time.



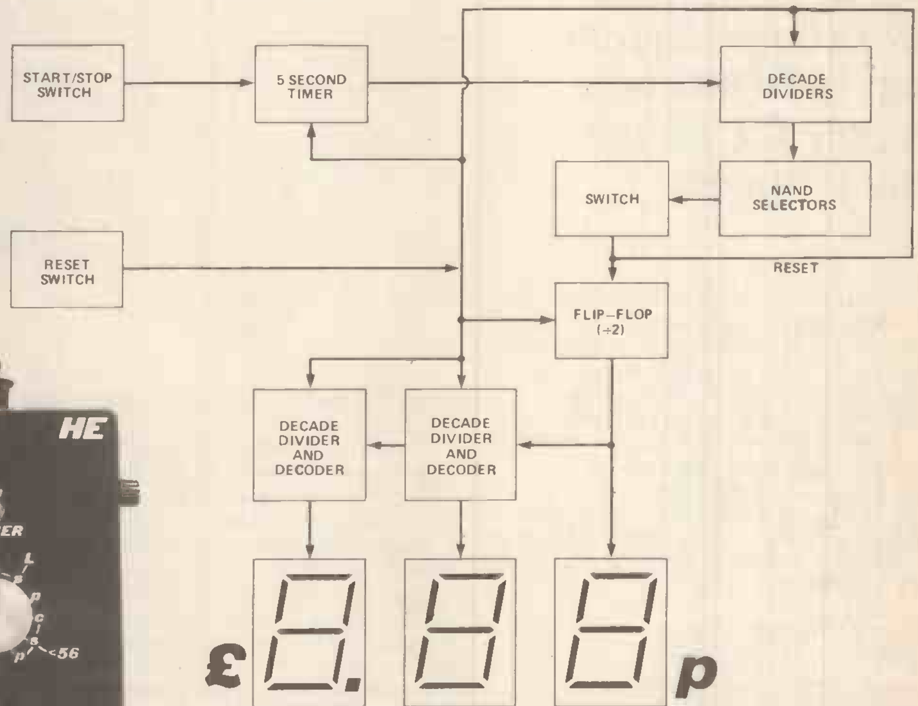


Table 1.

Distance	Rate	Rate seconds for 5p	No. of 5 S units*
LOCAL	CHEAP	480	96
	STANDARD	120	24
	PEAK	90	18
< 56 km	CHEAP	144	29
	STANDARD	45	9
	PEAK	30	6
> 56 km	CHEAP	48	10
	STANDARD	16	*4
	PEAK	12	*3

* ROUNDED UP.

Table 1. The telephone charge bands and the times allowed for a 5p unit. The last column shows the number of five second units in each band; the bottom two figures are rounded-up so that the amount calculated by the Timer will be slightly higher than the actual charge.

Parts List

RESISTORS
(All ¼ watt 5% carbon)
R1,2,3,4 . . . . 1M
R5 . . . . 330R
R6 . . . . 1k
R7 . . . . 100k
R8-22 . . . . 1k2
R23 . . . . 560R
R24 . . . . 330R

POTENTIOMETERS
RV1 . . . . 100k
sub-min. horizontal preset

CAPACITORS
RV1 . . . . 100n
disc ceramic or polyester
C2 . . . . 22u 25 V
tantalum bead

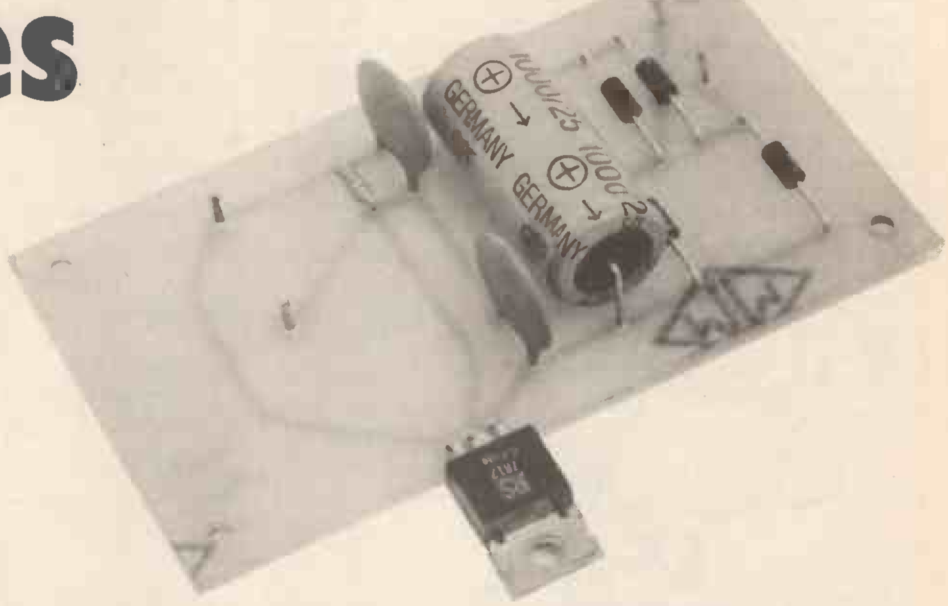
SEMICONDUCTORS
D1,2 . . . . 1N4148
signal diode
ZD1 . . . . BZY88C8V2
zener diode
Q1 . . . . 2N3819
N-channel FET
IC1 4001
CMOS quad 2-input NOR
IC2 4027
CMOS dual J-K flip-flop
IC3 . . . . NE555 timer
IC4,5,6 4011
CMOS quad 2-input NAND
IC7,8 4017
CMOS decade counter/divider
IC9,10 4033
CMOS counter/decoder/divider
DISP1,2,3 . . . . DL704 or similar
common cathode 7-segment display

MISCELLANEOUS
SW1 . . . . rotary switch, 1-pole 12-way
SW2,3 . . . . SPDT miniature push-to-change switch
SW4 . . . . DPDT miniature toggle switch
Bulgin 3-pin mains plug, socket; 20 mm panel mounting fuseholder; 750 mA fuse; knob; plastic for display window (red); PCBs; mains cable; mains plug; ribbon cable; case; screws, nuts and bolts; 12 V power supply (see PSU Design project); Veropins; IC sockets (optional); solder; wire etc.

BUYLINES . . . . **page 23**

Designing Power Supplies

Using this simple procedure, anyone can build a simple supply for almost any purpose.



THE POWER SUPPLY is one of the most fundamental circuits in all electronics. It is also one of the easiest circuits to design yourself, once you have the 'know how'. This article is intended to give you just that skill.

This month, we feature a project for a digital Telephone Timer which requires a 12 V, 400 mA regulated supply (**Figure 1**) and this will be used as an example, to demonstrate how the component values of a simple supply are calculated.

The Theory

Before you can begin to design a circuit, there is certain information that you must have at your fingertips. For power supplies, it is necessary to know the peak input voltage and the output voltage. The 'input' is the voltage delivered by the transformer to the rectifier. Unfortunately, this is not the voltage usually specified by transformer manufacturers, but it is easily obtained by multiplying the RMS voltage (which is specified) by 1.4 (see **Figure 2**). You might expect that this is the voltage delivered by the power supply — not so. Some voltage will be lost across the bridge rectifier. Most diodes produce a forward voltage drop (ie, when they are conducting) of about 0V7 and, since there are always two diodes passing current in a bridge, the drop across the bridge will be roughly 1V4.

The makers of voltage regulator ICs always specify some minimum voltage input to their device and it is generally about 2V5 higher than the required output voltage (eg, a 5 V regulator needs 7V5). To be on the safe side, assume that the minimum is 3 V higher. Now we know the maximum voltage which we can expect from the bridge rectifier, V_{BRIDGE}, and the minimum voltage needed to drive the regulator IC. The next step is to calculate the value of the filter capacitor, C1, which is there to 'smooth' the rectified mains voltage for the regulator IC.

The effect of the smoothing capacitor is shown in **Figure 3**. It charges up with each voltage peak, then discharges slowly as the rectified voltage falls to zero. The discharge time is such that C1 will not discharge completely, however, so the voltage never falls below a certain level which (aha!) must be the regulator minimum input voltage. The difference between the voltage peaks and the regulator minimum is the ripple voltage, V_R. Obviously, the value of the smoothing capacitor must be chosen so that the input voltage to the regulator never falls below the specified minimum.

The diagram of **Figure 3** shows cycles of the rectified mains voltage, enlarged. The quantity 'T' is the time (Period) between voltage peaks and it is equal to twice the mains frequency of 50 Hz ie, 100 Hz. Since the period, T, is the inverse of the frequency, T is 0.01 seconds.

Now a capacitor in a circuit which has resistance (and every circuit will have at least some resistance) will take a definite time to discharge the voltage stored on its plates. This time is the familiar RC time contant:

$$t = RC,$$

where t is the time, in seconds; C is the capacitance in Farads and R is the resistance in Ohms. Now from Ohm's Law, we also know that:

$$R = \frac{V}{I},$$

therefore, substituting the second equation into the first, we get:

$$t = \frac{CV}{I}$$

where I is the current required from the circuit; t is the time period over which the capacitor discharges and V is the voltage discharged in time t.

Now, since we don't want the capacitor voltage to drop below a certain minimum, V is the ripple voltage V_R, the difference between the rectified voltage peaks and the regulator minimum, and t is the period of the full-wave rectified mains.

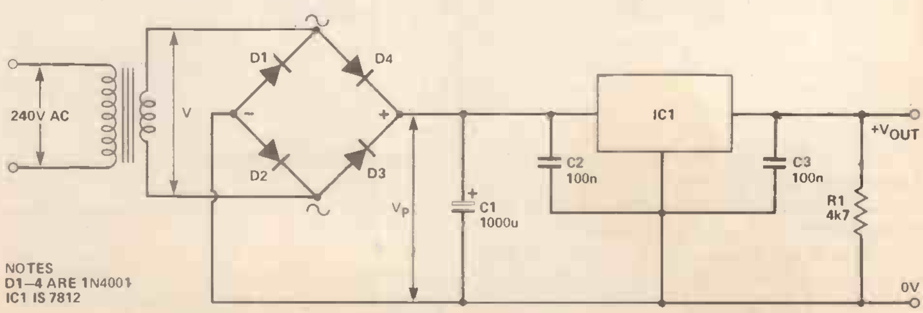


Figure 1. A simple regulated supply using one of the common three-terminal regulator ICs.

For Example

The remainder of the procedure is best illustrated by a practical example. The Telephone Timer requires a 12 V, 400 mA supply, as mentioned earlier. To choose a suitable transformer, select one which produces a slightly higher voltage than that required — usually the next one up in the range will do the trick, ie one with a 15 V winding. The power handling of a transformer is sometimes specified as Watts, but more often in terms of VA (Volt Amps). To calculate how many Watts (or VA) are required, use the simple power formula:

$$W = VI = 12 \times 400 \times 10^{-3} = 4.8 \text{ VA (Watts)}.$$

In fact, the most suitable transformer available was one with twin 15 V windings, each supplying 3 VA; the windings were simply connected in parallel to give the required voltage and a power capability of 6 VA.

The next step is to calculate the voltage output from the bridge rectifier:

$$\begin{aligned} V_{BRIDGE} &= V_p - 1.4 \\ &= (V_{RMS} \times 1.4) - 1.4 \\ &= (15 \times 1.4) - 1.4 \\ &= 19.6 \text{ volts.} \end{aligned}$$

The regulator IC needs at least 15 V, so we are on the safe side with 19V6. The difference is the ripple, V_R:

$$V_R = 19.6 - 15 = 4.6 \text{ V}.$$

Now, using the formula for calculating the value of the smoothing capacitor C1, we have:

$$C = \frac{tI}{V_R} = \frac{0.01 \times 400 \times 10_{-3}}{4.6} = 870 \text{ uF}$$

This is not a preferred value, so use the next highest in the range, which is 1000 uF. It must cope with peak voltages of 15 x 1.4 = 21 V, so use a 25 V working electrolytic type.

Another point to consider is that the bridge diodes must be able to handle both the current and the peak voltage; the popular 1N4001 diodes, rated at 50 V and 1 A, are quite suitable here.

Finally, there is the regulator IC. The one used for this supply is the common 7812 variety, a 12 V 1 A three-terminal device. It would need a heatsink if used to pass current greater than 500 mA so in this case, a sink is not needed. Capacitors C2, 3 are essential to prevent high frequency oscillations; the values are generally specified in the maker's data so they are not a problem; the point to note, however, is that they should be mounted as close to the IC as possible. Resistor R1 is included to prevent the IC from running into an open circuit; this could result in damage to the device so R1 is used to draw some current (2.5 mA) even if the output is open circuited.

And that completes the circuit design — it's as easy as that! Although we have illustrated this procedure with a specific supply (12 V at 400 mA), it can be used with any three-terminal regulator IC to design a supply for any voltage and current. The next step is one you must make yourself! **HE**

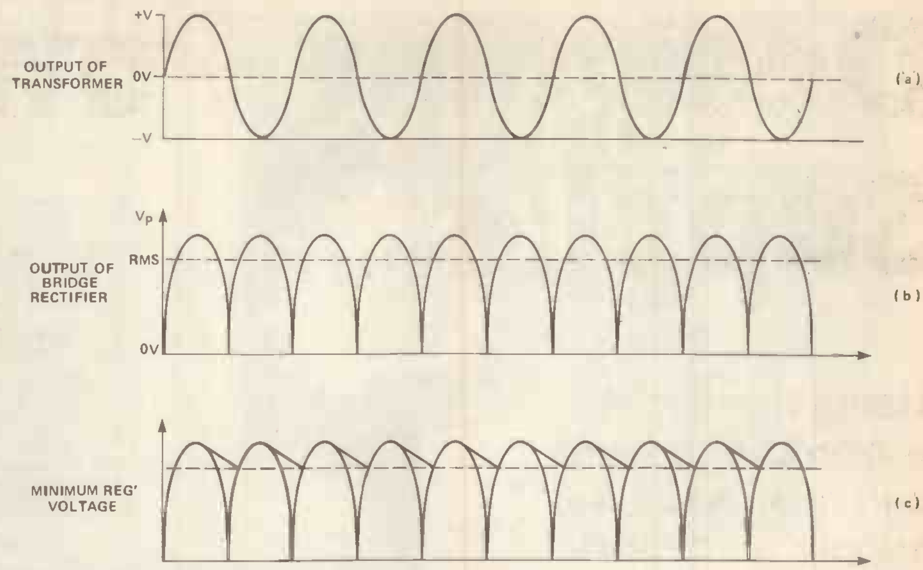


Figure 2. Power supply waveforms: (a) The output of the transformer; (b) Output of the bridge rectifier; (c) Input to the regulator IC.

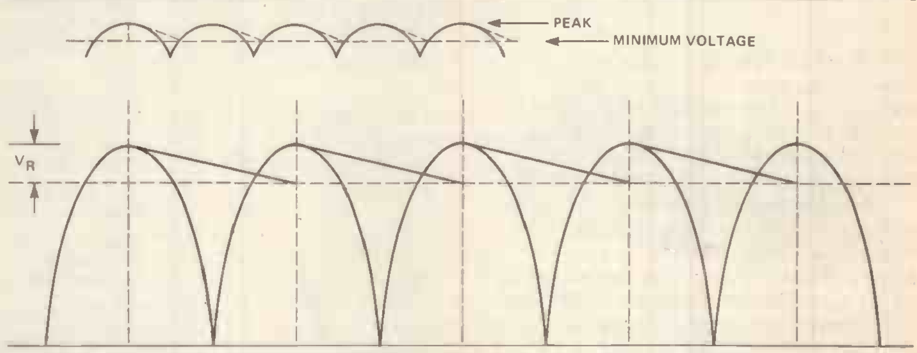


Figure 3. An enlarged view of Figure 2(c), showing the effect of the smoothing capacitor.

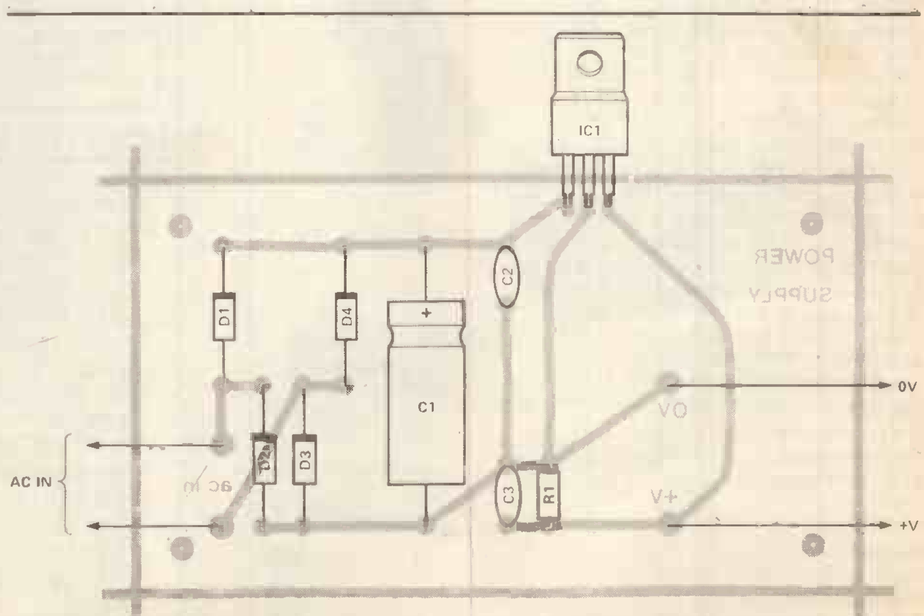


Figure 4. A PCB layout for the supply for the Telephone Timer. The foil pattern is reproduced on the PCB page.

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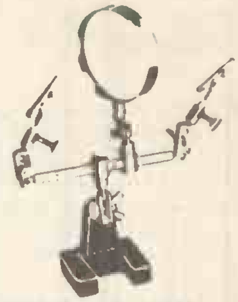

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POINTS OF VIEW

Pointed Suggestions

Dear Sir,
May I take advantage of your invitation in Points of View and submit two circuit ideas I have not yet seen published anywhere, but which would be very useful to amateur photographers who are interested in colour printing.

The first one is a mains stabiliser suitable for the transformer system of the Durst and many other colour enlargers. The second is a good colour analyser for colour balancing negatives while printing. This would be a great saver of time, paper and temper.

Thank you for a friendly and informative magazine. I am off, now, to make the Digital Capacitance Meter (April '82 issue). I've needed one as good as that for a long time!
G. Walton,
Darlington,
Co. Durham.

We receive many and varied requests for photographic equipment projects. Unfortunately, many of them have to be ruled out because of the complications involved (optics, mechanics, reliability and accuracy, to mention just a few of the difficulties) and the colour analyser certainly falls into this group. There are several commercial units, though, that should not "break the bank". The Melico range, for example, starts at about £80, while Durst's analysers are priced from around £90. They are available from Wallace Heaton's, New Bond Street, London. The mains stabiliser is a more practical project and, after lengthy discussions with our photographic staff, we have commenced work on a suitable design. Our Digital Capacitance Meter, incidentally, has proved to be one of our all-time most popular projects. Thanks are due to the designer, Owen Bishop.

CB Circuits

Dear Sir,
Please could you help me. I have a CB radio and sometimes, when talking to people, the conversation comes round to professions and I am asked if I could do something about an ailing rig — my profession is telecommunications.

Okay, when you look at a transmitter or receiver, you can pick out the various stages, ie RF stages, mixers, IF and so on, but when it comes to actually fault-finding and there is no circuit diagram to work from, the trouble really starts.

Could you tell me where I can get hold of CB radio circuit diagrams? I have thought of writing to the manufacturers, but I think they would turn me down. I hope you can help me.
N.J. Treacher,
RAF Henlow,
Beds.

This is a problem often encountered by those who know something about electronics and, as a consequence, are often asked to do a repair job on friend's hi-fi or CB rig. Without a circuit diagram, what could be a simple job can turn into a nightmare. Unfortunately, there is no easy solution; we certainly don't keep circuits for commercial equipment of any kind, so we can't help you. In fact about the only thing you can do is try the manufacturers — you might be lucky!

Filter Scratched

Dear Sirs,
I have recently completed the Scratch and Rumble Filter project from your Projects Special Vol. 1.

Everything in the filter seems to be working but — the power output from the amplifier has dropped. I don't know by how many watts, but the loss is considerable. Wearing headphones, before fitting the filter, number '8' on the volume slider would have blasted my head off; now the volume almost disappears at about '3', going down the scale.

I would like to add that I have built the unit into my record player and not in a separate box. Is it possible that the pick-up lead is now too long, thereby increasing the resistance to the signal from the stylus? If not, maybe you could shed some light on what has gone wrong.

I have, by the way, made the unit in stereo. I would be very grateful for any help.
L.T. Daniels,
Havant,
Hants.

The clue to this problem is in the suggestion that the pick-up lead may be too long — though this is not actually the cause of the fault. The suggestion hints that the filter is connected between the pick-up and the pre-amplifier. If this is so, it's the cause of the problem. The filter does not include a pre-amplifier, so it simply cannot work well in this position. Place it between the pre-amplifier output and the main amp input, and full volume should be restored to you!

Circuit Diagrams and Backnumbers

Dear Sir,
I am doing an electronics project on various types of remote control, ie infra-red, ultrasonic and radio control. I would be grateful if you could send me any circuit diagrams of transmitters or receivers for each particular type; also applications and the project layouts.
P.A. Robinson,
Birmingham.

Once more, we have to point out that we simply cannot accept blanket requests, such as Mr. Robinson's, for circuit diagrams of HE projects. Of course we have published many remote control projects, of all types, and they are always available from our Back Numbers department (see page XX), but they too can only deal with specific requests. The essential information they need is the name of the project and the issue in which it appeared. If you do not have this information, then why not send in for photocopies of the Indexes to Volumes 1, 2 and 3? We strongly recommend this to anyone who requires either a single circuit or a number of circuits, for a particular project.

0-60 In 3 Hours

Dear Sir,
I have recently made the Speed Controller for R/C models featured in the April 1980 issue of Hobby Electronics. I bought the Hobbyprint and constructed the circuit, making slight alterations to fit it in my Tamiya Rough Rider, namely; mounting the relay alongside, instead of on the board, changing the two parallel TIP3055s for a single 2N3055 and putting in an 18R, 1 W resistor on the base. After making the checks explained in the magazine, I tried out the Controller.

The motor reaches full speed in both directions and the proportional speed control also works — but the acceleration of the car is seriously impaired. It used to reach full speed in a couple of yards but now it takes ten times that distance and, at the start, it just crawls along. This is no use, for this type of car. Please can you help me?
A. Anderson,
Glasgow.

There are a number of possible reasons why your super-car has turned into a plodder. For example, are you using heavy gauge wire for the motor cables, and the correct battery? The most likely cause, however, is the substitution of a single transistor where the design called for two. The current gain of any transistor falls off at high currents — such as those passed when the motor is building up speed — so it is unlikely that one 2N3055 will handle the peak current. Remember, the design is intended to supply up to

15 A, which is the absolute maximum current rating of a 2N3055! The solution must be to either revert to the original circuit or, if you are cramped for space (and also wish to indulge a taste for over-kill), substitute an MJ11016; this is a high power Darlington rated up to 30 A and with a minimum current gain of 1000 at 20 A. One of those, and you can really burn up the track!

CB Supplies

Dear Sir,
I am writing to ask if you can produce for me, and the many others who read Hobby Electronics, a circuit for a Citizens' Band radio power supply, ie a supply producing 12 V DC at between 3.5 and 5 amps, at a budget price. For a small unit such as this, one can easily spend £12 for something quite plasticky.

I would be extremely grateful if you could publish one as a project in HE. I'm sure that such a project would sell like 'hot cakes'. If it is not possible, please could you send me a copy of a suitable circuit? Many thanks, and thanks also for a great mag.
A. Postle,
Letchworth,
Herts.
PS. It would be nice if you had an article about how CB is getting on!

A CB power supply project has already been published — by our cousins, Citizens' Band magazine. It appeared in their January 1981 issue and a copy is available from their Backnumbers Department, at our usual address. Alternatively, you might like to try designing and building your own — see our Power Supply Design feature on page XX. The only additional precautions you should take are to make sure that the smoothing is adequate (you don't want 50/100 Hz hum on the speaker) and to use a good heatsink.

Baby's Alarming

Dear Sir,
I have been trying to build the Baby Alarm project from the October 1981 issue of Hobby Electronics. Unfortunately, despite a lot of experimentation, I cannot get it to work. When I connect a microphone and speaker, all it produces is a constant high pitched note. As far as I can see, I've made no mistakes in the construction.

The microphone I have used is a 600R capacitance mic running from a 1V5 battery. Is this inappropriate? The article mentions that several track breaks are required on the board, yet they are not shown on the diagram and I can see no need for them. Is this an error?

If you have any idea of what mistakes I have made, I would be grateful if you could tell me.

Secondly, I have been trying to obtain a dual-gang variable capacitor (208pF plus 176pF, Jackson type 'O'). If you have any idea where I might obtain one I would appreciate your advice.

Thank you very much.
P. Lusley,
Islington,
London.

No track breaks are actually needed, as the circuit is laid out — however, if the board is mounted using metal machine screws, breaks will be required between the mounting holes and the components. The "high pitched note" described above sounds suspiciously like acoustic feedback; eliminate this possibility by separating the mic and speaker by at least six feet — more, if it can be arranged. If the howl persists, other causes must be sought. There is no reason why a capacitance mic should be unsuitable, provided it is AC coupled to the base of Q1, as shown in the circuit. The variable capacitor you're after is listed in the Maplin catalogue as a Type 00.

Reader's Mods

Dear Sir,
With reference to the Intruder Alarm (HE, October 1980), could you please tell me how to incorporate a delay in to the system so that one has, say, fifteen to thirty seconds in which to close the outside door when leaving the house, and a similar delay time in which to switch off the system when you return?

I cannot see any reference to this facility, although I would have thought it to be a logical requirement.

Also, could you recommend a suitable source of supply for the components, including the reed switches and magnets, alarm box for external fitting and the control box?

I thank you in anticipation of your kind attention.
M. Toogood,
Southampton.

An excellent idea, which has been passed to our design team. A satisfactory modification should not be too difficult to devise. As to a source for the components, try Magenta Electronics, 135 Hunter Street, Burton-on-Trent, Staffs. DE14 2ST.; Tel. 0283 65435.

Alarm Wanted

Dear Sir,
I am a student attending The College, Swindon, where I am studying a course in Technology and Engineering.

As part of the course I am required to carry out a project to design and build a device to detect the presence of a human or animal intruder in a building. Some system of control monitoring is required and if an intruder is detected it should activate a control monitor.

I am writing to ask for a design for a simple circuit that I can use. It should work as a movement detector or light detector, sound detector or an all-in-one device.
Yours,
G.A. Kembo,
Swindon,
Wilts.

We have published a great many burglar or intruder alarms, over the years — the latest was the Ultrsound Alarm, mentioned above. A photocopy of the article can be obtained from our Backnumbers Department.

Errata

Clever Dick has passed on a letter from G. Beckingham of Gloucester, who has noted an error in the HE Echo-Reverb (May '82 issue). The mains transformer should be a 7V5-0-7V5 type, if it is to be connected as shown in the component overlay, ie the windings in series. An alternative, for anyone who already has the transformer, is to connect the windings in parallel by modifying the PCB as follows: cut the track joining the two windings and, using insulated wire links, join the two 15 V pins together, then join the 0 V pins.

The Parts List for the Digital Capacitance Meter (April '82) shows PR2 as 47k; it should be 4k7, as shown on the circuit diagram. In addition, R3 and R5 on the component wiring diagram (Figure 3, page 28) should be in reverse order ie, R3 should be at the top and R5 at the bottom.

W.D. Hughes of Bristol has a problem with the Infra-Red Remote unit, from the February 1980 issue; the fault probably lies with R24 which should be 1k0 as shown in the Parts List, not 1M0 as indicated on the circuit. Also, the last paragraph on page 32 should read: "(1) The EARTHS of the mains input cables . . .", not the neutrals, as stated.

J. Reed of Edinburgh has noted (yet another) error in the Intruder Confuser (January '82). On the Veroboard layout, a track-break should be made between the ends of C1. This project is the only one this year which has contained major errors; they arose from our misguided attempts to 'tidy up' the circuit and layout — unfortunately, we "got our wires crossed" in the process, but at least we've learnt from the experience (leave well enough alone!).

A correction for the Kitchen Timer (October 1980), which we published in these pages in the March '82 issue, may interest Mr. P.S. Woodward, from Worthing in West Sussex; R17 should be 3k9, not 82k.

Writing to Hobby Electronics

Would readers please note that we cannot reply personally to letters unless a stamped, self-addressed envelope is included. This applies particularly to ALL technical enquiries.

HE

Hobby Electronics

NEXT MONTH . . .

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A practical guide to the essential technology of solar power, together with some simple Breadboard-style ideas for experimenters.

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RADIO RULES

Getting to grips with the theory.

Ian Sinclair

THE MOST important type of wave, for radio, is the sine wave. The name, incidentally comes from a Latin word meaning "snake" and the shape of the graph of voltage plotted against time for a sinewave shows why the name was chosen! The name 'sine' is also given to a mathematical function; it is the ratio of two of the sides of a triangle, as shown in **Figure 2**. The sine of an angle is a number whose value lies between 0 and 1 and which is negative if the angle is between 180° and 360°. If we plot the sine of an angle against the size of the angle, then we end up with a perfect sinewave.

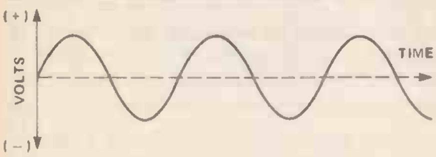


Figure 1. A sine wave — voltage (or current) plotted against time.

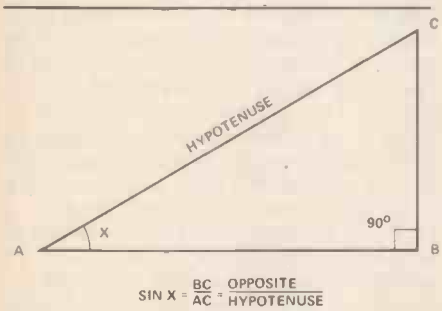


Figure 2. In mathematics, the sine of an angle is the ratio of two sides of a triangle, ie the side opposite the angle, X, divided by the hypotenuse.

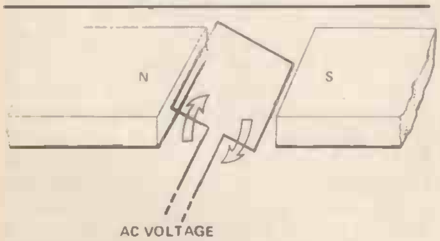


Figure 3. A sine wave is generated when a coil of wire rotates between the poles of a magnet.

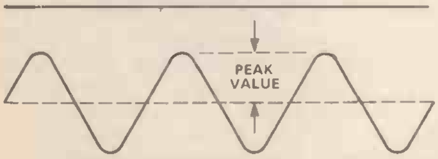


Figure 4. Peak and RMS values of a sinewave. Peak values are more useful in radio work because they are easily measured on an oscillocspe. Meters give RMS values.

Like any other wave, a sinewave will have a frequency, ie the number of com plete cycles of the wave in one second. It will also have an amplitude, which we measure as a peak value (**Figure 4**) or as an RMS value, which is 0.707 x Peak value (or Peak divided by 1.4, which comes to the same thing). Two sinewaves with the same amplitude and the same frequency may not be identical, however, because there may be a phase angle difference. This means that the peaks of the waves do not coincide; it's the effect you would expect to see if one wave started before the other, or if one were delayed. The instantaneous voltage of a sinewave at any time is the voltage at that instant (logically enough) and it is given by the equation:

$$V_i = V_p (\sin 2\pi f_t + \phi)$$

We aren't forced to use this mathematical way of working with phase and instantaneous voltage, because there is a simpler way, using what are called phasors. A phasor (no, it itsn't Capt. Kirk's ray-gun) is a line whose length represents the peak value of a sinewave and whose angle to the horizontal represents the phase of the wave. **Figure 6** shows a simple phasor diagram — this method of representing phase is very useful and we'll return to it when we start to look at the behaviour of inductors, capacitors and resistors in AC circuits. But now it's time to look at some even more basic ideas.

Magnetic Appeal

Magnetism is one topic we need to know something about. Ignoring permanent magnets for the moment, we can create magnetism by passing a current along a piece of wire. Doing that (**Figure 7**) causes the shape of space (yes, invisible space), around the wire to change, so that when you hold a compass needle at different points round the wire, at the same distances, the needle points in directions which indicate a circle. We call this particular distortion of space a magnetic field and it affects all materials, but a few materials, like iron and its alloys, are very strongly affected. We can, therefore, use these materials to trace the shape of the magnetic field.

The field around a straight wire does not extend for a great distance beyond the wire — it tails off to almost zero at a distance of a few centimetres. When wire is wound into a coil, however, and current is passed through it, the magnetic field becomes much stronger because the effect of each turn of the coil is added to the effect of the other turns. The shape of the new field is

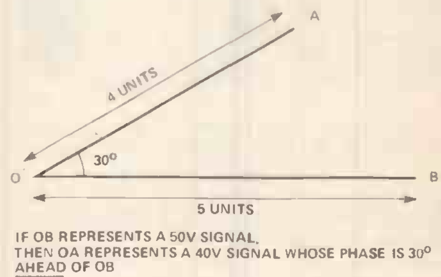


Figure 6. A phasor diagram. Imagine that both lines are revolving anticlockwise around point 'O'; the line OB is the zero-phase position. As both lines revolve, the line OA passes through zero before the line OB; OA is said to 'lead' OB, by 30 in this example.

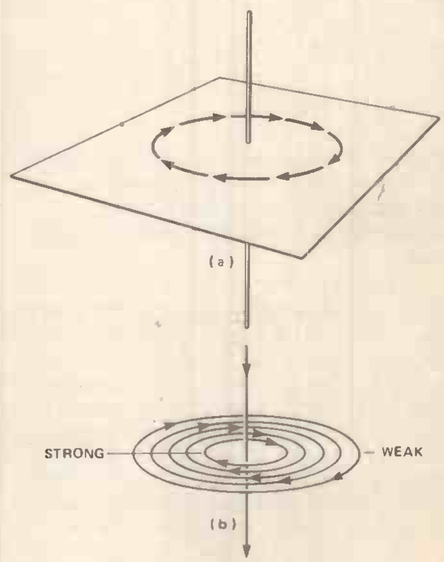


Figure 7. The magnetic field around a wire carrying a Direct Current. The shape of the field is circular and it is very weak at distances of more than a few centimetres.

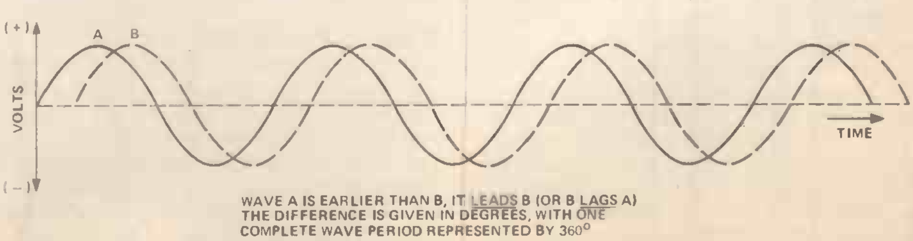


Figure 5. The phase relationship between two sine waves.

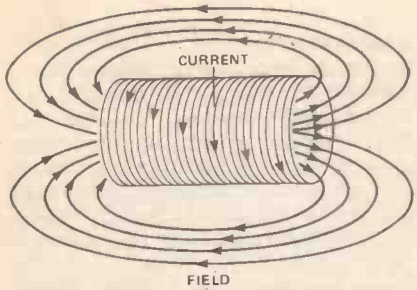
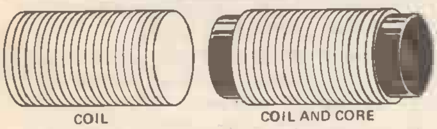


Figure 8. The shape of a field produced by a solenoid is almost identical to that of a bar magnet.



$$\text{RELATIVE PERMEABILITY OF CORE} = \frac{\text{FIELD STRENGTH WITH CORE}}{\text{FIELD STRENGTH WITHOUT CORE}}$$

(SAME COIL, SAME CURRENT)

Figure 9. A mathematical definition of relative permeability.

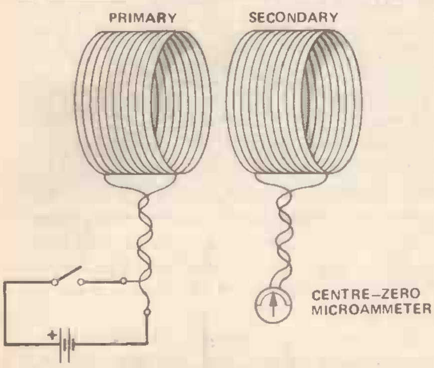


Figure 10. Induction without movement — the transformer effect; changing current in the primary coil causes a voltage to be induced in the secondary coil.

shown in Figure 8 and it's pretty much the same as the shape of the field that you get from a bar-shaped permanent magnet. The strength of the magnetic field of any coil is greatly increased by placing magnetic materials inside the coil (a core) and the shape of the field also becomes more compact, particularly when the materials are of the type called "soft" magnetic materials. The word "soft" doesn't mean that you can squeeze them out of shape — some of these materials are, in fact, very hard and brittle — it simply means that they are magnetically "soft"; you can't magnetise them permanently. Unlike hard magnetic materials, which are used to make permanent magnets, soft magnetic materials lose their magnetism whenever they are removed from the coil, or when the current is switched off.

The ratio by which the strength of the magnetic field is increased by the presence of a core is called the *relative permeability* of the core; it is the quantity defined in Figure 9. The word "relative" is sometimes omitted though, strictly speaking, this changes the meaning. Soft magnetic materials can have very

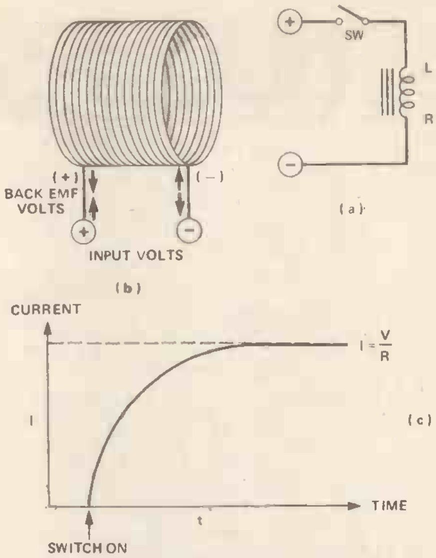


Figure 11. (a) A Back-EMF is always produced when a voltage is switched across a coil; (b) Its direction is such that it always opposes the current, and hence the voltage, which is actually causing the Back-EMF; (c) The result is that when a voltage is applied, the current changes only gradually.

large values of relative permeability — one million or more — but the value is not constant; it depends on a lot of factors like the previous history of the material (was it magnetised before, was it heated?) and the way in which it has been magnetised.

Electricity From Mag

Just as we can produce a magnetic field from the current flowing in a wire, so we can also produce electricity from a moving magnetic field — this was the great contribution that Michael Faraday made to electrical history. A permanent magnet, for example, moved into a coil of wire (a solenoid) will cause a voltage to be generated and we can obtain a similar effect, without any visible movement if we place two coils close together (Figure 10) and switch a current on and off in the circuit connected to one coil, the primary coil. This will cause a voltage to be generated in the second coil, the secondary, but only for as long as the current in the primary coil is changing. A steady (DC) current causes no voltage to be generated. The effect is called electromagnetic induction and the voltage produced in the second coil is an induced voltage. This principle is that of the transformer, which can be used with AC only, because only in AC circuits will the current in the primary coil be changing continually.

Induce Yourself

Changing the current through a coil of wire won't just induce a voltage in another nearby coil, though, it will also induce a voltage in itself! This effect is called self-inducation and the voltage which is induced will be in a direction which *opposes* the changing current that actually causes it (Figure 11). This is a *back-EMF* (the EMF means Electro-

E = L x RATE OF CHANGE OF CURRENT WRITTEN AS

$$E = L\frac{\Delta I}{\Delta T}$$

WHERE Δ MEANS 'CHANGE OF'

Figure 12. The equation for the self-inductance of a coil.

$$L \propto \frac{AN^2}{l}$$

A = AREA OF CROSS SECTION
N = NUMBER OF TURNS
l = MAGNETIC LENGTH
$\propto$ = 'PROPORTIONAL TO'

Figure 13. This formula cannot be used for calculating the inductance of a coil, but it does show how changing diemnsions changes the inductance.

$$N_2^2 = \frac{N_1^2 \times L_2}{L_1}$$

L_1 = INDUCTANCE, N_1 = TURNS — FIRST EXAMPLE
L_2 = INDUCTANCE, N_2 = TURNS — SECOND EXAMPLE

Figure 14. The formula of Figure 13 can be rearranged to calculate the number of turns that must be removed (or added) to change the inductance of a given coil.

Motive Force, an old word for a generated voltage) and we can use this voltage to measure a useful quantity, the self-inductance of the coil, usually indicated by the letter 'L' in radio formulae. The equation that links inductance with back-EMF is shown in Figure 12. The unit of self-inductance is the Henry, named after the American physicist, Joseph Henry; one Henry is the self-inductance when a current changing at the rate of one amp per second produces a back-EMF of one volt. One Henry is a very large amount of inductance — a quantity we aren't likely to use except in smoothing inductors for power packs or in loudspeaker cross-over networks — so that smaller quantities such as the millihenry (mH), one thousandth of a henry (0.001 H) and the microhenry (uH), which is one millionth of a henry (0.000001 H), are more usually found.

The inductance of a coil can be measured, but it can't be calculated simply from its dimensions and the number of turns, so that we need to use charts, nomograms and other aids to calculation. One useful, approximate, relationship is shown in the formula of Figure 13, however — the inductance is proportional to the area of cross-section of the wire multiplied by the square of the number of turns and divided by the 'magnetic length'. This last quantity refers to the length of the magnetic field in the core and isn't necessarily equal to the physical length of the coil but, all other things being equal, it means that if you separate the turns of a coil you will increase its magnetic length and reduce its inductance. Similarly, increasing the number of turns will considerably increase the inductance — doubling the number of turns without changing the length (by using thinner wire) will make the self-inductance four times as great (because $2^2 = 4$).

Because this formula applies reasonably well to a coil which has already been designed, it is a useful way of adjusting the value of inductance

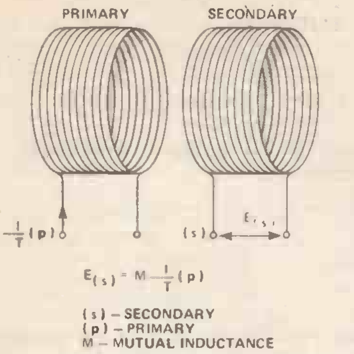


Figure 15. Mutual inductance is the basis of the transformer effect of Figure 10.

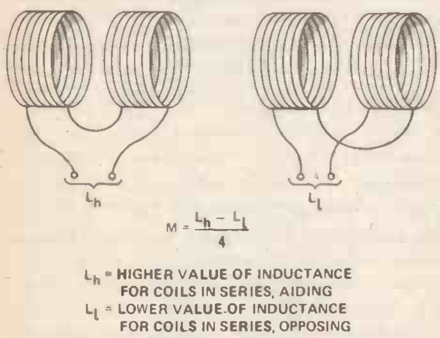


Figure 16. Mutual inductance cannot be easily calculated but it can be measured.

slightly. For example, suppose you have a coil of 80 turns which has an inductance, with the core in place, of 300 uH. How many turns do you have to take off to make the inductance 280 uH? The answer can be obtained by chopping the formula around to the form shown in **Figure 14**, retaining only the number of turns because the other quantities can be kept approximately constant. Yes, the length will change, but not by much and you could, if you wanted to be fussy, adjust the remaining turns to take up the same length on the core. Using

$$N_2^2 = \frac{N_1^2 \times L_2}{L_1},$$

we have

$$N_2^2 = \frac{80^2 \times 280}{300},$$

which is 5973.3. The square root of N_2^2 is 77.3, equal to N_2. That's only about three turns off the coil (told you it wouldn't change much!) to make the adjustment. In practice, you don't have to worry about fractions of a turn, except for VHF coils, because you can make fine adjustments by pulling out the turns of the coil (increasing length) or compressing them closer (decreasing length).

It's Mutual

A pair of coils arranged as a transformer will have mutual inductance as well as two lots of self-inductance and this quantity is defined in the same way as self-inductance, except that the change of current is measured in one coil and the induced voltage in the other (**Figure 15**). The mutual inductance is also measured in units of Henrys but is a lot more difficult to calculate, because it depends on how closely the coils are coupled — meaning how much of the magnetic field of one coil affects the other. Mutual inductance can very seldom be satisfactorily calculated; it normally has to be measured by a bridge circuit or by making two separate measurements of the self inductance of the coils, connected in series with each other. Two measurements are made and the connections to one coil are reversed for one of the measurements. The readings are then used to find mutual inductance using the formula in **Figure 16**.

In practice, there's a huge variation in the shapes and sizes of inductors, according to the job that they are intended to do. Basically, the slower the rate of change of current (which means lower frequency), the bigger the inductor needs to be and the heavier the core. For smoothing 50 Hz ripple in a half-wave power supply, you might need a couple of thousand turns of fine wire wound on a paxolin bobbin with a set of soft-iron laminations inserted tightly into the centre of the bobbin to make a core inside and outside the coil, guiding the magnetic field around it. At the other end of the scale, if you were dealing with VHF, where the rate of change of current is extremely fast, a couple of turns of thick wire in air, with no core, might be all the inductance you needed. For UHF, you find that you don't need coils at all — a straight strip of metal a few centimetres long is as much inductance as you need.

Between these extremes, a very useful form of construction that sees a lot of use is the iron-dust or ferrite cored inductor. This consists of a plastic tubular former with a core of a non-conducting magnetic material. The coil is wound on to the former and its inductance value is varied by screwing the core up or down inside the former. Transformers for frequencies ranging between 100 kHz and 50 MHz or so can be made in this way.

In general, if you are constructing equipment and you are instructed to wind a coil of 30 turns on a 10 mm diameter former which is fitted with a specified type of core, don't be tempted to deviate from this specification unless you know how much inductance is needed — and you have some method of measuring exactly how much you end up with.

Capacitance

The other electrical quantity which is important in AC circuits is capacitance. Capacitance is the ability to store electric charge, the stuff whose movement we call electric current, and there is always *some* capacitance between any two points which are at different voltages, even momentarily. Capacitance is defined as the ratio of charge stored to the voltage between the points. Some capacitances in our circuits are 'stray', meaning that they exist simply because there are pieces of metal close to each other in the circuit, but most of the capacitors we use have been deliberately designed and manufactured.

The simplest type of capacitor consists of two plates of metal which are separated by an insulator; this arrangement is called a parallel-plate capacitor. The amount of capacitance — how much charge the arrangement can store, per volt placed across the plates — depends on the area of the plates (assumed to be identical and aligned with each other), the distance between the plates and the type of insulating material placed between the plates. The formula is shown in **Figure 17** — note, in particular, that the capacitance is *increased* by putting the plates closer together and is also increased by using materials like ceramics, which have a large 'relative permittivity' as insulators. Don't confuse relative permittivity with relative permeability (of a magnetic material); permittivity is quite a different quantity and its values are lower; a relative permittivity of 100 or more is very unusual.

The insulating material, or dielectric, between the plates also provides the insulation for the capacitor and the voltage applied between the plates must never be so great that it will break down this insulation. The type of dielectric also depends on the frequency of the signals that are to be handled. Mica, for example, can be used at the highest frequencies for which we make capacitors, whereas paper is useful only to about 20 MHz and is seldom used nowadays.

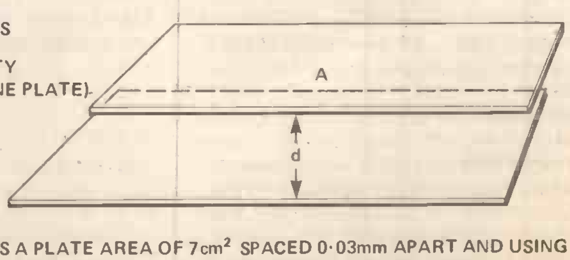
The value of a capacitance is measured in units called Farads — you have a capacitance of one farad when a charge of one coulomb causes the voltage across the plates to increase by one volt. Unfortunately, the Farad is a huge unit and we need to use smaller units, such as microfarads (uF, 0.00000

$C = \frac{E_r A}{d} \times 0{\cdot}884$ PICOFARADS

E_r = RELATIVE PERMITTIVITY

A = AREA IN SQUARE cm (ONE PLATE)

d = SPACING IN mm



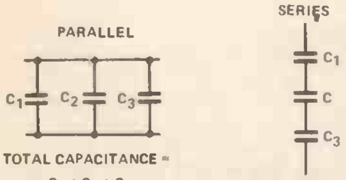
EXAMPLE: A CAPACITOR HAS A PLATE AREA OF 7cm² SPACED 0·03mm APART AND USING MICA WITH RELATIVE PERMITTIVITY = 5, WHAT IS ITS CAPACITANCE ?

SOLUTION: CAPACITANCE = $\frac{5 \times 7}{{\cdot}03} \times 0{\cdot}884$p = 1031p OR 1n03

Figure 17. The capacitance of two parallel metal plates, slightly separated.

PARALLEL

SERIES



TOTAL CAPACITANCE = $C_1 + C_2 + C_3$

IF C_T IS TOTAL CAPACITANCE

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

EXAMPLE: CAPACITORS OF 100p, 150p, AND 200p IN PARALLEL GIVE A TOTAL OF 450p

EXAMPLE: CAPACITORS OF 100p, 150p AND 200p IN SERIES

$$\frac{1}{CT} = \frac{1}{100} + \frac{1}{150} + \frac{1}{200} = 0{\cdot}0216 \qquad \therefore CT = \frac{1}{0.0216} \approx 46p2$$

Figure 18. Calculating the overall value of capacitors connected in series or in parallel.

1 F), even smaller units such as nanofarads (nF, 0.001 uF) or picofarads (pF, 0.00000 1 uF). Watch carefully which values are used in equations, because some make use of the capacitance measured in Farads, some in microfarads and some in picofarads.

Fixed capacitors can be made from metallised mica or ceramics and the metallized plates can be stacked together to provide larger values, because connecting capacitors in parallel gives an increased value — see **Figure 18** for capacitor connections in series and in parallel. Mica capacitors are used in 'important' parts of radio circuits, where any change in the value of a capacitor would cause de-tuning, for example. Ceramics, by contrast, are used mainly in less important places in which the precise value is less important.

Paper and (particularly nowadays) plastic dielectric capacitors are made by metallising both sides of a thin film of the dielectric material, which is in the shape of a long strip. The strip is then wound into a cylinder with another metallised strip to act as insulator (**Figure 19**). This type of construction is used for the larger values of capacitance, normally in audio stages or in some supply decoupling applications. Electrolytic capacitors use 'plates' (usually thin foil, wound into a spiral) made from aluminium or tantalum and separated by sheets of paper or cloth which have been impregnated with chemicals (ammonium perborate, if you must know). The chemicals are conducting — the insulator is the very thin film of aluminium oxide (or tantalum oxide, if this is the metal that is used) that forms on the metal surface when a voltage is applied to the capacitor to 'form' it. Once an electrolytic capacitor has been formed, the voltage should never be reversed, hence the polarity markings on electrolytic capacitors. Very large values of capacitance can be obtained in very small sizes, using electrolytics because the insulating film is so thin, but there is always a 'leakage' of DC current through an electrolytic and the voltages at which they can be used are comparatively low. Their main application is for smoothing power supply voltages and signal coupling in transistor audio circuits.

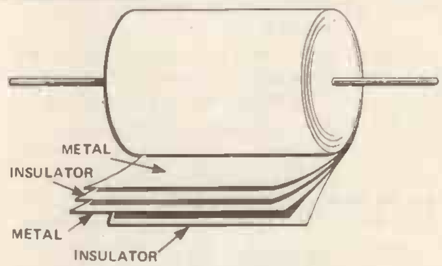


Figure 19. The rolled-strip construction commonly used for paper and plastic film capacitors.

Finally, variable capacitors allow us to alter capacitance and this is one of the main methods of tuning radio circuits, as we shall see later. Variables can be air-spaced, as they usually are in transmitter circuits, or solid-dielectric spaced, as they usually are in pocket radios, but the principle is the same — one set of plates is fixed, and the other can be meshed with them, so that the area of overlap changes. It is the changing area of overlap that accounts for the change of capacitance. The radio receiver types usually have minimum and maximum values of 30 pF and 300 pF respectively, but miniature types with much smaller values and ranges are used in radio transmitters and in short-wave receivers.

Join us next month to find out about time constants, reactance and tuned circuits.

HE

BUYLINES

ANOTHER month, another Buylines Page — making sure you know exactly where to buy ALL our project components. The listed suppliers are not the only sources for particular items, but are those companies we know who generally stock the components mentioned. Of course, if you intend buying a complete kit for a project, then you need not worry about getting separate parts. However, don't abandon this page, since we often include new suppliers and handy construction tips — both worth further investigation.

Power Supply

FOR such a straightforward project, the parts will be easy to obtain. However, the suppliers mentioned here are a good source for the necessary components.

The voltage regulator (7812), and other similar types are stocked by **Rapid Electronics** and **Delta Tech**; take your pick — you might also find a local stockist of these often-used ICs. Transformers can be bought from specialist suppliers — such as **Barrie Electronics** — or from other sources like **Watford** and **Technomatic**. If you fancy a toroidal type then you can order one direct from **ILP Electronics** using their freepost service.

The large value smoothing capacitor is available from **Electrovalue**, or you may be able to pick up a bargain from **Crimson Components** — remember, a higher voltage rating is fine, so long as the capacitor still fits on the board!

The cost for components will vary according to the voltage selected, but will be between £6-£10.

Auto-Wah

The Auto-Wah uses a few rare components but, in most cases, more standard types can be substituted for those used in the prototype. If you want to stick with the original design, the polycarbonate capacitors (6n8) are available from **Electrovalue**, though the commoner C280 variety will do; either way, you will find their range quite comprehensive. They have also assured us that they can obtain the unusual 'make' contact jack-sockets used to switch on the unit.

The semiconductors should not be hard to find, but you might like to try a new company for the 2N5088 transistors. **Benning Cross** are getting together their stock lines at the moment, so if you want anything particular then drop them a line. The only other supplier of 2N5088s that we could find, is **Cricklewood Electronics**. However, a suitable equivalent is the BC109C — a lot easier to buy.

The RC4558 is a relatively new IC that combines two 741s in an 8-pin DIL package. It is equivalent to the 1458, which is stocked by most companies. If you have any problems, try **Bi-Pak** or **Summit Electronics** (another new name for your checklist).

The case for our Auto-Wah (and rather smart it is too) is from the RS Components catalogue (No. 508-201); it can be ordered from any component supplier who normally stocks parts from the RS range. If you'd like to try a different one, then take a look at the new **West Hyde** catalogue, where you'll also find the PCB supports (standoffs to you!).

The total cost — using our PCB — will be around £15.

Auto Greenhouse

SOMETHING to bear in mind, when you're testing the HE Sprinkler, is to make sure you have a plentiful supply of water and somewhere to spray it — an early bath awaits those who don't heed this warning!

The components for this project are all fairly easy to obtain. The ZTX300 transistors are to be found in just about every supplier's list, so it's worth shopping around for the best buy. **Crimson Electronics** offer these, and other components, at very reasonable prices.

The CMOS ICs are all stocked by **Technomatic** who can also supply an alternative to the relay we used (RS catalogue No. 349-658). The siren is also from the RS catalogue (No. 249-794) and can be ordered from most suppliers. On the mechanical side, the water pump included in the design is, in fact, from a car-spares shop — just ask for a 12 V windscreen washer pump! Again, it's worth shopping around since you don't need anything elaborate.

One final point concerning the power supply circuit. The bridge rectifier in our prototype had a much higher spec than necessary so, unless you intend to run other items from the supply, any bridge that can handle 6 A at 50 V will do — **Delta Tech** are worth a call for a good deal on these and other commonly used components.

Without the case or windscreen-washer pump, the cost of the sprinkler will be around £12 (including our PCB).

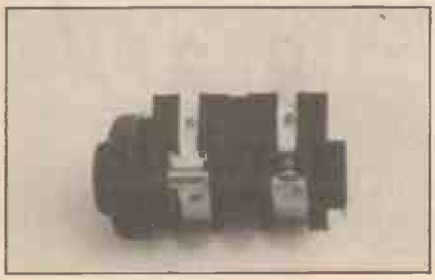
Telephone Timer

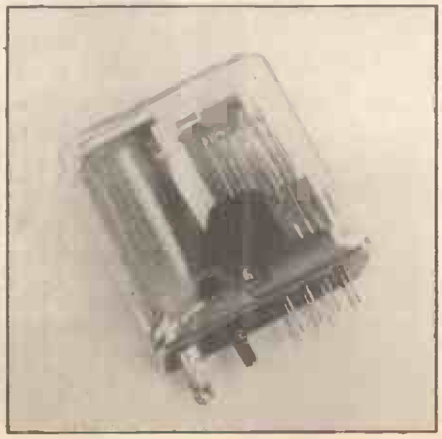
BEFORE starting this project, it's a good idea to sort out exactly where you want to put it. Ours is intended to be wall mounted, so the display was placed on a flat front panel. If you want yours to lay on the telephone table, you can try a case with a slanting top. Take a browse through one of **BICC-Vero's** catalogues for something suitable.

Now for the components themselves. The CMOS ICs are no problem with a company like **Technomatic** — their range is quite staggering. Another company well-known for its semiconductors is **Cricklewood Electronics**. For this project they can also supply the 22u tantalum capacitors, along with the small 7-segment displays. The ceramic disc capacitors are usually very easy to buy but, in this case, the required values are quite high (although you could try fitting a C280). The specified components are stocked by **Electrovalue** and, at the other end of the parts list they also keep the Bulgin mains connectors. **Bi-Pak**, who don't just sell bargain component packs, stock the rotary switches (Lorlin) and the push-to-break switches; alternatively, **Benning Cross** are stocking up on a wide range of switches and other associated hardware.

The only remaining parts you might have trouble with are the fuseholder (panel mounting) and the ribbon cable. Conveniently enough, both of these are available from **Watford Electronics**.

The components for the timer will be about £15, excluding the case, power supply and PCBs. **HE**





HE Auto-Wah

HE's auto-effect takes the work out of wah-wah.

Steve Giles

IT IS some sixteen years since the first guitar processing units became available. Those first effects units paved the way for controlled distortion and sophisticated filtering systems. Eventually, the development of phasers and flangers, in the seventies, gave the musician versatility and control from circuitry entirely within the unit's case. Other effects, like the wah-wah pedal, have external controls (a foot pedal attached to a pot which sweeps the filter up and down). Phasers and flangers are voltage controlled, by a slow oscillator, to provide their characteristic cyclic sweeping effect. So, no matter how hard the strings are plucked, the sound processing remains the same. This led to a desire for some additional responsiveness and, towards the end of the 1970s, guitar processing units appeared which were triggered by command signals from the guitar. This is similar to the way commands from a keyboard synthesiser can trigger envelope generators when a key is played. Of course, in the case of a guitar, this occurs when a string is plucked. The HE Auto-Wah is one such 'guitar triggered' effects unit. It can be built for a fraction of the cost of similar commercial units and will process signals in a number of interesting ways.

The usual circuit for a device of this type first feeds the guitar signals through an envelope follower. This produces a DC voltage that corresponds to the overall amplitude of the output from the instrument — strumming harder produces a higher DC output voltage. This feeds a comparator which goes high when the envelope follower voltage exceeds a certain threshold. It then drops back to zero when the envelope drops below this threshold. However, there is a problem in the case of guitar notes. Although the initial peak of a note will be more than sufficient to trigger the comparator, as the amplitude falls, there may be one or two extra peaks among the generally decaying level. These cause the envelope voltage to momentarily rise and retrigger the comparator. This is illustrated in **Figure 1** which shows two additional peaks *after* the envelope voltage has fallen below the comparator threshold. A considerable amount of circuitry is necessary to minimise such false triggering. Apart from being outside the scope of this article, it was not too much of a problem with our prototype unit, which simply used a high gain input amp to trigger a comparator. This allows the production of a new 'frequency-band' sweep each time a note is played (dependent on the settings of the sweep controls), so long as you don't pick too quickly.

With such sudden changes of state — a high output or zero — it's important to ensure that a complete filter cycle sweeps smoothly across the frequency range. To do this we used a field effect transistor, as a variable resistor, to control a bridge-T filtering network around an op-amp. By carefully adjusting the threshold control, it's possible to play chords with virtually no false triggering and produce quite a deep wah-wah effect.

Circuit Description

The circuit of **Figure 2** has two basic sections, one consisting of 1C1, Q1 and Q2 to produce the control voltage, and the other formed by IC2 and Q3 — the inverting bandpass filter. The signal is fed to IC1a, a non-inverting amplifier, whose gain is set at a high level by a large feedback resistor (R3). This ensures the unit functions properly from even low output guitars. The output from IC1a is then fed to pin 5 of IC1b via R4, where threshold control RV1 sets the point at which it will be triggered by 1C1a. The output from the comparator is rectified by D1 and passed to emitter follower Q1 (via R6) after charging C4, which is in parallel with R15. When IC1b goes high, it is followed by Q1, providing a smooth charging action on C2 until the emitter voltage is attained. At this point, C2 discharges through R7, RV2 and RV3 to the 0 V rail. The voltage level for Q1 is set by RV2, since it controls the point at which C2 begins to discharge. The ramp voltage on C2 is fed to RV4 and also via R9 to an inverter, based around Q2. The inverted signal goes to the other end of RV4, which acts as a balance control to provide some control over the shape of the envelope. The voltage at RV4's wiper is then passed to the gate of Q3, a field effect transistor (FET), which operates as a part of the input, via C8 and R17. In this way the signal is band-pass filtered, with C5 and C6 chosen for optimum sound effect. These two capacitors determine which narrow band of the guitar signal is boosted. This band is moved up and down the audio spectrum by varying the drain-source resistance of Q3 — producing the familiar wah-wah effect. The voltage fed to Q3's gate is therefore affected by the setting of RV4, which sweeps the filter from the bass or treble end. Since this type of FET requires a control voltage negative to half the supply rail, the series combination of R14 and RV5 provide a bias to shift the gate voltage between 0 V and half the supply.

Filter decoupling is provided by C7

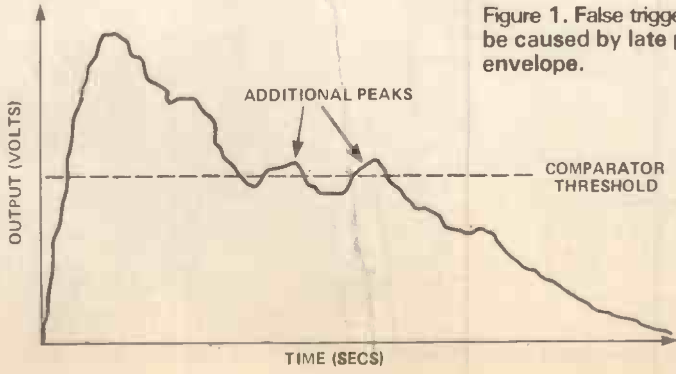


Figure 1. False triggering of an auto-wah can be caused by late peaks in the voltage envelope.

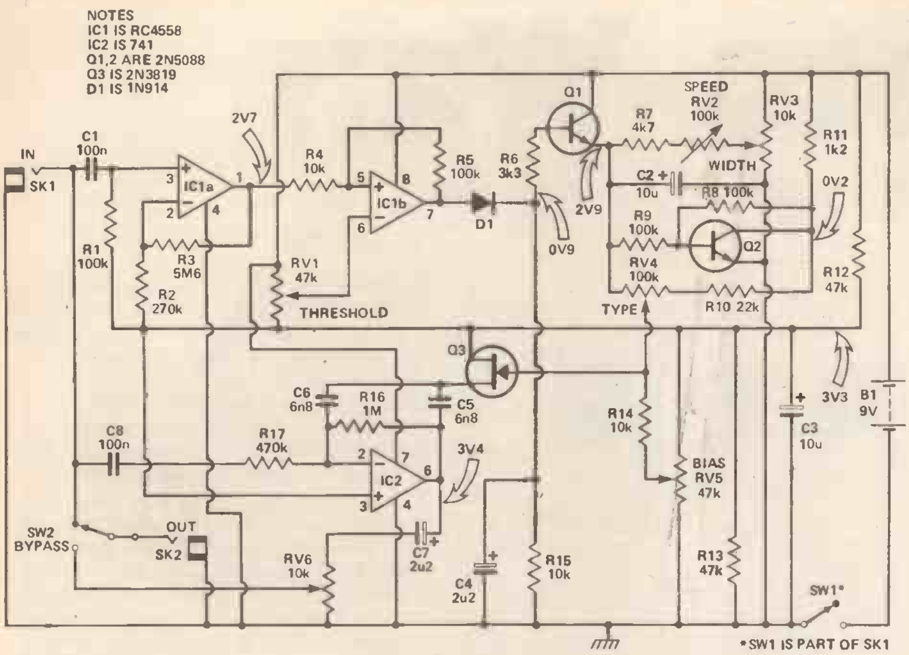


Figure 2. The complete Auto-Wah circuit with some typical DC voltages indicated. Note these measurements apply with no input signal applied.

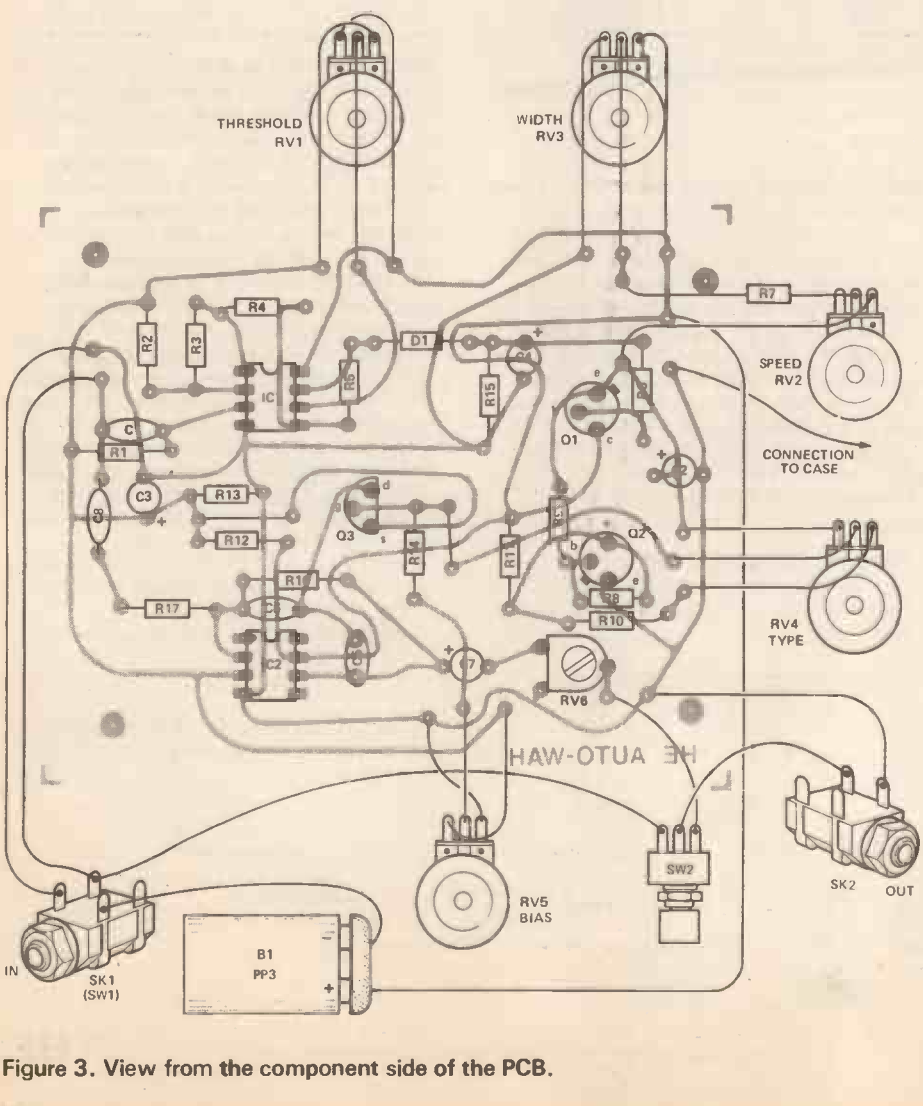


Figure 3. View from the component side of the PCB.

and attenuated by RV6, allowing the output to match the input level. As a single-ended supply is used, R12 and R13 set the mid-supply voltage, which is by-passed by C3. Current consumption is rather high at 12.5 mA, so we recommend you use a long-life (alkaline) PP3 type battery for extended use.

Construction

Referring to the component overlay diagram of **Figure 3**. Begin by soldering the two wire links and resistors. Next, the capacitors, making sure that correct polarities are observed for the tantalum types. Now, assemble the three transistors and the diode (D1). You must ensure these are placed with their leads in the proper positions. The diode must have its banded end (cathode) nearest R15. Transistor Q2 needs its base lead bent to fit the right

Parts List

RESISTORS (All ¼ W, 5%, Carbon)

R1,5,8,9	100k
R2	270k
R3	5M6
R4,14,15	10k
R6	3k3
R7	4k7
R10	22k
R11	1k2
R12,13	47k
R16	1M
R17	470k

POTENTIOMETERS

RV1,5	47k linear carbon
RV2,4	100k linear carbon
RV3	10k linear carbon
RV6	10k sub-miniature preset

CAPACITORS

C1,8	100n C280 polyester
C2,3	10u 10 V radial electrolytic
C4,7	2u2 10 V radial electrolytic
C5,6	6n8 polycarbonate (metallised)

SEMICONDUCTORS

IC1	RC4558 dual op-amp
IC2	741 op-amp
Q1,2	2N5088 silicon NPN transistor
Q3	2N3819 N-channel FET
D1	1N914 silicon diode

MISCELLANEOUS

SK1 (SW1)	¼" jack socket with make contacts
SK2	¼" jack socket
SW2	push-to-make switch
B1	PP3 9 V alkaline 'Long Life' Battery

Case (RS 508-201), PP3 battery clips, 8-pin DIL socket, collet knobs (3 off), shallow knobs (2 off), short standoffs (4 off), PCB, solder, wire, etc.

positions; the other two transistors fit without changing the position of any leads. The IC's are not fitted yet, but if you are using sockets these can be soldered into place, ready to take the IC's.

Lastly, wire up the five pots, two sockets and footswitch — don't forget the battery connector. The (red) positive wire from the connector, is soldered direct to the PCB. The negative (black) wire is taken to one earth tag on the input jack. The other earth tag is connected to the board so that the battery is only switched on when a jack-plug is inserted.

To make sure you have the leads connected to the right tags, put a standard jack-plug into the input socket. This should push the earth connector to link the two earth tags together. If your jack socket has 'break' rather than 'make' contacts, you will have to bend the short tag connector backwards and over the top of the other one. Of course, this is avoided if you buy a socket with 'make' contacts, in the first place.

When you have completed all the off-board wiring, it only remains to plug in the ICs and switch the unit on by inserting a jack-plug into the input socket. However, before starting to play with the effect, its a good idea to check on some voltage readings. These are shown on the circuit diagram (Figure 2), and apply when no input signal is present. The control settings are as follows: RV1, RV4 and RV5 — full rotation; RV2 and RV3 midway along the track. It is essential you set the pots in this way, since some of them have a large effect on quiescent voltages. One final point to note is that readings must be taken using a high-impedance DC meter.

If everything seems OK, you can hook the output up to an amplifier and set RV4 for maximum downwards sweep. Pluck a string on your guitar gently, so as not to trigger the comparator, and set RV5 at the base end of the filter's passband. Now pluck the string hard and the filter should sweep from treble to bass.

Now try setting RV4 at the other end — this point may lie halfway along its track. You will then hear the pass-band sweep from bass to treble. Somewhere close to the mid-setting of RV4, the filter acts in a confused manner, giving some very interesting effects, especially to chords. Altering RV3's setting changes the width of the sweep and produces a gentler effect.

However, the most effective way of setting up the unit is to adjust RV2 and RV3 to their minimum rotations. Then, with RV4 set about two-thirds along it's travel and RV1 full-on, adjust RV5 until the unit produces a wah-wah sound. Finally, turn back RV5 so that triggering only occurs as you pluck the string. Once this is done, RV1 and RV5 can be left alone while you 'play' with the others.

After getting used to the various control settings, drill holes for the pots, sockets and footswitch in the case. Our prototype used short 'stand-offs' to secure the PCB. With the unit fully assembled, you can mark the positions of the threshold and bias controls, as necessary. However, the bias control can still be adjusted to produce some weird variations to the basic sound. It's really up to you to discover just how versatile this unit is. It is also possible to alter the basic effect by changing certain component values. For instance, for a less pronounced bass response, change C8 to a smaller value (say 10n). The mid position of RV4 will give different effects if R10 is changed. Lastly, a different filter response will be achieved if the values of C5 and C6 are changed — try 10n for starters.

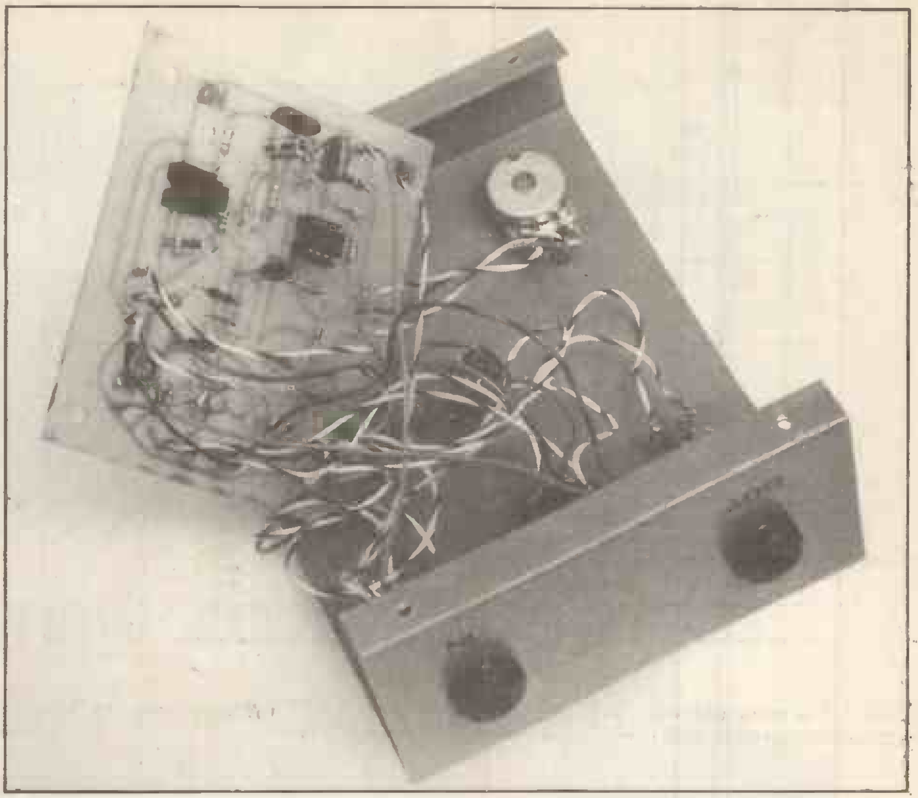


Figure 4. The Internal wiring will be neater if sections of 2 and 3-core strip cable are used.

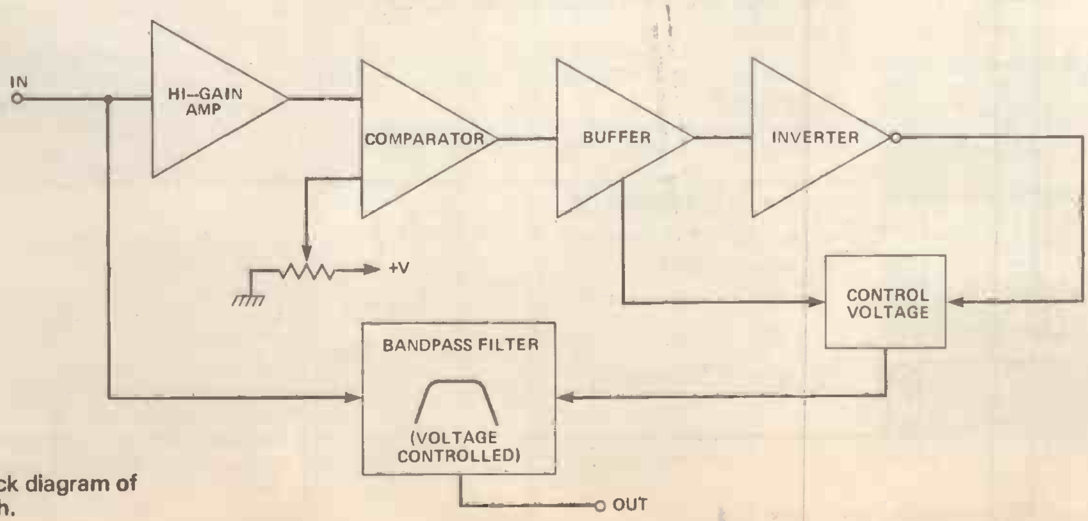


Figure 5. Block diagram of the Auto-Wah.

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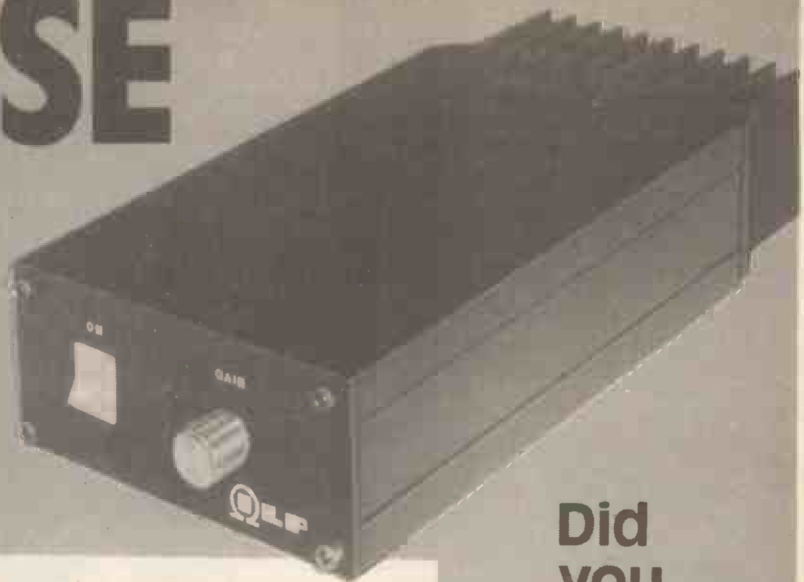

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Sebastian De Ferranti

Kelvin J Williams

The founder of one of Britain's leading technological organisations.

BORN IN LIVERPOOL in 1864, Sebastian Ziani de Ferranti was a direct descendant of a Doge of Venice, Sebastian Ziani, one of the more respected and influential Doges during the twelfth century. The family later added 'Ferranti' to the name during the eighteenth century. His father owned a photographic studio in Liverpool, while his mother was a talented concert pianist who gave recitals all over Europe.

Sebastian showed scientific tendencies at a very early age and, while still at school, he devised an electric arc lamp and generator, the forerunner of a machine he was to develop later.

He left University at 17 and went to London where he was given employment by the Siemens Company, at Woolwich, for £1 a week. Here, he was asked to assist Sir William Siemens himself in research work and superintended the installation of electric lighting plants. He did not stay with Siemens for long, however. His potential was quickly recognised by a Mr Alfred Thomson, a photographer, and Mr Francis Ince, a lawyer with interests in electrical work. They persuaded Ferranti to leave Siemens and form a company, 'Ferranti Thomson and Ince Ltd', to manufacture an alternator with an ingenious zig-zag armature which Ferranti had designed himself. This was a most efficient machine, with a much greater power output than others of the same size and weight, at the time. It was found, however, that the generator which Ferranti had patented, with Alfred Thomson, had very similar features to a machine designed by Sir William Thomson (later Lord Kelvin). The machine became known as the Ferranti-Thomson dynamo and firmly established a reputation for the young engineer.

The company broke up in 1883, so Ferranti formed his own company, based in a small workshop in Hatton Garden, London, where he continued his work on electricity meters. The new company expanded quickly with products such as dynamos, meters, transformers, power switches and fuses. Ferranti's design and development of accurate meters for the measurement of electricity was a great asset to the new, fast growing technology. At the time, much of London was still lit by gas, oil and candles.

Battle of the Systems

Electric lighting was a rare sight and there was great controversy between DC and AC systems. Ferranti, who was fast becoming an expert on AC, was approached by the proprietor of the Grosvenor Gallery, in London, to review a small installation which had been installed to enhance the display of the exhibits. The small plant had become so successful that a profitable business had been formed to supply neighbouring customers. The demand for electric lighting was so great, though, that the system was soon overloaded and in need of urgent redesign. As a result of his advice, Ferranti, at the age of 22, was offered the position of engineer to the Grosvenor Gallery Company. Using transformers and switchgear of his own design, he quickly reformed the entire system, changing from serial to parallel operation, doubling the working voltage from 120 volts to 240 volts and extending the network to cover over 100 miles of streets in just three years.

By now, the controversy over the different supply methods had become known as the 'Battle of the Systems', although the Electric Lighting Act of 1882 had encouraged low voltage DC systems. Ferranti, however, had his mind on bigger and better things. He proposed a large central generating station for transmission of AC at high voltages. These plans were taken up by the Grosvenor Gallery Company and, in 1887, the London Electric Supply Company Ltd. was formed to set up a large generating plant at Deptford — with Ferranti as chief engineer.

Ferranti was responsible for the whole venture, from the design of the building, its architecture and materials, the generating plant itself, transformers, switchgear, meters and supply cables.

The Deptford Experiment

The Deptford site was ideal, as there was easy access by road, rail and water for the supply of materials, equipment and coal. His decision to transmit at 10,000 volts was received by many as highly dangerous and foolhardy, but Ferranti's solution was to use a specially designed underground cable with concentric conductors and an outer sheath connected to earth. Unfortunately, this was contrary to the Board of Trade Regulations but, so convinced was Ferranti of the correctness of his idea, that he disregarded the Regulations and pressed on. Fortunately, his courage and determination won the day and he laid down the first, safe system for high voltage distribution.

He made the cables, in 20 foot lengths and they consisted of hollow copper tubes insulated with wax impregnated paper; the outer cable was wrapped around the paper and the two were contained in a protective iron tube, filled with molten wax forced in under pressure. To prove the safety of his system Ferranti organised a demonstration where his foreman held a metal chisel, in his bare hands, over a live cable while an assistant hammered the chisel through the cable using a sledgehammer. He was protected by fuses and switchgear designed by Ferranti and so, as the chisel pierced the cable, no harm was brought to man or machine. According to the story, somebody asked the foreman if he had been afraid of the possible consequences; his reply was, "Yes, my assistant had never used a sledgehammer before!".

In 1889, the Deptford generating station was visited by Thomas Edison and, although he was the leading exponent of the DC system, he was very impressed with Ferranti's work and surprised at the advances made with AC transmission.

Generation of electricity from Deptford began in 1891 and the two cables laid between Belvedere Road and the Grosvenor Gallery, over Charing Cross Bridge, remained in use until 1933 when the whole network was finally closed down to make way for more modern systems.

After the opening of the Deptford station, Ferranti went back to manufacturing again and set up a business in London to continue production and development of generators, transformers, switchgear and meters. By 1896, the company acquired new premises at Hollingwood, in Lancashire. Soon he employed over 700 workers and enjoyed a profitable business from his new designs and developments. His engineering interests were many, outside the field of electrical work, and some of his major ventures included turbines, cotton spinning gyroscopes and radio transformers.

Ferranti had been elected a member of the I.E.E. (Institute of Electrical Engineers) in 1891 and he became President of the Institute during the year 1910/11. He received the degree of Doctor of Science of the University of Manchester in the following year. Ferranti died in 1930, at a hospital in Switzerland. His restless mind, however, was active to the last and he was described by many of his contemporaries as both a visionary and a practical engineer.

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Pioneer of Electric Power Transmission — An Account of Some of the Early Work of S. de Ferranti 1864-1930 by S.Z. de Ferranti.

S.Z. de Ferranti — His Influence Upon Electrical Development by W.L. Randell.

Ferranti Company Brochure Sept. 1979.

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Breadboards

THIS MONTH in order to revive the popular 'Short Circuits', we are beginning a new series of circuits for the experimenter's among you. The idea is that we will present a circuit design that works and is easy to put together, but which can be modified as required. In order that you can play around with the designs, we've provided a breadboard (hence the name) layout. These layouts are by no means critical and you may make up your own, if you wish. One last point: the circuits presented here are for experimentation and development only. We cannot offer any technical back-up or further advice about *any* of them. However, each has been tested in its original form, and will function as stated in the accompanying text. Also, we will accept designs from readers for *possible* publication, so if you've got a particular circuit that you'd like to see in Hobby Electronics, send it right away — mark the envelope 'Breadboards' and enclose an SAE if you want your design returned.

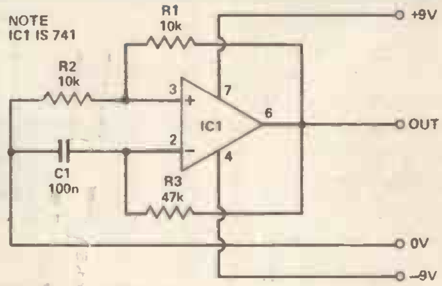
To start the series, we're providing two circuits based on that most widely used of all ICs, the 741. The first design is for an ultra-simple square wave generator. It produces quite a well defined square wave at the lower end of the audio spectrum. Possible uses include; calibration of test gear, tone generators for models and toys, and as a pulse generator.

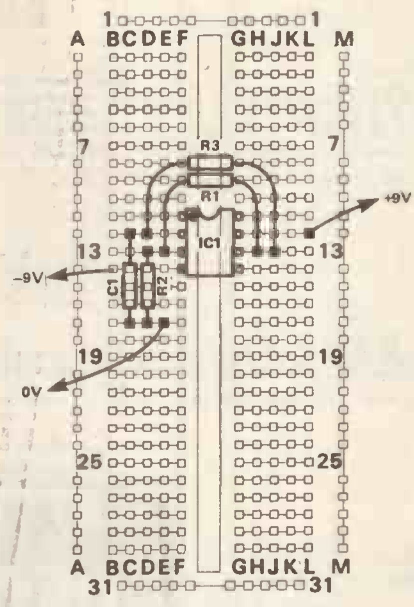
The second circuit uses two 741s in a 14-pin DIL package designated a 747 (not a Boeing). One op-amp provides the rectification and the other is a simple mixer to allow both halves of the wave to be added together. One novel application for this arrangement is as an audio frequency doubler. With the addition of decoupling and stabilising components, some quite unusual 'musical' effects can be produced.

Square Wave Oscillator

IF you thought that the only way of producing a square wave was to use a 555 timer IC, then here's a circuit to change your mind. It's a square wave generator requiring only five components, including the IC — a 741 op-amp. The circuit consists of a Schmitt Trigger with positive feedback provided by the 10k resistors. The timing components, C1 and R3, control the frequency of oscillation and this can be varied over quite a large range (50 Hz to about 7 kHz) before the shape of the wave is no longer square.

If you monitor the voltage at pin 2, it can be seen to follow an exponential charge/discharge pattern, determined by the RC constant of R3 and C1. The mark-to-space ratio can be altered by placing a 10k resistor and a series signal diode in parallel with R3. This makes C1 discharge 11 times faster than it charges up. Current consumption is about 1.5 mA per rail.

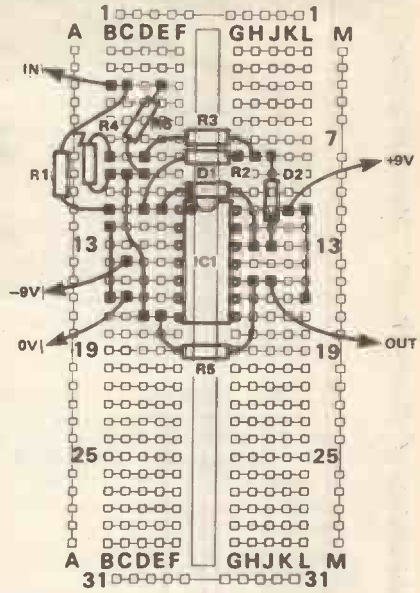




Circuit (top) and Veroboard layout (bottom) of the square wave oscillator.

Full Wave Rectifier/ Frequency Doubler

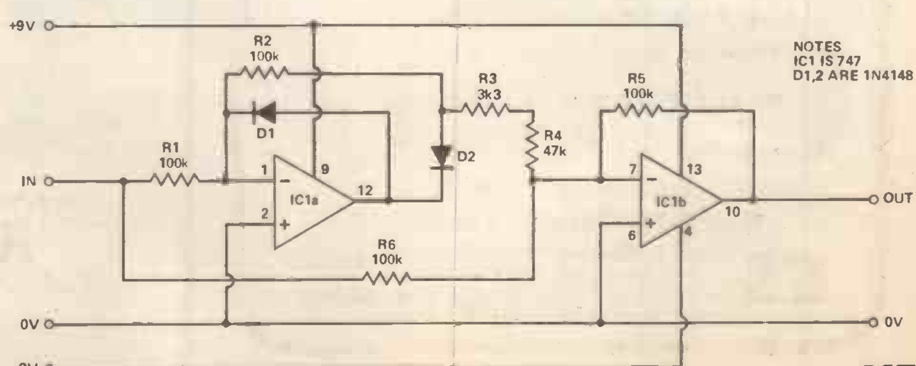
THE EASIEST way of converting AC into something resembling DC is to use a bridge rectifier followed by a large smoothing capacitor. Without the capacitor, the resulting waveform consists of positive half waves, at twice the original AC frequency. This is fine for typical power supply voltages; but at lower levels a problem arises. The voltage drop across the diodes



Rectifier/doubler layout.

(about 600 mV for silicon) becomes significant and the usual bridge circuit is unsuitable. A simple way to overcome this problem is to use an op-amp, like IC1a, in the circuit shown. This consists of an inverting amplifier with negative feedback (pin 12 to pin 1), so there is a 'virtual earth' at pin 1. When the input is positive, D1 maintains the virtual earth (D2 is reverse biased) by conducting and leaving the output 'looking at' 100k to the O V rail. When the input goes negative, D2 is turned on and D1 turned off. The output is then the exact inverse of the input — positive going half sinewaves. We now have half wave rectification from a low-level AC input. By adding the original waveform to the output in the right amount, the result is full wave rectification (with some distortion). This mixing is carried out by the summing amplifier IC1b.

If R3 and R4 are replaced by a 100k pot, the output is fully adjustable from half wave rectified, through full wave to a sloping edge square wave — dependent on the input level. Current consumption is around 2 mA per rail.



Circuit of the full wave rectifier/doubler

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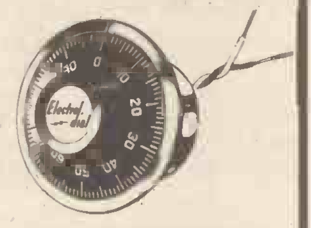

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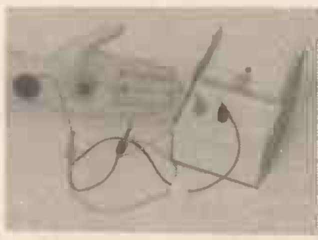

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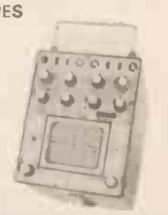

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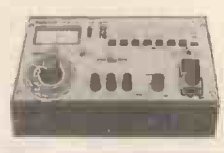

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Building Blocks

WITH SUMMER fast approaching (hopefully), we thought you might like something to help while away those long evenings. What better way than to get acquainted with the more technical details of some ICs used in our projects? In this and subsequent issues, we are including a page or two on the workings of various ICs and other interesting semiconductors.

Out For The Count

The 4017 is a fairly cheap, but very useful little chip. As a decade counter or dividing network, it has obvious applications in counting circuits; several ICs can be wired in cascade (one following the other) to produce the count required. However, a more exciting feature of this chip is its ability to drive LEDs to give novel opto-effects, or to drive astables to produce musical tone generators — rather like those musical watches you can buy.

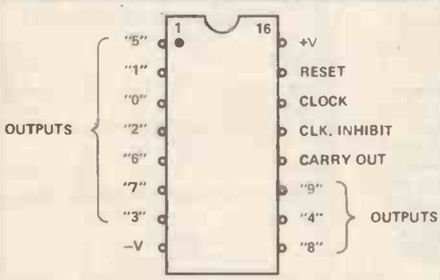


Figure 1. The pin-outs for the 4017 decade counter/divider IC.

The basic pin layout for the IC is shown in **Figure 1**. As you can see, the arrangement of the outputs is not in the same order as the pins (if anyone knows why, please let us in on the secret). This means you need to be careful about 'what goes to where'.

The way this IC works is quite simple and can best be understood by referring to the timing diagram of **Figure 2**. A clock signal is fed into pin 14 (the clock input)

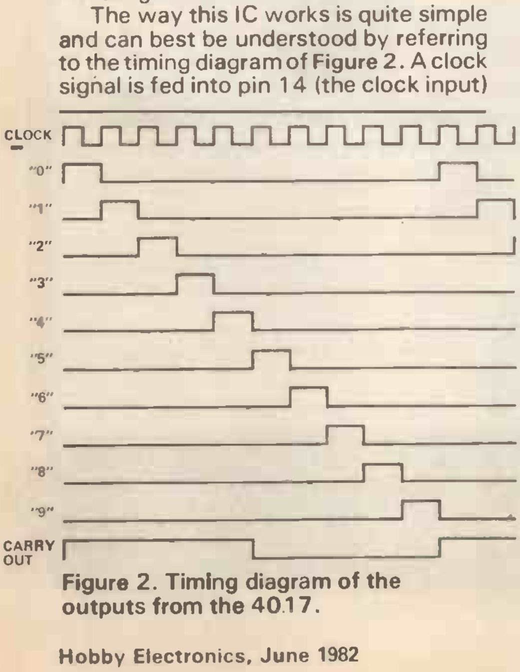


Figure 2. Timing diagram of the outputs from the 4017.

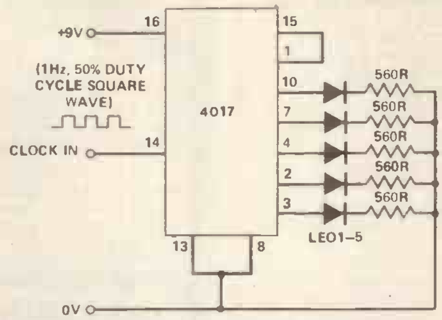


Figure 3. Circuit to provide a 'one-to-five' count. The reset pulse comes from pin 1, so the display keeps repeating.

which is then divided to produce ten separate outputs. These run sequentially from '0' to '9', each at one-tenth of the clock frequency (assuming the reset is enabled at the end of every tenth pulse). If the clock frequency is set low enough (around one pulse per second) then it's possible to create some interesting displays with LEDs on the outputs. These are wired in series with a resistor and then to ground. This circuit produces the familiar light chaser. Another application is shown in **Figure 3**, where five LEDs are used to provide a one-to-five second count.

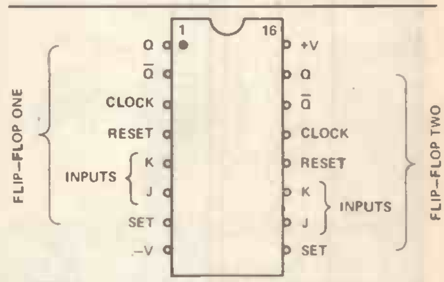
The counter can be prevented from repeating a cycle by simply providing a high input to the clock inhibit pin. This is done by taking the output from the final pin in the sequence back to the inhibit pin. The sequence can still be re-started, though, by momentarily connecting pin 15 (reset) to the positive supply. A more *tuneful* application is to connect up a 555 astable to the decoded outputs, via a resistor chain from pin 7 on the 555. If you set it up properly, you can obtain a sequence of pulsed tones — you can even add a bit of rhythm (man) by missing out one or two of the outputs!

Flippin' Ripple Counters

The versatile count/divide function of the 4017 can be compared to our other device for this month; the 4027 dual J-K flip-flop. The 4027 is a more basic chip than the 4017 and, rather than divide-by-ten, it offers a divide-by-two (per flip-flop) facility. **Figure 4** shows the pin configuration for this IC, which is divided into two identical sections with a shared power supply. The divide-by-two function is achieved by connecting together the 'set', 'reset' pins and taking them to 0 V, then taking the 'J-K' inputs up to the positive supply. Incidentally, the clock signal must have a fast rise and fall time (<5 uS) for reliable operation. When the J and K inputs are held high (the input frequency being divided by two), the output states of Q *and* Q̄ will be changed or 'flipped' over. The other input states are shown in **Figure 5**, but it should be noted that the flipping action only occurs when J and K are *both* high.

The set and reste inputs operate asynchronously (independently of the clock). This means the outputs are forced into high and low states (set and reset repectively) whenever each set or reset input is taken high (unlike TTL). The 4027 will operate in this mode at frequencies up to 8 MHz.

However, the reason for using this type of circuit in the first place is that some applications (shift registers, for example, which are discussed later) must have no change in the output state whilst the clock pulse is high. In other words, whatever is occurring at the inputs must not affect the output. The system used is rather like a master control, followed by a slave back-up which is only engaged when the clock goes back to zero. This is achieved, within the chip, by using an inverter in series with the slave section; when the clock input is low, the slave is receiving a high level. However, the master section is locked and stores what was left from the last high on the clock pulse. When the clock goes high *again*, the master circuit is reacting to the 'set/reset' inputs and when the pulse reaches zero, the Q output is held in the new state. Now the slave can be enabled and it *seems*, from the output's position, we are changing states on the falling edge of the clock signal. This means the Q output can be in one of four conditions; high, low, unchanged or 'toggled', and it is this which makes the chip so versatile.



J	K	Q	Q̄
0	0	UNCHANGED	UNCHANGED
0	1	0	1
1	0	1	0
1	1	TOGGLES	TOGGLES

Figure 4. Pin designations for the 4027 dual J-K flip-flop.

One obvious application for a chip which halves a given input frequency is to wire several in series to give division by powers of two — 2, 4, 8, 16 etc. The clock signal appears to 'ripple' down the dividing chain, which is why ICs with many such stages are called 'ripple counters' — an example is the 4040, with twelve stages. Another type of counter is known as the 'Johnson' or 'Walking Ring', where the stages are clocked in parallel.

The main reason for using this arrangement rather than the ripple counter, is that parallel clocking of the 'walking ring' type only produces a single stage of delay, since each stage is clocked simultaneously. This produces clean decoding of signals. A useful consequence of this is in shift register circuits, where signals are transferred down the line — one stage for every rising edge on the clock pulse. **HE**

Clever Dick

The results of Hobby Electronics' latest survey (the one that carried a grossly distorted caricature of myself on the back — I do not look like that, nor am I in the habit of grovelling, like one of you!) are currently cluttering the already papered floor of the HE office. The results, when they are finally tabulated, should be interesting. One not entirely unexpected result of the previous survey was that most Hobby readers are male (surprise, surprise). That is apparently changing; I've already had one letter, this year, from a charming lady from Portsmouth, so imagine my surprise when I received the following letter shortly afterwards.

Dear Clever Dick,
Your ending to your column in February, "Grovelling isn't everything", intrigued me. As a female reader and practitioner of your magazine and an anti-female-libber, I now propose to take extremely unfair advantage of my sex and offer you unlimited kisses (on paper) if you can donate one HE binder to the above address. I possess a total of five HEs but I definitely don't like untidiness about the place, so a binder would be much appreciated. Of course, if you can't send one I will cry.
Yours hopefully,
Maggie,
Biggleswade,
Beds.

PS My organ didn't work, either.
PPS I enclose a couple of stamps — I believe in going 'Dutch'.
PPPS I didn't think much of Wilding's cartoons.
PPPPS [Here follows an embarrassingly large number of 'Xs']

Don't worry, Maggie. Ladies have been taking unfair advantage of me for years!

Some of the reasons invented to try and coax a binder from my special store are more imaginative than others. Here's a good one!

Dear CD,
"Hello". Due to unavoidable circumstances, ie my dog ate it, my August '81 edition of HE has gone, never to return. So could you please send me a copy of the wiring for the HE Organ. I enclose a large stamped addressed envelope.
J. Pullen,
N. Yorks.

PS I've been reading HE since I was eleven so please send me a binder because I started so young and to stop my dog eating my HEs. Great mag, keep it up.
PPS Clever Dick for King.

Thank you, thank you, but my natural modesty forbids, you see. I've already decided to send a binder, this month, to Maggie — her stamps are now speeding back to Biggleswade (always assuming the trains are still running) wrapped around one of my precious binders. As a consolation prize, though, I'll send the circuit you need, even though you are supposed to get it from the Backnumbers Department.

When I was an electronics constructor myself (many years ago, of course) I remember that the mechanical details — metalwork, lettering and getting a 'professional finish' — were usually the most difficult bits. Now, I have minions who take care of all these details — and it's all plastic now, which is much easier to work than sheet aluminium. However, this letter reminds me of the mechanical problems that still make life difficult for the electronics hobbyist.

Dear CD,
Can you suggest ways for me to cut holes in the boxes that are used for your projects? I have great difficulty with this and regularly make a mess of it. I would be grateful if you could give me some ideas.
Keep up the good work. I'm pleased to see quite a few cheap projects and I will be making the Digital Dice, soon.
R. Mitron,
Nottingham.

PS Please can I have a binder as I have spent all my money on your Universal Relay Driver (grovel, grovel).

I have suggested to the Ed that this is a good subject for Hobby and he is looking in to it. I'll keep reminding him.

I do enjoy the occasional odd-ball letter; it makes a change from the usual desperate pleas for help and the pathetic grovelling.

Dear Clever Dick,
The circumjacence to which this field of enquiry is intrinsic is sacrosanct to the amplitude that is relevant to this leit-motiv. Professionals have hortated over the denouement of this milieu, but ineffectively. Strategists pontificate the derivative of this, but advocates are unauthorised to evaluate the efficacy of such measures.
The encompassment to which supposition is symbiotic to the relative quantity is apposite to this field of enquiry. Savants have sat in conclave over the contingencies of this situation, negatively. Virtuosos dialogise the consequence of this, but coadjutors are unqualified to assess the advantages of this action.
Yours sincerely,
I. McAlpine,
Co. Armash,
N. Ireland.

PS How about a medium HE T-shirt? They are much cheaper than a binder.

It almost makes sense, doesn't it? Doesn't it? Well, all except the PS, then; can't understand that at all.

Finally, this month, I am happy to say that Mr. Lawrence has not suffered greatly from the mistaken advice I passed on to him.

Dear Sir,
I wish to thank you very much for your reply to my letter in the February issue and also for your letter of 15th January. I would also like to thank Mr. Thomas for the enclosed sheet, which has been a great help to me.
The response and the consideration displayed by your magazine has been very much appreciated.
A.M. Lawrence,
Chessington,
Surrey.

I would also like to thank, personally, those many readers who wrote in with advice for Mr. Lawrence. There are far too many to acknowledge individually — so thank you, all. 'Bye now. **HE**

REVERB REVEALED

Paul Coster

STAND inside any large, bare room and you'll notice how sounds tend to linger on after you first hear them. A similar, though less marked, effect occurs in smaller rooms, especially if they contain plenty of hard, bare surfaces (such as a bathroom). This effect is reverberation.

A single pulse of sound, eg a handclap, will send a set of waves out across a room and, if they strike objects in the room, the direction and intensity of the wave will be changed (the intensity of a sound wave is just the amount of energy 'flux' it contains, measured in Watts per square metre). Changes in direction are caused by sound waves being reflected, as light is reflected from a mirror, and it is these reflections which are the main cause of reverberation — if there are no objects to cause reflections, there can be no reverberation!

In most rooms, the 'objects' which are the main reflecting surfaces are, of course, the walls but anything large, in relation to the wavelength of a sound, can cause reflection.

The other important factors in determining the amount of reverberation are the intensity of the reflections themselves (if most of the sound is absorbed by the walls, the reflected sound wave will be too weak to carry back to a listener), the intensity of the sound (a weak sound won't carry to the walls whereas a very loud sound might bounce around for some time) together with the size of the room and the frequency of the sound.

All the factors play a part in how long it takes a sound to fade away. This period is called the Reverberation Time (RT); it is the time it takes for the intensity of a sound to fall to one millionth of its initial value. This is rather a clumsy figure, so it is more usual to express this ratio in decibels.

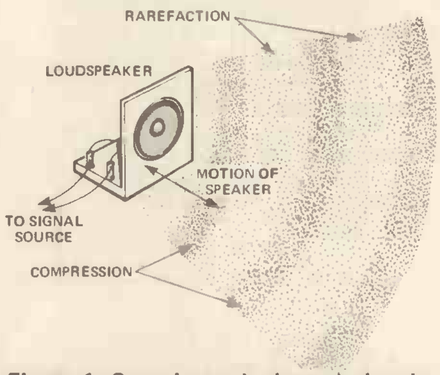


Figure 1. Sound travels through the air as alternate bands of compression (high pressure) and rarefaction (low pressure), created by the rapid motion of a vibrating source. The progression of the sound waves is a physical transference of energy.

For Whom the Bel Tolls

Decibels are a relative measurement, like percentages, often used to express a relationship between the very large numbers which are so often encountered in acoustics (and in electronics). A ratio is expressed in decibels (abbreviated as 'dB') by taking its logarithm and multiplying by a constant — 20 for pressure (or voltage) ratios and 10 for intensity (or power) ratios. So, an intensity level difference of one millionth is equal to

$$10 \times \log \frac{1}{1\,000\,000}$$
$$= 10 \times -6 = -60 \text{ dB}$$

The minus sign is a natural result of the calculation and indicates that the level we are measuring is 60 dB lower (60 dB 'down', in the jargon) than the original sound — a sound one million times louder would be +60 dB because log 10^6 = +6.

This raises an important point; since a sound intensity expressed in decibels is a ratio, it is meaningless in itself. It's no help being told that a sound is, say, 10 dB down, unless we know what its 10 dB down *from*. It's rather like asking "How far is it from London to Liverpool" and being told, "Oh, about twice as far." Twice as far as . . . what? If, on the other hand, we're told that its "twice as far as from London to Birmingham" then we have a base by working out the distance from London to Liverpool. The London-Birmingham distance is a *reference*.

In acoustics, it is usual to describe sound levels in terms of the ratio, in decibels, between two Sound Pressure Levels (dB SPL). The reference level for all acoustic mesurements, in dB SPL, is the Threshold of Hearing, ie the lowest sound pressure level that can, on average, be heard; that is a sound pressure of 0.00002 Pascals (Pa). This is made clear in Figure 2, which shows some examples of typical sound pressure levels, in Pa and dB SPL.

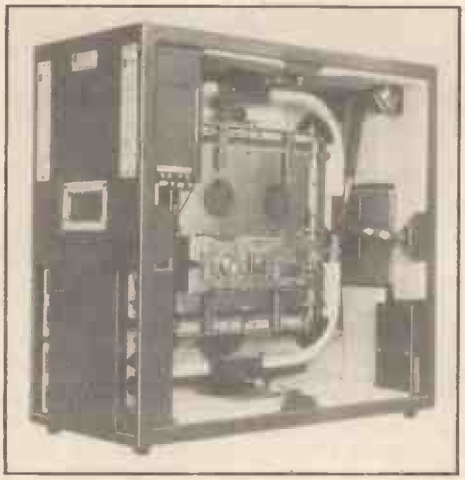
Mirror, Mirror

A single pulse of sound has a definite start and finish but, as this pulse, or 'wave set', travels around a room, it is influenced by the structure and contents so that, by the time it reaches a listener, it is no longer so sharply defined. Instead, it looks more like the shape of Figure 4.

The first thing heard is the original sound that has not encountered any objects en route; this is the 'direct sound' and is usually closely followed by a few distinct reflections from nearby surfaces. After these, the remaining sound is composed of reflections and re-reflections of ever decreasing intensity. Eventually, (a matter of seconds), the sound dies away, having been absorbed completely by the air and by absorbant surfaces.

In a room with mainly smooth, hard surfaces there will be numerous reflections followed by reflections of reflections and re-reflected reflections, and so on. This process is the building block on which reverberation depends. Absorption determines how long the reflections continue; that is, the Reverberation Time.

If a single reflected sound seems distinct from the other reflected sounds, it is called an echo. Echoes are a repeat of the original sound, as a separate entity. The more distinct they sound, the more marked the effect.



The EMT 240 Reverb Foil (left) is probably the finest plate reverb unit made. Two tiny piezoelectric drivers induce bending waves throughout the 24 karat, 18 micron thick, gold foil plate. Reproduction of the signal is achieved by miniature pickups, also bonded directly to the foil surface. Our own Echo-Reverb unit (above) uses more modest techniques!

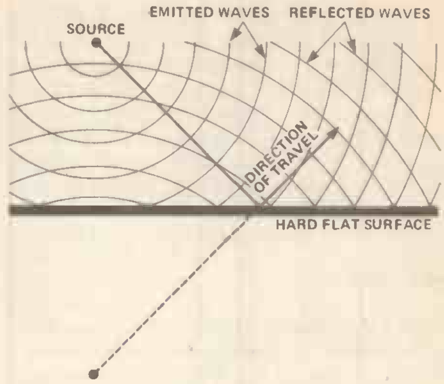


Figure 3. Sound reflections from a flat surface are analogous to the reflection of light from a mirror.

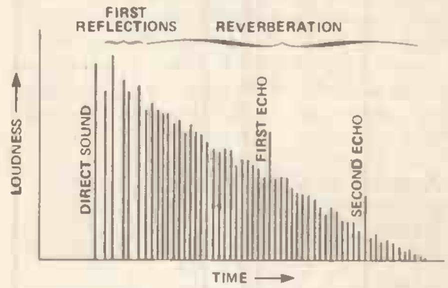


Figure 4. The profile of reflections of a single pulse of sound.

Another distinct effect is the emphasis of particular frequencies. These are 'resonances' and they occur when a dimension of the room equals, or is a mulitiple of, the wavelength of one of the frequencies of the sound. When this happens, the wavelength tends to remain long after the others have decayed. Such 'standing waves' can be extremely objectionable and unpleasant.

Walls Have Ears

Whenever a sound wave 'bumps into' an object, some of the energy in the wave is absorbed and dissipated as heat. Although the amount of heat produced is very small, the reduction in the sound intensity is significant. The amount by which a material will absorb sound, in this way, is called its Coefficient of Absorption. For example, cork tiles have a coefficient of absorption of 0.2 (at a frequency of 500 Hz and with an angle of incidence of 90°) whereas the value is ten times smaller (0.02) for concrete. In other words the tiles will absorb 20%, but concrete only 2%.

In the case of concrete, this means that nearly all (98%) the sound is either reflected or transmitted. The main factor of how well a material transmits sound is its mass, it's weight. Concrete is quite heavy and, therefore, a good sound insulator (doesn't transmit very much). So, for frequencies around 500 Hz, at least, concrete must be a good reflector because it's a bad absorber/transmitter of sound!

The reason for specifying a particular frequency (and angle of incidence) is that absorption coefficients are frequency dependent. The change is often quite large; cork tiles, for instance, have a coefficient ranging from less than 0.1 up to 0.6, across the audio frequency spectrum (20 Hz – 20 kHz). If you are still unsure of the difference between an insulator and an absorber of sound, just think of an open window; its a good absorber of sound (it does not reflect), but is useless at preventing sound from reaching the outside!

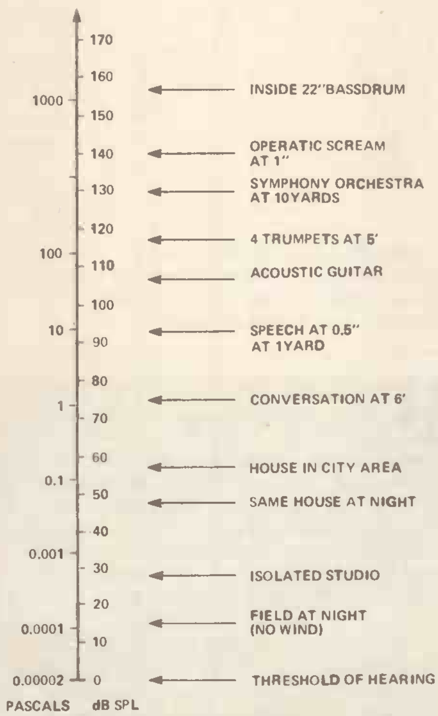


Figure 2. The Sound Pressure Levels, in Pascals and dB SPL, of fairly typical sounds.

Growing Strong

Since reverberation is the result of the combined effects of reflection and absorption, we would expect that sound emitted at a constant intensity would not get louder and louder but, rather, tail off due to the amount being absorbed. This is indeed what happens, in a very short time, as shown in **Figure 5**. The growth in sound intensity is quite rapid at first, but as more and more is absorbed, the rate of growth decreases until a steady state is reached. At this point the amount of sound energy being absorbed is equal to the amount being produced — the sound has reached saturation level. If the source is switched off, the sound intensity falls off steeply, then more gradually, until it eventually fades away. The final diagram in **Figure 5** is a graphical representation of this process and fairly typical of the growth/decay characteristics encountered in most rooms or halls.

Although the basic shape of the 'sound energy' curve is fairly constant, the time taken to reach steady state and then decay depends on the particular room. In free space, (open air), a series of sharp sounds (pulses) will have almost vertical rise-and-fall slopes (**Figure 6a**) corresponding to when the source is turned on and off. In a room with a short RT, though, the familiar curve returns (**Figure 6b**), showing a small overlap at each end. A longer RT produces more of an overlap and this can be disasterous in some cases, as the sounds of speech, for example, will tend to merge before they have decayed (**Figure 6c**). Consequently, it's not difficult to see that reverberation time is an important consideration when using a hall for a particular purpose. A lecture theatre, for instance, requires a short RT (less than a second) for speech to be heard clearly, but that same value would produce a very 'dead' sound in a large concert hall — it would also be difficult to achieve without using an enormous amount of absorbent material all around the 'sound stage'. Organ music presents quite a different problem, requiring a reverb time between three and five seconds. So, to fully realise a rich organ sound, the hall must be large and contain plenty of reflecting surfaces — something like a church or cathedral would do nicely!

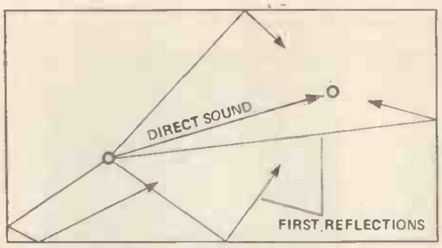
As a mark of importance of reverberation, some concert halls have the seats upholstered with material that has a similar absorption coefficient to clothing, in an attempt to ensure that the quality of the sound is not dependent on the number of people in the audience! Of course, most rock music venues pay little attention to such details, so the acoustics during a 'sound check' are not reproduced when the crowds arrive (in some cases, this lack of sonic continuity makes little difference!).

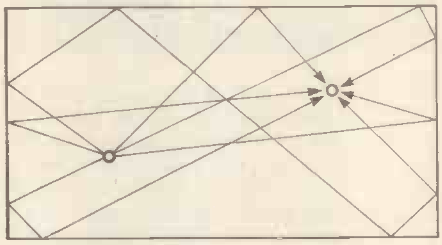
Reverb On Demand

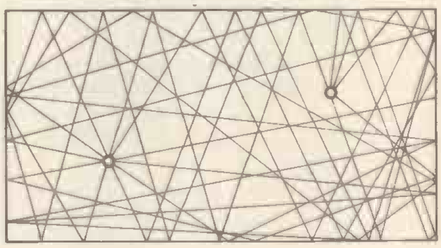
Room acoustics are extremely hard to alter. Equalisation techniques can be used to flatten-out the peaks (due to resonances) and dips (due to 'dead spots' at particular frequencies), within limits, but there's nothing that can be done *electronically* to reduce reverberation. On the other hand, if you're stuck with a 'dead' room — or just like 'playing in the bathroom' — then it is possible to add artifical reverberation. There are commercial units that can produce quite realistic effects, but it should be realised that electronic reverb is, at best, only a subsitute for the real thing. In practice, its impossible to duplicate the hundreds and thousands of reflections and absorptions that are produced in a particular room or hall. For this reason, it's better to view 'add-on' reverberation as an effect in its own right — it is, after all, the final sound that counts.

All electronic systems used for adding reverberation depend on the same basic principle; the signal is delayed for a short time and part of it is fed back to the input. By carefully controlling the delay and amount of feedback, quite effective reverb can be produced. The best units, using multiple delay paths and complex mixing circuitry create something approaching genuine reverb. In reality, all that's being done is to recirculate a series of short echoes' — a process labelled 'regeneration' or, sometimes, 'recirculation'. If this is taken to extreme levels, oscillation results; this is hardly surprising when you consider that signals are being added, one on top of the other. However, when proper attention is paid to setting the levels, the sound can be quite impressive.

The most effective device for creating reverb is the reverberation plate. It is an electro-mechanical device which consists of a large steel plate mounted in a suspending framework, with transmit and pick-up transducers at either end. Sound waves travel through the plate, more slowly than they do through the air,







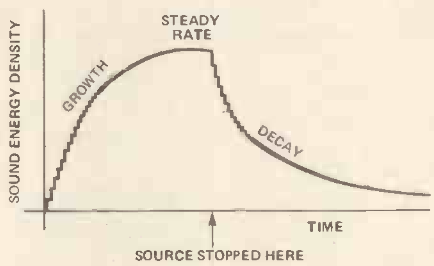


Figure 5. The energy density growth/decay characteristic of a sound pulse (after Olson, H.F., "Music, Physics and Engineering").

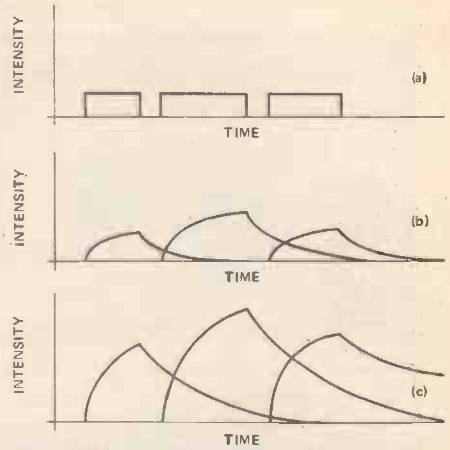


Figure 6. Growth/decay characteristics of a series of sound pulses produced by different reverb times; (a) free field (short); (b) medium; (c) long (after Olson).

and are reflected by the *edges* of the plate, before being picked-up. This results in a distinctive and high quality effect; the major drawbacks are a lack of mobility (the plates are heavy) and prohibitive costs (mortgages are available!).

A cheaper, more popular, but less effective alternative is the springline. This takes the form of one or more springs, suspended at each end and fitted with transmit and pick-up tranducers. A small power amplifier is used to send signals down the springline which then appear at the other end with the characteristic 'twangy' sound. Indeed, the springline is often used specifically because of its unique 'sound'. The disadvantage of this arrangement is that the slightest knock causes a loud 'boing' sound.

Electronic reverb units are basically variable delay lines. There are two types; analogue (like the HE Echo-Reverb) and digital. Analogue delay lines are based on specialised ICs known as Charge Coupled Devices (CCDs), which 'sample' the input signal and 'clock' each sample through to

MXR's Digital Delay unit provides a variety of effects, ranging from discrete echoes, doubling and hard reverb through to flanging, frequency modulation (vibrato etc) and infinite repeats. The Flanger/Doubler (top) uses analogue methods to produce a more limited range of effects.

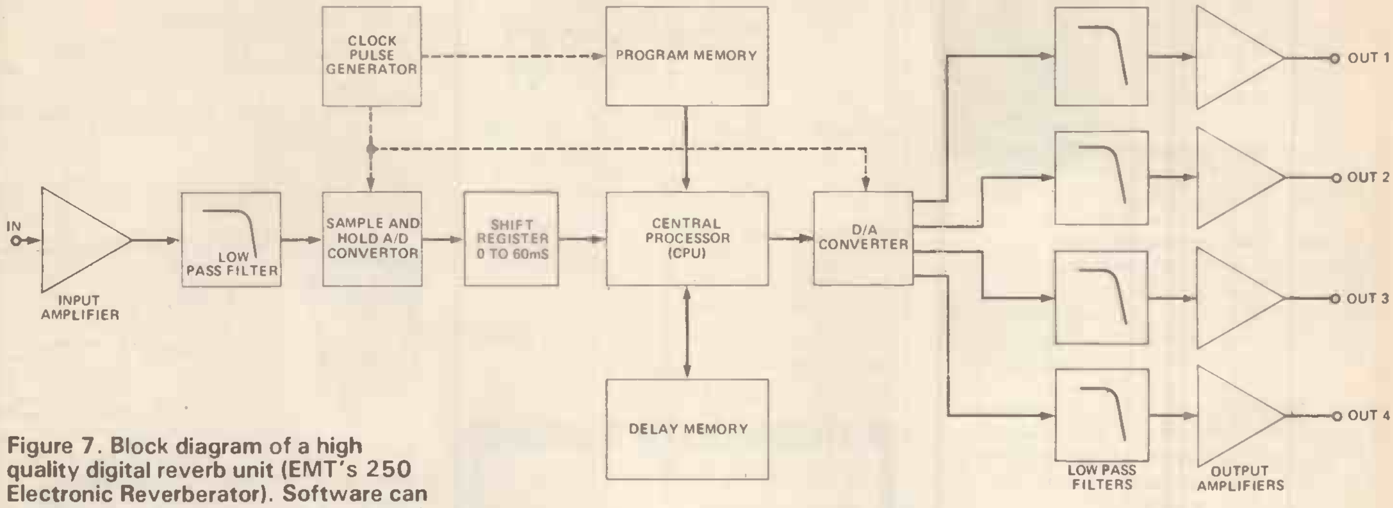


Figure 7. Block diagram of a high quality digital reverb unit (EMT's 250 Electronic Reverberator). Software can be written to generate almost any kind of delay effect.

output. (The operation of CCDs is decribed more fully in the 'How it Works' section of our reverb project, in last month's issue).

Digital reverberation units are much more sophisticated and versatile (**Figure 7**). If the software is clever enough, these units can create just about any type of sound! They do this by converting samples of analogue signal into a digital word using an ADC (Analogue to Digital Convertor) which can then be stored in a Random Access Memory and manipulated in various ways, limited only by the type of program used. After processing, the signals are converted back into their original analogue waveforms by an ADC (Analogue to Digital Convertor). Digital reverb provides opportunities for creating reverbertion effects that exist only in the mind of the programmer! Obviously, such capabilities don't come cheaply.

One of the original techiniques for adding reverberation (and still used today, for quick, easy echo) was to use a tape loop strung out between two tape recorders. Special tape machines, with multiple playback heads (**Figure 8**) were also produced and these were capable of some quite good sounds. The heads were arranged with different spaces between them, so that a set of delays got progressively longer; each head had its own playback level circuitry, feeding a mixer, allowing the response to be accurately controlled.

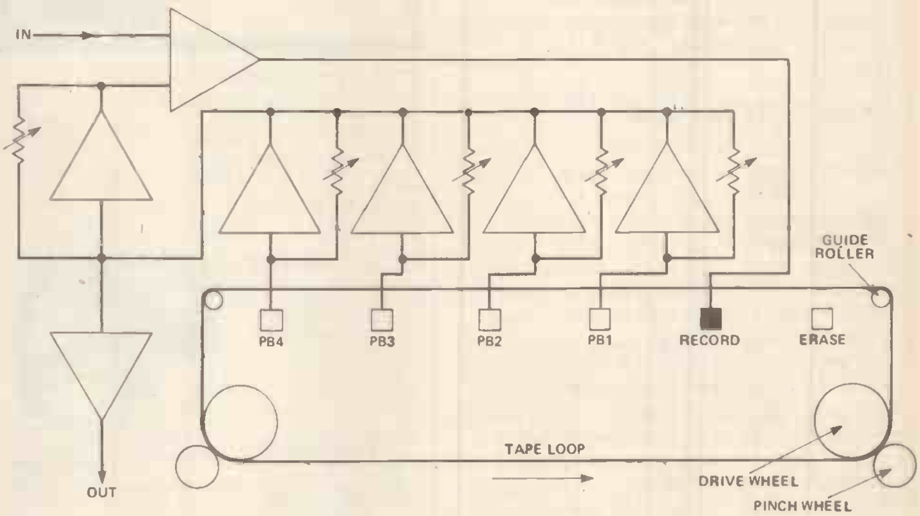
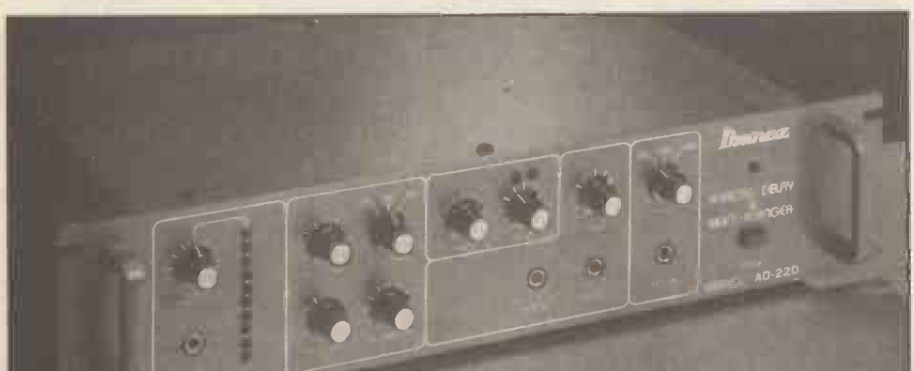


Figure 8. Block diagram of a tape-loop reverb system, using multiple playback heads to produce closely spaced discrete echoes.



The Ibanez Analog Delay/Multi-Flanger is a budget priced unit suitable for producing a number of interesting delay effects, including echo, reverb and flanging.

Listen to the Music

With all the electronic equipment available and working knowledge of reverberation effects, the creative musician should be able to use both the gear and his knowledge to create some really outstanding sounds. Unfortunately, it is virtually impossible to do much about strong resonances in a room, although equalisation can help (this will be the subject of the next Project: Music feature). The most important thing to remember is that, if the room is at all 'live' (you can get a good idea of the sound of the room by clapping hands once, sharply, and listening to the reflections, if any), playing *loud* will only make the sound worse! **HE**

SUPER HI-FI SPEAKER CABINETS

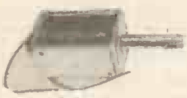
Made for an expensive Hi-Fi outfit — will suit any decor. Resonance free. Cut-outs for 6½" woofer and 2½" tweeter. The front material is Dacron. The completed unit is most pleasing. Supplied in pairs price £6.90 per pair (this is probably less than the original cost of one cabinet) carriage £3.00 the pair.

GOODMANS SPEAKERS

6½" 8 ohm 25 watt £4.50. 2½" 8 ohm tweeter. £2.50. No extra for postage if ordered with cabinets. Xover £1.50.

UNIVAC KEYBOARD BARGAIN

50 keys, together with 5 miniature toggle switches all mounted on a p.c.b. together with 12 i.c.'s, many transistors and other parts.
£13 50 + £2.00 post.
This is far less than the value of the switches alone. Diagram of this keyboard is available separately for £1.



SOLENOID WITH PLUNGER

Mains operated £1.99
10 — 12 volts DC operated £1.50.

POPULAR KITS

3 - 30v VARIABLE VOLTAGE POWER SUPPLY UNIT
With 1 amp DC output, for use on the bench, students, inventors, service engineers, etc. Automatic short circuit and overload protection. In case with a volt meter on the front panel. Complete kit £13.80

IONISER KIT
Refresh your home, office, shop, work room, etc. with a negative ION generator. Makes you feel better and work harder — complete mains operated kit, case included £11.95 plus £2.00 post.

MORSE TRAINER
Complete kit £2.99.

DRILL SPEED CONTROLLER
Complete kit £3.95.

MAINS POWER SUPPLY
Gives any voltage from 3v to 16v at up to 300mA. Complete kit less case £1.95. Case 90p.

OUR CAR STARTER AND CHARGER KIT has no doubt saved many motorists from embarrassment in an emergency you can start car off mains or bring your battery up to full charge in a couple of hours. The kit comprises: 250w mains transformer, two 10 amp bridge rectifiers, start/charge switch and full instructions. You can assemble this in the evening, box it up or leave it on the shelf in the garage whichever suits you best. Price £12.50 + £3.00 post.

CHANCE OF A LIFETIME

We have to clear a big store. 100 tons of stock must go. 10 kilo parcel of unused parts. Minimum 1,000 items includes panel meters, timers, thermal trips, relays, switches, motors, drills, taps and dies, tools, thermostats, coils, variable condensers, variable resistors, etc. etc. Individually these must cost in excess of £100. YOURS FOR ONLY £11.50 plus £3.00 post.

MILLIONS OF HOMES WILL BE BURGLED THIS SUMMER — SAY THE EXPERTS

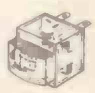
Don't let yours be one of them. Install our burgar alarm. Install our burglar alarm. Complete kit includes 6" external alarm bell, mains power unit control box with key switch 10 window/door switches 100 yards of wire. With instructions £29.50.

TINIEST MICROPHONE

Not much bigger than a pea, 600 ohm condenser type. Ideal for bugging and similar applications. 50p each or 10 for £4.50.

LEVEL METER

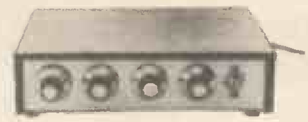
Size approximately ¾" square, scaled signal and power but cover easily removable for rescaling. Sensitivity 200 uA. 75p.



THERMOSTAT ASSORTMENT

10 different thermostats. 7 bi-metal types and 3 liquid types. There are the current stats which will open the switch to protect devices against overload, short circuits, etc., or when fitted say in front of the element of a blow heater, the heat would trip the stat if the blower fuses; appliance stats, one for high temperatures, others adjustable over a range of temperatures which could include 0 — 100°C. There is also a thermostatic pod which can be immersed, an oven stat, a calibrated boiler stat, finally an ice stat which, fitted to our waterproof heater element, up in the loft could protect your pipes from freezing. Separately, these thermostats could cost around £15.00 -- however, you can have the parcel for £2.50.

3 CHANNEL SOUND TO LIGHT KIT



Complete kit of parts for a three-channel sound to light unit controlling over 2000 watts of lighting. Use this at home if you wish but it is plenty rugged enough for disco work. The unit is housed in an attractive two-tone metal case and has controls for each channel, and a master on/off. The audio input and output are by ¼" sockets and three panel mounting fuse holders provide thyristor protection. A four-pin plug and socket facilitate ease of connecting lamps. Special snip price is £14.95 in kit form or £25.00 assembled and tested.

STANDARD RELAYS

3 changeover 10 amp contacts, single screw fixing, mains operated. £1.25. 12 volt operated £1.50. 6 volt model 99p.
Other coil voltages — please enquire.

ULTRA SMALL 12v RELAYS

Single pole gold plated contacts. Tubular construction, 17mm long 10mm dia. Ideal for models. PCB or freemounting. £2.30 ea.

MINAITURE PLUG IN RELAYS

12v operated. 3 changeover. £2.45, base 45p.
12v operated. 2 changeover. £1.87, base 35p.

THIS MONTH'S SNIP

0 - 100 MICRO AMP PANEL METER

Japanese made, flush mounting, size approximately 45mm x 50mm x 30mm deep.
PRICE £2.95.

ROTARY WAFER SWITCHES

5 amp silver plated contacts. ¼" shaft. 1" dia. wafer.

Single wafer types, 29p each, as follows:		
1 pole 12 way	2 pole 6 way	3 pole 4 way
4 pole 3 way	6 pole 2 way	4 pole 3 way
Two wafer type, 59p each, as follows		
2 pole 12 way	4 pole 5 way	4 pole 6 way
6 pole 2 way	8 pole 3 way	12 pole 2 way
3 wafer types, 99p each,		
3 pole 12 way	6 pole 5 way	6 pole 6 way
9 pole 4 way	12p 3 way	18p 2 way

EXTRACTOR FAN

Mains operated — ex-computer
5" Woods extractor £5.75, Post £1.25.
5" Plannair extractor £6.50. Post £1.25
4" x 4" Muffin 115v. £4.50. Post 75p.
4" x 4" Muffin 230v. £5.75. Post 75p.

8 POWERFUL BATTERY MOTORS

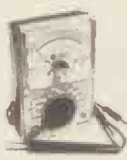
For models, maccanos, drills, remote control planes, boats, etc. £2.95.

TAPE PUNCH & READER

For controlling machine tools, etc, motorised 8 bit punch with matching tape reader. Ex-computers, believed in good working order, any not so would be exchanged. £17.50 pair. Post £4.00.

MINI-MULTI TESTER

Deluxe pocket size precision moving coil instrument, Jewelled bearings - 2000 o.p.v. mirrored scale.
11 instant range measures: DC volts 10, 50, 250, 1000.
AC volts 10, 50, 250, 1000.
DC amps 0 — 100 mA.



Continuity and resistance 0 - 1 meg ohms in two ranges. Complete with test prods and instruction book showing how to measure capacity and inductance as well. Unbelievable value at only £6.75 + 60p post and insurance.

FREE Amps range kit to enble you to read DC current from 0 - 10 amps, directly on the 0 - 10 scale. It's free if you purchase quickly, but of you already own a Mini-Tester and would like one, send £2.50.

12V FLUORESCENT LIGHTING

For camping — car repairing — emergeny lighting from a 12v battery you can't beat fluorescent lighting. It will offer plenty of well distributed light and is economical. We offer an inverter for 21" 13 watt miniature fluorescent tube. £3.45. (tube not supplied).

FREE OUR CURRENT BARGAIN LIST WILL BE ENCLOSED WITH ALL ORDERS.

TRANSMITTER SURVEILLANCE

Tiny, easily hidden but which will enable conversation to be picked up with FM radio. Can be made in a matchbox — all electronic parts and circuit. £2.30. (not licenceable in the U.K.)

RADIO MIKE

Ideal for discos and garden parties, allows complete freedom of movement. Play through FM radio or tuner amp. £6.90 comp. kit. (not licenceable in the U.K.).

FM RECEIVER

Made up and working, complete with scale and pointer needs only headphones, ideal for use with our surveillance transmitter or radio mike. £5.85. or kit of parts £3.95.

VENNER TIME SWITCH

Mains operated with 20 amp switch, one on and one off per 24 hrs. repeats daily automatically correcting for the lengthening or shortening day. An expensive time switch but you can have it for only £2.95. These are without case, but we can supply a plastic base £1.75 or metal case with window £2.95. Also available is adaptor kit to convert this into a normal 24 hr. time switch but with the added advantage of up to 12 on/offs per 24 hrs. This makes an ideal controllerfor the immersion heater. Price of adaptor kit is £2.30.

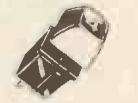
STEREO HEADPHONES

Very good quality, 8 ohm impedance, padded, terminating with standard ¼" jack-plug £2.99 post 60p.

TIME SWITCH BARGAIN
Large clear mains frequency controlled clock, which will always show you the correct time + start and stop switches with dials. Complete with knobs. £2.50.

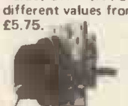
ZX81 OWNERS

Make yourself a full size keyboard! Key switches complete with plain caps. 6 for £1.15.



RESISTORS

Carbon film, 1/4 or 1/3 watt, standard leads, not pre-formed, all 5% values: 1p each 100's. 2p each 10. 5p each less than 10 per value. OR — INVENTOR'S PACK, containing 10 of each of 60 different values from 1 ohm to 10 megohm, packed separately, £5.75.



DELAY SWITCH

Mains operated — delay can be accurately set with pointers knob for periods of up to 2½hrs. 2 contacts suitable to switch 10 amps — second contact opens a few minutes after 1st contact. £1.95.

MOTORS FOR ROBOTICS

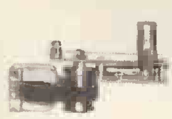
If its a toy robot you are making then one of our eight battery motors (see centre column) may do. If its a bigger one, however, then see below If still not big enough then enquire — we have larger motors but these are usually mains driven.

12v MOTOR BY SMITHS

Made for use in cars, these are series wound and they become more powerful as load increases. Size 3½" long by 3" dia. These have a good length of ¼" spindle — price £3.45.
Ditto, but double ended £4.25.

EXTRA POWERFUL 12v MOTOR

Made to work battery lawnmower, this probably develops up to ¼ h.p., so it could be used to power a go-kart or to drive a compressor, etc. etc. £6.90 + £1.50 post.
(This is easily reversible with our reversible switch - Price £1.15).



SPIT MOTORS

These are powerful mains operated induction motors with gear box attached. The final shaft is a ½" rod with square hole, so you have alternative couplingmethods — final speed is approx. 5 revs/min, price £5.50. — Similar motors with final speeds of 80, 100, 160 & 200r.p.m. same price.

REVERSIBLE MOTOR WITH CONTROL GEAR

Made by the famous Framco Company this is a very robust motor, size approximately 7½" long, 3½" dia. 3/8" shaft, Tremendously powerful motor, almost impossible to stop. Ideal for operating stage curtains, sliding doors, ventilators etc., even garage doors if adequately counter-balanced. We offer the motor complete with control gear as follows:

1 Framco motor with gear box
1 manual reversing and on/off switch
1 push to start switch
1 x 100w auto transformer
2 limit stop switches
1 circuit diag. of connections.
£19.50 plus postage £2.50.

J. BULL (Electrical) Ltd.

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MAIL ORDER TERMS: Cash, P.O. or cheque with order. Orders under £10, add 60p service charge. Monthly account orders accepted from schools and public companies. Access & Barclaycard orders phone Haywards Heath (0444) 454563. Bulk Orders: Write for quote. Delivery by return.

INTO ELECTRONIC COMPONENTS

Nearing the end of the Series, we consider Transducers — electrical Input/Output devices.

A TRANSDUCER is simply a converter and, though neither of the signals (input or output) need be electrical, the transducers that are of most interest to us are the ones which have, as either input *or* output, an electrical signal. These signals can be AC or DC or a mixture of both, according to the type and design of transducer.

Though transducers can be as different as a light-bulb and a microphone, they have one factor in common — none are ever 100% efficient. The efficiency of a transducer can be measured in terms of the energy of the signals into it and out of it. A 100% efficient transducer would produce an output whose energy was exactly the same as that of the input signal, over the same time. Efficiencies ranging from 0.1% to 80% are more usual, with the lower values, alas, predominating. The efficiency is officially defined as:

$$\frac{\text{Energy out}}{\text{Energy in}},$$

In the same time. There are so many transducers used with electronic equipment that we cannot hope to cover more than a few, here, but we can at least look at those which are of greatest interest.

One important point to note is that an electrical input or output will have a measurable resistance. The input resistance will be stated as a parallel resistance, the output resistance as a series resistance (**Figure 11.1**) and these resistances will form potential-divider circuits with any other resistances in the external circuits, cutting down the amount of electrical signal which enters or leaves the transducers. The principle should already be familiar to you after the discussion of transistors, a few months ago. The values of input and output resistances vary very greatly from one transducer to another, so that circuits which are used with transducers have to be tailored to the characteristics of the particular device — you cannot necessarily use an amplifier which has been developed for a microphone on a strain-gauge, for example.

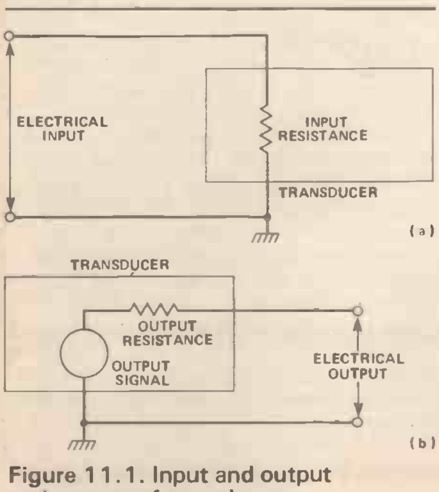

Figure 11.1. Input and output resistances of transducers.

Over to You, Mike

A microphone is a sound-wave to electrical signal transducer which converts a reasonable percentage (around 10%, for some examples) of the sound energy reaching it into electrical energy. Since what we call sound is composed of waves of pressure in the air, the electrical output of a microphone is also in the form of a wave and, if the microphone is to be of any use, the waveshape should not be changed. That means a graph of air-pressure plotted against time (the waveshape of the sound) should look the same as a graph of electrical voltage, from the microphone, plotted against time (the electrical waveshape).

There are a lot of different microphone types and we don't have space to go into details of them all, but one important point is that they all belong to one of two groups — velocity operated or pressure operated. A velocity-operated microphone uses the movement of the air to obtain its signals, whereas the pressure-operated type uses (you guessed!) the pressure. The most important difference between them is that the pressure-operated microphones are omnidirectional — they will pick up sounds from any direction, no matter which way the microphone is facing. By contrast, velocity-operated microphones are unidirectional — they have to be pointed at the source of sound and they pick up much less sound from other directions. The way in which a microphone responds to sounds from different directions is shown in a polar diagram for that microphone (**Figure 11.2**) An omnidirectional microphone should give a round polar diagram, a directional microphone a sharply pointed one.

In the early days of tape-recording, crystal microphones were used but nowadays most microphones are of a type which make use of electromagnetic induction. The principle is that the soundwaves move a stretched diaphragm, and the movement of the diaphragm causes a magnet to move in and out of a coil (dynamic microphone) or a coil to move in and out of a magnet (moving-coil microphone). A variation on this theme is the ribbon microphone, in which a thin metal strip is vibrated by the air and, because the metal ribbon is located between the poles of a magnet, it generates a signal. Of these types, the dynamic type produces the greatest amount of signal for a given amount of sound, and also has the highest resistance. The ribbon types produce least signal and also have very low resistance; the particular virtue of the ribbon type is that it is particularly easy to make in velocity-operated form.

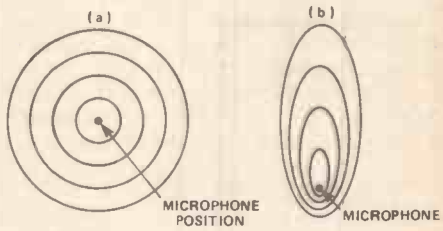

Figure 11.2. Polar diagrams for microphones; (a) omnidirectional; (b) unidirectional.

The Other 'Arf

The other end of the amplification system needs a transducer for electrical signals to sound — the loudspeaker. One type of loudspeaker has dominated for many years and that one is the moving-coil type. In a moving-coil speaker (**Figure 11.3**), a cone, which is usually made from stiff paper with a corrugated support to act as a suspension, is held in a frame and a coil of wire is wound on to a cylindrical former at the narrow end of the cone. This former fits in the poles of a cylindrical magnet, magnetised so that one pole is at the centre and the other pole is all round the outside. This

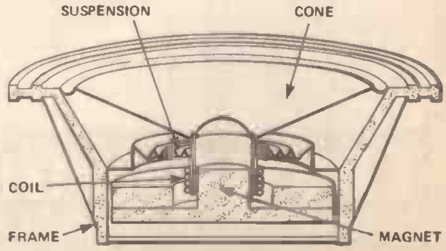

Figure 11.3. The moving-coil loudspeaker.

arrangement produces a strong magnetic field, cutting directly across the turns of wire on the former so that, when a current is passed through the coil, a force is generated which will move the coil, taking the core along with it. The direction of the force, and so the movement, is reversed when the direction of the current is reversed, so that an alternating current will produce alternating movement, to and fro, which is what we need to create a sound wave.

Moving-coil loudspeakers (and the principle is used for many types of earphones as well) have low resistance values, mostly in the range of 3R to 16R, which is why we have so many problems with power amplifiers. Another problem is that loudspeakers are very inefficient — only a tiny fraction of the electrical energy put into them results in useful sound energy output. The snag is that the size of the loudspeaker is tiny compared with the size of the sound source it is trying to re-create. We try to get over this by mounting the loudspeakers in cabinets but, unless we use truly gigantic cabinets, the efficiency is only slightly improved. The most efficient type of cabinet (or enclosure, to use a more technical word) for loudspeakers is the exponential horn (**Figure 11.4**) which, if you're prepared to tolerate a length of nine feet or more and a mouth which can be the size of a doorway, can give efficiency figures of 10% or more. At the other end of the scale, small 'bookshelf' speakers of good quality may have efficiency figures of less than 0.5%.

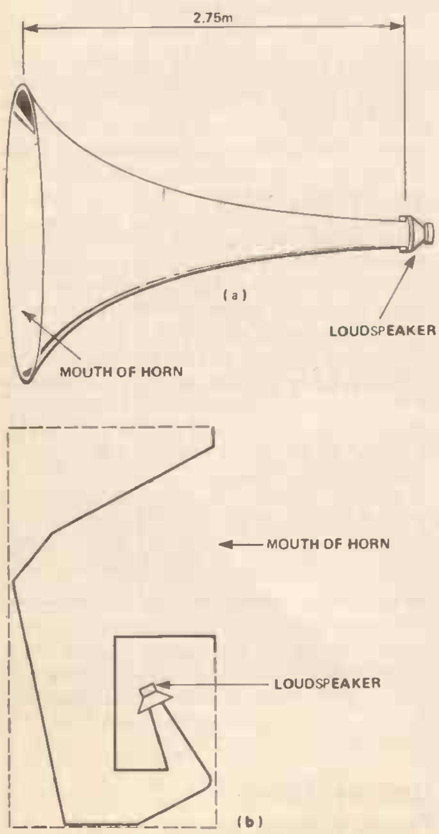

Figure 11.4. Cross-section of a small exponential horn; folded horns are more usual because of the enormous length of a straight horn.

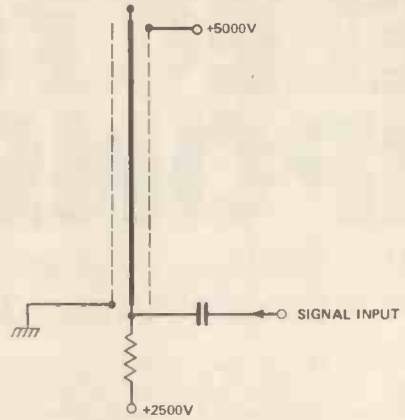

Figure 11.5. The principle of the electrostatic loudspeaker — as the voltage on the diaphragm changes, the electrostatic forces move the diaphragm in and out.

Though the moving-coil principle dominates loudspeaker design, it is by no means ideal. Very fine results can be achieved with electrostatic speakers, in which a large sheet of metal-coated plastic is moved between wire meshes (**Figure 11.5**) by electrostatic forces. A high "polarising voltage" is needed, as a bias for the diaphragm, and the resistance of the speaker is very high — almost infinite. The speaker manufacturers Quad are the only company who have used the electrostatic principle seriously and their speakers are very highly regarded by those who can afford them. The use of electrostatics has been more widespread in headphone design, where size is less of a problem and some excellent results have been achieved by Sennheiser, the pioneer of electrostatic headphones.

A few types of loudspeakers are produced using other effects. For hi-fi, it is impossible to produce a moving-coil loudspeaker which deals adequately with both very high notes and very low notes, so that moving-coil speakers are used for the low and mid-range notes and small units, called 'tweeters', are used, sometimes in large numbers, for the highest notes. Both ribbon and ceramic crystal tweeters are found, the ribbon type being of almost the same construction as a ribbon microphone. Ceramic tweeters work on the principle that a thin plate of certain materials, called piezoelectric crystals, will vibrate when an alternating voltage is applied to metal contacts on each side of the sheet. These ceramic tweeters have a very high resistance, but the ribbon types have a very low resistance.

Strike a Light

Our first lot of transducers dealt with conversions between sound waves and electrical waves. The next lot is different because, although light is also a wave, it is an electromagnetic wave like radio waves, whose frequency is very much higher than any we can deal with by electronic methods. Transducers for light to electrical signals, therefore, do not give out an electrical wave when light strikes them unless the light itself is modulated, with its amplitude varying at a rate that we can cope with. Transducers of this type are called photocells and several varieties, classed as photoconductive, photovoltaic, photoemissive, photodiode or phototransistor exist. Let's take them one by one.

A photoconductive cell is made from a material whose resistance changes as the amount of light falling on it changes. Obviously, a cell of this type does not have a steady value of output resistance and we must use it in a circuit similar to that which we use for a transistor, with a constant value load resistor connected in series across a steady supply voltage (**Figure 11.6**) The photoconductive cell does not generate any signal; it simply controls the current from an external power supply, so that whenever a photoconductive cell is used there must also be a battery, or other power source. The most commonly used photoconductive material is cadmium sulphide and **Figure 11.7** shows the arrangement of a typical cell, along with its measurable characteristics. These cells are reasonably sensitive, but they suffer from a time-lag — once they are conducting, they will stay conducting for a fraction of a second after the light is cut off. Such cells are, therefore, useless if the light is modulated with a signal whose frequency is more than a few Hertz.

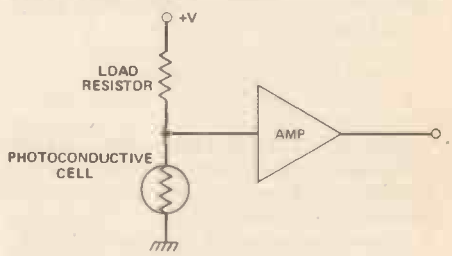

Figure 11.6. Connecting a photoconductive cell to a circuit.

Photovoltaic cells have a very long history. The first photovoltaic material to be discovered was the element selenium, a close relative, chemically, of sulphur; its photovoltaic effects were noted more than a century ago. As the name suggests, you don't get a change of resistance across a selenium element when you shine light on to it, you get a voltage. This happens only when the selenium is in contact with another material and it is, in fact, a primitive type of semiconductor junction. Like cadmium sulphide cells, selenium photovoltaic cells have a time lag which makes them unsuitable for anything but low-frequency operation. This was the problem which hindered the advance of television in the 1870s, when Nipkow demonstrated the system which was later to be improved by Baird.

Nowadays, we have found ways of making photovoltaic cells using silicon, and these are a great improvement, both in sensitivity and in response time, over the old selenium cells. They can, for example, be combined in one package with LEDs as an opto-coupler, so that signals can be transferred between points which

TYPICAL CHARACTERISTICS FOR THE ORP12	
MAX. DISSIPATION	200 mV
MAX. VOLTAGE	100 V
DAYLIGHT RESISTANCE (APPROX)	2k
RESISTANCE RANGE	75R TO 10M
RESISTANCE RISE TIME (APPROX)	75 mS
RESISTANCE FALL TIME (APPROX)	350 mS

Figure 11.7a. Characteristics of an ORP12 photoconductive cell.

Figure 11.7b. The physical arrangement of a typical photoconductive cell.

are at very different voltages. The advantage of the photocoupler, as compared to capacitors or transformers, is that it can transfer DC signals, not just a limited range of AC frequencies.

Photoemitting cells also have a surprisingly long history, dating back to research in the latter part of the 19th century. A photoemissive cell uses one of the chemically-active metals, such as sodium, potassium, rubidium or, most commonly, caesium. All of these are extraordinarily soft and light metals (sodium will float on water, for instance) which are violently chemically active (but it dissolves, almost explosively).

Lenard discovered that when a block of sodium was contained in a vacuum and the surface scraped clean (using a knife operated by a magnet), the clean sodium surface would emit electrons when it was struck by light. These electrons can then be attracted to an 'anode', a metal surface a few hundred volts positive, relative to the sodium surface, and this flow of electrons constitutes a current. Like the photoconductive cell, the photoemissive cell is used with a power supply and a load resistor; a cross-section of a cell, and a circuit, is shown in **Figure 11.8**. The response time of a photoemissive cell is very much faster than that of a photoconductive type, however, so that the photoemissive cell was, at one time, the only type of cell that could be used for the conversion of flickering light, from the soundtrack of movie films, into electrical signals. The television camera tubes which were in use until comparatively recently were all photoemissive, although modern cameras make use of new, fast-response photoconductors, such as lead oxide.

Photodiodes and phototransistors are the most recent types of photocell to be discovered. When a diode junction is created, the current which can flow when the diode is biased in the reverse direction is controlled by the depletion region, because this region is the main obstacle to the movement of carriers. Anything which alters the number of carriers in the depletion region will greatly affect the conductivity of the diode and light, in fact, does just this. The energy of a light wave is enough to separate an electron from a hole and, if this happens in the depletion region, each new electron/hole pair will contribute to the conductivity of the diode and so will allow the current to increase for as long as the light is affecting the depletion region.

This effect is not normally noticeable with diodes, because the reverse currents are very small and we seldom use them in circuits which are sensitive to changes in reverse current. For diodes which must have very low values of reverse current, however, it is essential to exclude light from the junction.

The phototransistor is a logical development of the photodiode. If light is allowed to strike the base layer of a transistor which is biased off, the extra electrons and holes which are generated by the light will cause a base current (assuming there is a voltage applied to the collector). This makes the phototransistor a much more sensitive device than the photodiode, though at the expense of a slower response.

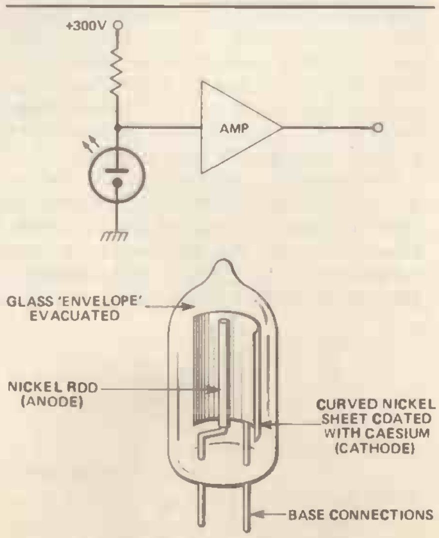

Figure 11.8. The photoemitting cell and how it is used in a circuit.

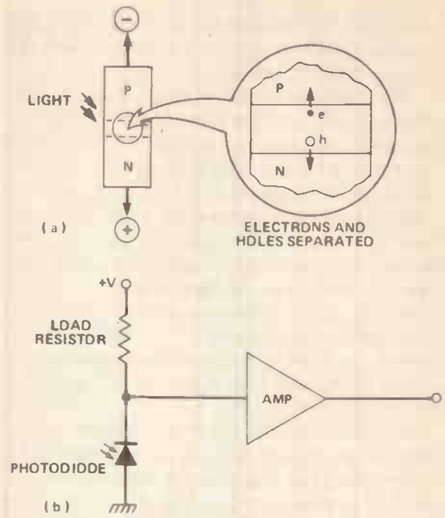

Figure 11.9. How light can cause the reverse current of a diode to increase (a), and the circuit (b) which makes use of this.

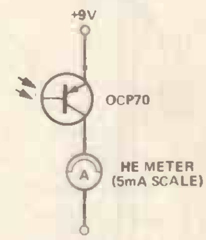

Figure 11.10. Testing a phototransistor with the HE meter.

Early types of germanium transistor, such as the classic OC72s, used glass cases which had to be coated with black paint to prevent light from affecting the bias currents. If the paint is scraped away, an OC72 can be used as a phototransistor, equivalent to the OCP70. The difference is that the OC72s can usually be picked up as scrap, but people still want money for OCP70s.

If you can get hold of one of these old-timers, scrape off the black paint, and set up the circuit of **Figure 11.10**. Remember that the OC72 was a PNP transistor, which is why the collector is connected to the negative terminal. The HE meter will show a considerable increase in current when a light is shone on to the transistor, demonstrating the photoelectric effect.

All of these transducers can change light signals in to electrical signals and so there just have to be transducers which operate the other way round. An ordinary light bulb is, of course, an electrical-signal-to-light transducer, but it suffers from an unacceptably long time-lag, so that it is useful only for steady light signals. The LED (described in Part 6) is much more useful in this respect.

Heated Topic

Temperature is another quantity for which we have transducers. All conductors operate as electrical-to-heat transducers; because of their resistance, electrical energy is converted to heat energy, causing the temperature of the material to rise. Normally, this is a conversion we do our best to avoid.

The opposite conversion uses temperature levels, rather than heat. A thermocouple consists of a pair of different metals, arranged in two junctions as indicated in **Figure 11.11**. These are not junctions in the transistor or diode sense, but simply wires of different types soldered together. When the junctions are at different temperatures, a small voltage will be measurable at the ends of the wire. This is only a few millivolts, at most, so that it is not easily measurable but it is enough to pass current through a sensitive meter and we can use the HE meter, along with lengths of iron and copper wire, to demonstrate the action of a thermocouple. With one junction in ice and the other in air, the thermocouple will pass a noticeable current when the HE meter is switched to a low-current range (**Figure 11.12**).

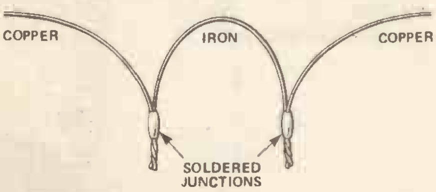

Figure 11.11. A thermocouple arrangement, using copper and iron wires.

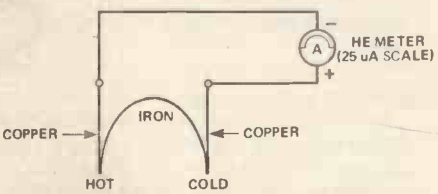

Figure 11.12. Demonstrating thermocouple action, using the HE meter on its most sensitive current range.

The trouble with thermocouples is that they can be operated reliably only over a limited range of temperatures. At some high temperature (the inversion temperature), the voltage output of any thermocouple reaches a maximum and the voltage then reduces as the temperature is taken over this value (**Figure 11.13**). Despite this drawback, thermocouples are widely used for temperature measurements in industry. Their advantages are small size, quick response to changes of temperature, and the ability to measure high temperatures such as are found for furnaces, for example.

A device that is more familiar to users of electronic circuits is the thermistor. It is a form of resistor, which is made from metal oxides rather than from carbon. Depending on the types of materials that are used, thermistors can be PTC or NTC. The TC part of the name (no, it's not Top Cat) means Temperature Coefficient and the P and the N mean positive and negative, respectively (**Figure 11.14**). A positive temperature coefficient thermistor has a resistance value which *increases* as the temperature increases; a negative temperature coefficient thermistor has a resistance value which *decreases* as the temperature increases. The NTC types are more common, for most electronics applications.

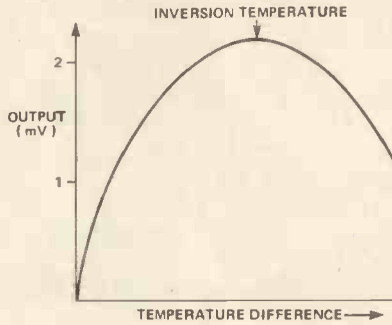

Figure 11.13. The graph of thermocouple output plotted against temperature has a maximum value, so that very high temperatures will give the same readings as low temperatures.

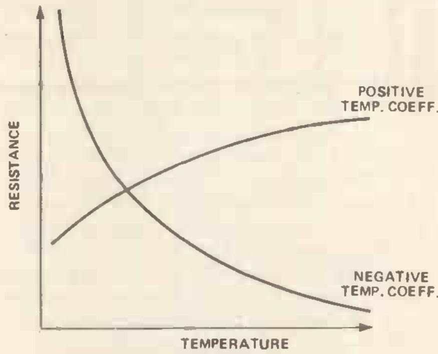

Figure 11.14. Graphs of resistance plotted against temperature for two typical thermistors.

Since it's the resistance of the thermistor which changes, they must be used with a voltage supply and a load resistor. Though thermistors are excellent for detecting temperature levels in thermostat applications, controlling the central heating for example, they do not make ideal thermometers, because the change in resistance per unit change of temperature is not a constant. (Our Digital Thermometer, last month, used, instead, a current-source whose output current varied with temperature).

Thermistors are made in various shapes and sizes, with resistance values ranging from a few ohms to several megohms (at the conventional room temperature of 20°C), and ranging in size from pinhead dimensions to large blocks. The pinhead types are used for temperature measurements on small objects and also for stabilising the amplitude of oscillations in R-C oscillator circuits (for example, the Audio Signs Generator project in the May issue). This depends on 'self-heating'; the temperature of the thermistor depends on the amount of current which is flowing through it, rather than the temperature of the air around it.

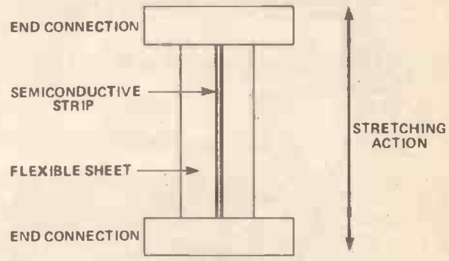

Figure 11.15. The semiconductor strain gauge. The resistance of the material increases as it is stretched.

Some of the Others.

We have only scratched the surface of transducers, looking at a few types which are common and familiar. In fact, there is a transducer for almost every physical quantity and two which are less familiar, but very useful, are the strain gauge and the tachogenerator. A strain gauge, nowadays, consists of a thin strip of semiconductor deposited on a flexible material. The resistance of the strip can be measured and the flexible carrier can be glued to almost any structure — a beam of a bridge, the wall of a house, the side of a container. Even very small changes in the length of the strip will cause noticeable changes of resistance so that strain, which means small changes of length, can be measured. Strain gauges are an essential part of modern civil engineering — they show how much your bridge is affected by loads and winds, how secure the foundations of your building are, how well your tank stands up to high pressure.

Tachogenerators are little dynamos; spin the shaft of a tachogenerator from another revolving shaft and the output voltage of the tacho generator will be proportional to the speed of the shaft. They're used increasingly in disc turntables as part of a negative feedback system for keeping the motor speed constant.

That's only a flavour of transducers, but it should be enough to show what a varied bunch they are, and how they can be used to couple electronics circuits to almost anything else we like. Electronics wouldn't amount to much without them!

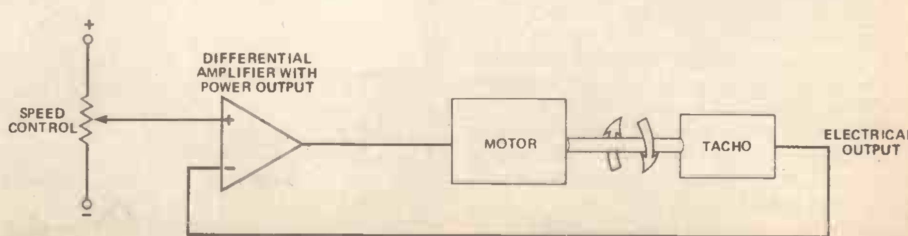

Figure 11.16. Using a tachometer in a motor speed control circuit.

HE

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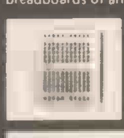

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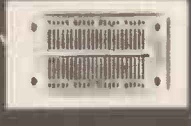

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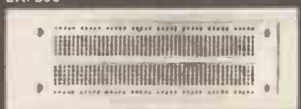

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9P

Automatic Greenhouse Sprinkler

Owen Bishop

A summer plant-saver that works automatically, triggered by the falling moisture level in a plant pot.

THE HOT sunny days that we hope to be having from now until September can play havoc with plants in a greenhouse. You need only to forget to water them once, or forget to open the windows on a warm day, and the plants are soon in a sorry state. Last minute watering *might* revive them but, on the other hand, it *might not*! This device not only warns you when the plants are beginning to need some water, but actually does the watering for you. You might need to supplement its action each evening by using the old-fashioned watering-can, but it will take care of those times during the day when a light sprinkling makes all the difference to the health of the plants.

The circuit consists of two sections. One part is concerned with sensing the water state of the plants and sounding an alarm when it gets too low. The other part turns on the pump to sprinkle the water. If you simply need a warning and are prepared to do the sprinkling yourself, there is no need to build the pumping section. If you are going to include the pump, you will certainly want the warning device, too. This sounds for about 30 seconds *before* the pump is turned on. Should you or the family happen to be admiring the tomatoes as the soil goes dry, the warning gives you plenty of time to retreat — out of range of the sprinkler. The warning period can be extended if 30 seconds is not long enough.

Anyone who has ever watered a potted plant knows that it is more effective to water for a short period, and then stop and allow the water to soak in before repeating the watering. The sprinkler works in this fashion too. The pump is turned on for 30 seconds, off for 30 seconds, repeating until the soil has been moistened to the right degree.

The Circuit

The amount of water in the soil is sensed by a circuit which measures the resistance of the soil between two metal rods buried in the soil (the probe). If we pass a *direct current* through the soil, the water and dissolved salts in the soil act as an electrolyte. In a few minutes, polarisation occurs and the resistance changes. Instead, we use an *alternating current*, to avoid polarisation. This is generated by a 1 kHz oscillator (IC1) in the sensor circuit. The alternating potential is rectified by a diode (D1) and smoothed by a capacitor (C7) to give a steady potential. As the soil becomes drier, its resistance increases. This gives the alternating voltage greater amplitude and so the steady DC potential rises. This rising potential eventually triggers a Schmit trigger (IC3) causing its output to change abruptly from low to high (0 V to 12 V). The level at which this change occurs can be controlled by adjusting the 'Set Level' control, RV1.

The output of the sensor is combined with the output from the 1 Hz timer (IC2) by a NAND gate. When the output of the sensor is low (moist soil), the output of the gate is steady at 12 V. When the soil dries, the output begins to alternate between 0 V and 12 V at a rate of 1 Hz. These pulses switch an audible warning device on and off, providing a bleeping tone. The pulses are counted and, after a fixed number (say 32), the selected output of the counter goes to 12 V. This switches on the pump. The output alternates from 0 V to 12 V regularly at (say) 1/32 the rate of the timer, giving periods of sprinkling followed by equal periods during which the water soaks in to the soil.

When the soil is sufficiently wet, the reverse actions occur. As the soil resistance drops, the DC potential falls and the Schmitt trigger output (IC3, pin 10) goes low, stopping the alarm. The low-going edge triggers a pulse generator (two gates of IC4) which sends a single high pulse to the reset input of the counter. This makes all its outputs go low, so turning off the pump.

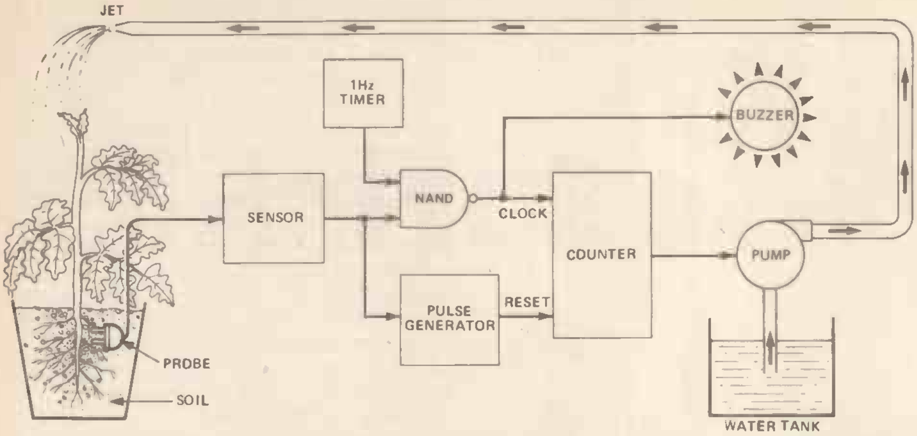
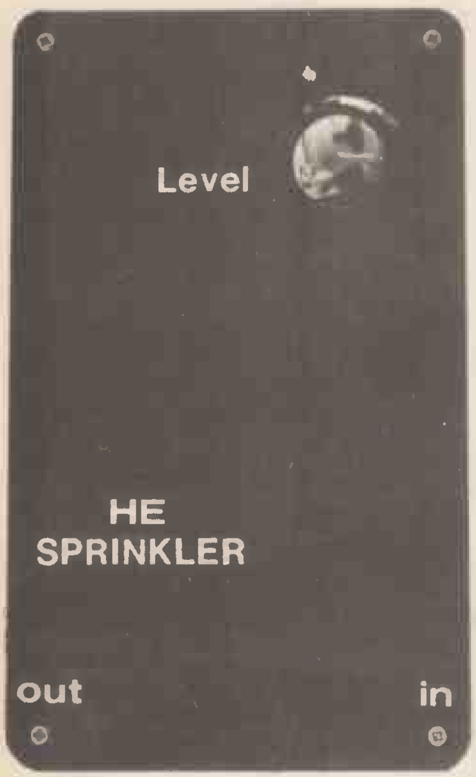


Figure 1. Block diagram of the Auto Sprinkler.



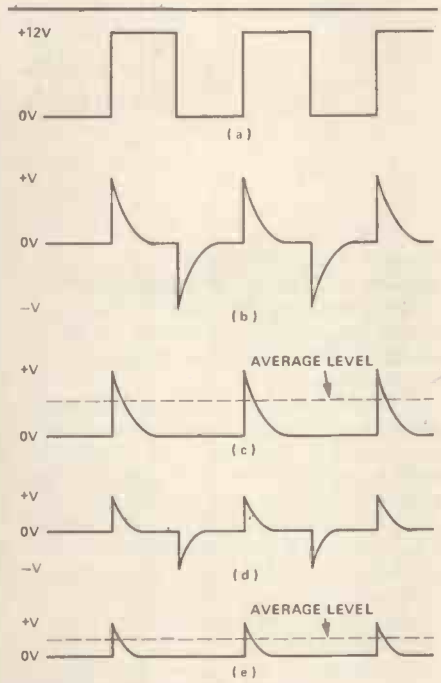


Figure 2. The timing digram shows: (a) Output from IC1; (b) Waveform at the 'live' pin of the probe; (c) Junctions of D1 and C7; (d) As (b) but with wetter soil; (e) As (d) with wet soil — the average level is lower so the alarm is not triggered.

Power Supplies

Before going on to constructional details, we must consider the matter of power supplies. The circuit uses an unregulated 12 V DC supply. This is best taken from a power-pack located indoors, with a light-duty lead to carry the current to the device in the greenhouse. The pump is a windscreen-washer pump, which needs at least 2 A. A circuit for a suitable power-pack is given later. If you have decided to use this only as a warning device, the power requirements are much less. Without the pump and its relay, the circuit uses only about 45 mA and almost any small power-pack can be used to provide this. Then it would be more suitable to locate the circuit indoors, with a lead running to the *probe* in the greenhouse. A low-current power supply could easily be fitted into the case.

Construction

The circuit is best built and tested stage by stage, beginning with the sensor circuit. The 1 kHz oscillator based on IC1 is the first part to assemble, including C6. If an earphone is connected between the free terminal of C6 and the 0 V line, a high-pitched tone should be heard, indicating that the oscillator is working. If all is in order, wire up RV1, D1, C7 and the probe. In the prototype, the probe is a 2-pin 5-amp mains plug of the old type, which was found in the scrap box. The essentials are two stout metal rods, preferably of brass or some other corrosion-resistant metal or alloy. They should be about 1.5 cm long and mounted on an insulating base about 1.5 cm apart. Connect these to the circuit board with ordinary lighting flex. While testing, you need a potted plant, or at least a pot of moist potting compost or good loamy soil. The probe can be simply pushed into the soil when testing. Later when the system is in use, it is better to bury the probe one to 2 cm deep in a pot of soil or the

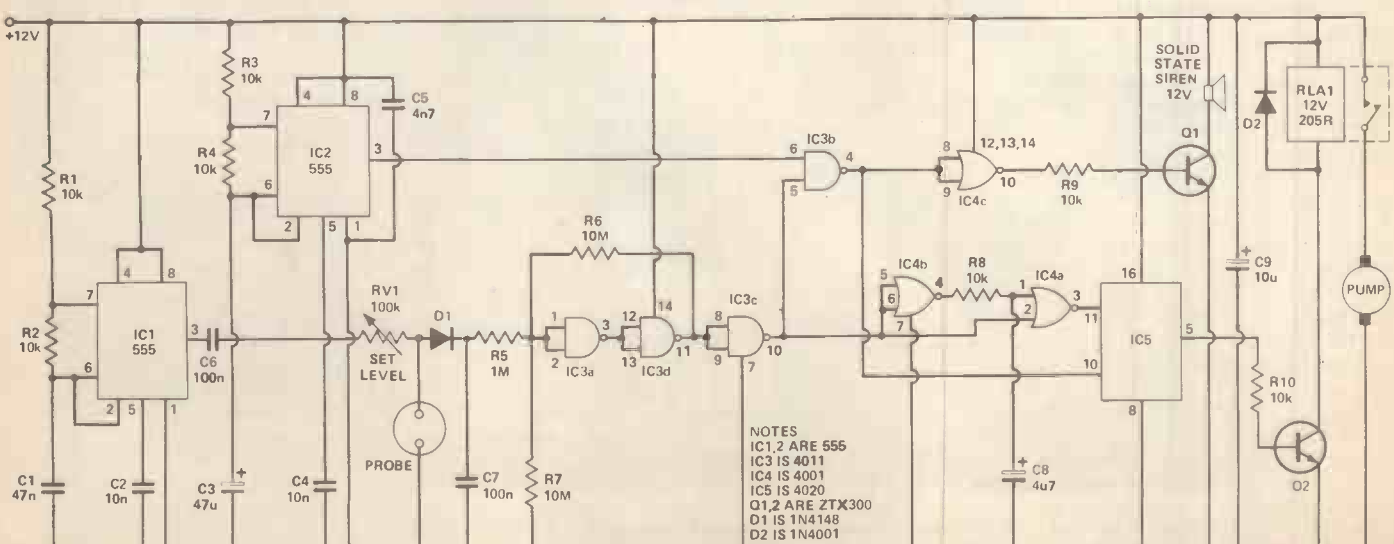


Figure 3. Complete circuit of the Auto Greenhouse Sprinkler. The power supply unit is shown over the page.

greenhouse bed. Place it on its side, so that the base does not prevent water from reaching the soil surface directly above the rods.

If you have an oscilloscope or FET voltmeter, the rectifying stage can be tested by connecting the probe of the scope to the junction of D1 and C7. As RV1 is turned, the voltage should range from about 1 V to about 10 V. Pulling the probe slightly out of the soil (simulating drying out) results in a fall in output voltage. Incidentally, the circuit does not work unless there is at least some conduction across the probe, so remember to water the plant occasionally, or your tests (and the plant) will probably fail.

Next build the Schmitt trigger circuit (IC3). Its output should flip neatly from 0 V to 12 V as RV1 is turned from one extreme to the other (with the probe in the plant-pot).

The next stage is to build the 1 Hz timer, based on IC2. Unless there is effective decoupling of the supply line between IC1 and IC2, the timer is triggered by noise from IC1. Decoupling capacitor (C5) was therefore placed as close as possible to the terminals of IC2. Too large a capacitor affects the operation of the sensor circuit, so keep to the value specified. The remaining gate of IC3 may now be wired in. With RV1 at one extremity (minimum resistance), the output of pin 4, IC3b, should be 12 V. At the other extremity it should alternate from 0 V to 12 V at approximately 1 Hz (the exact frequency does not matter).

One gate of IC4 simply inverts the output from IC3, so there should be no problems here. The other two gates form the reset pulse generator. This is not needed if you want only a warning, and no water pump. The pulse

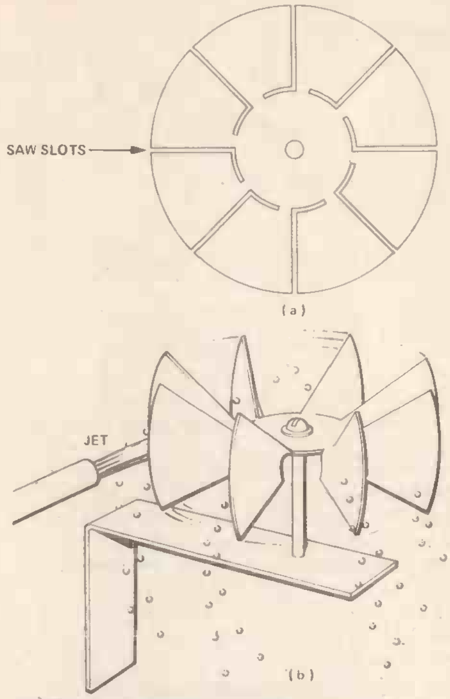


Figure 4. A simple turbine sprinkler: (a) cutting the wheel from a disc of sheet aluminium; (b) the turbine in operation. Note that the jet should be quite narrow or the plants will be flooded.

generator should normally have a low output which goes high very briefly when the output from IC3 goes low (ie when the soil has been watered enough). This pulse can be detected as an upward kick of the needle of a voltmeter connected to pin 3, IC4a.

The pump is controlled by the counter (IC5). First check the connections from IC3 and IC4. The output from IC5, pin 4, has 1/64 the frequency of the input and with a 1 Hz input, the output is low for 32 S and high for 32 S. This gives 32 S warning — to evacuate the greenhouse. If you think this is more than enough, take the output from pin 5 (as in **Figure 3**), which gives a 16-second warning. Since your timer may not be running at 1 Hz, anyway, the best thing is to test the output from the various pins — dotted lines on the component overlay — and find the one which gives the timing you prefer. Mount the relay with its protective diode, D2, and the switching transistor Q2. Join the base of Q2 to the selected output pin of IC5 by way of R10. The tracks to which the relay switch terminals are soldered were made as short as possible but, since they are to carry heavy current, it is advisable to run a thick coating of solder along them to aid conduction. Finally, mount the circuit board, RV1 and the pump in the case.

Installing The Sprinkler

The case housing the circuit should be sited well away from any area of the greenhouse which is to be sprayed or dripped on. A few trials may be needed to establish optimum operating conditions and methods, so perhaps it is best to mount the case temporarily, to begin with. The probe should be buried in a pot of soil. Preferably, this should have a plant in it too, to ensure that the soil loses water at the same rate as the soil in other pots. The probe can be buried in a bed if preferred, but it should be placed where it will receive an average amount of water and where it is likely to lose water at an average rate (ie not in the sunniest or shadiest part of the greenhouse).

The pump needs a supply of water. This is best held in a tank inside the

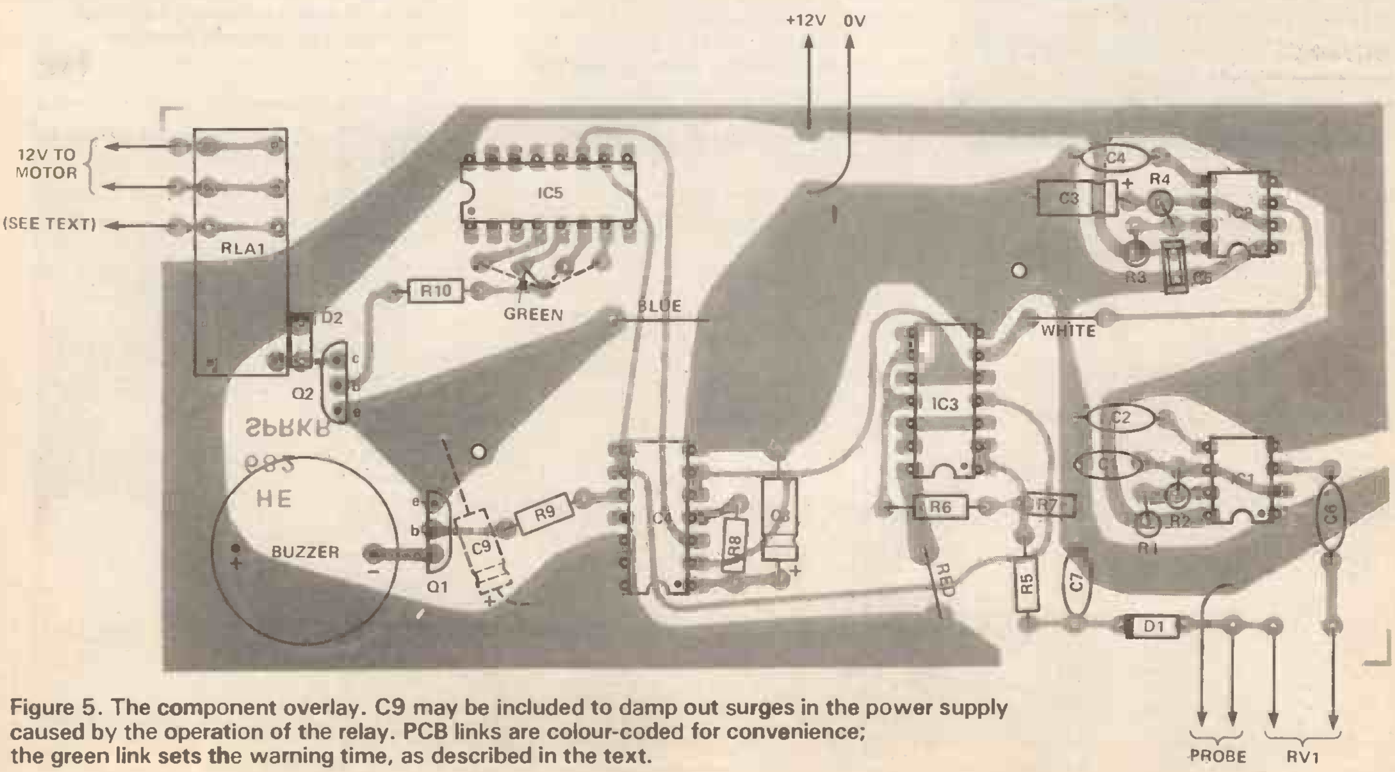


Figure 5. The component overlay. C9 may be included to damp out surges in the power supply caused by the operation of the relay. PCB links are colour-coded for convenience; the green link sets the warning time, as described in the text.

Parts List

RESISTORS
(all ¼ W, 5% carbon)
R1,2,3 . . . . 10k
R5 . . . . 1M
R6,7 . . . . 10M
R8,9,10 . . . . 10k

POTENTIOMETERS
RV1 . . . . 100k carbon track, linear

CAPACITORS
(all polyester, except where indicated)
C1 . . . . 47n
C2 . . . . 10n
C3 . . . . 47u 16 V electrolytic
C4 . . . . 10n
C5 . . . . 4n7 polycarbonate
C6,7 . . . . 100n
C8 . . . . 4u7 16 V electrolytic
C9 . . . . 10u 16 V electrolytic

SEMICONDUCTORS
D1 . . . . 1N4148
D2 . . . . 1N4001
Q1,2 . . . . ZTX300
IC1,2 . . . . 555 timer
IC3 . . . . CD4011BE
quad 2-input NAND
IC4 . . . . CD4001BE
quad 2-input NOR
IC5 . . . . CD4020BE
14-stage binary counter

MISCELLANEOUS
RLA1 . . . 12 V miniature PCB relay

PCB; 1 mm terminal pins (6 off); Knob for RV1; 12 V audible warning device, PCB mounting; 12 V automobile screen-washer pump unit; ABS case, approx. 180 mm x 110 mm x 50 mm; materials for making the probe (see text); bolts and nuts for mounting board and pump; plastic tubing and t-joints (standard 5 mm aquarium aerator tubing is suitable); water tank; materials for making the irrigating devices; connecting wire, solder.

BUYLINES . . . . page 23

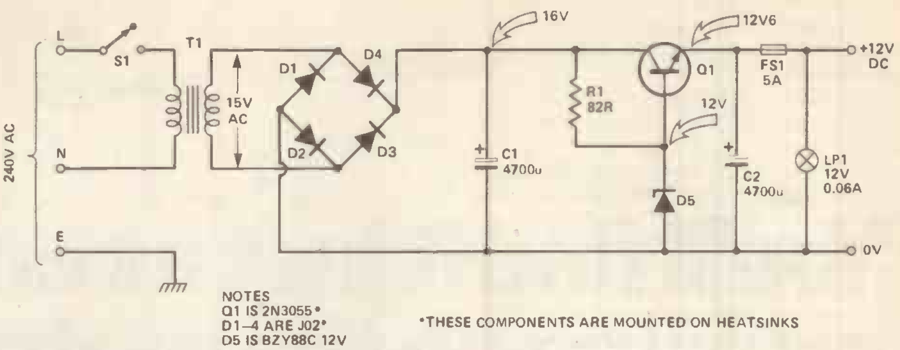


Figure 6. A power supply suitable for driving the complete unit, including the pump. Note that the output is a *nominal* 12 V.

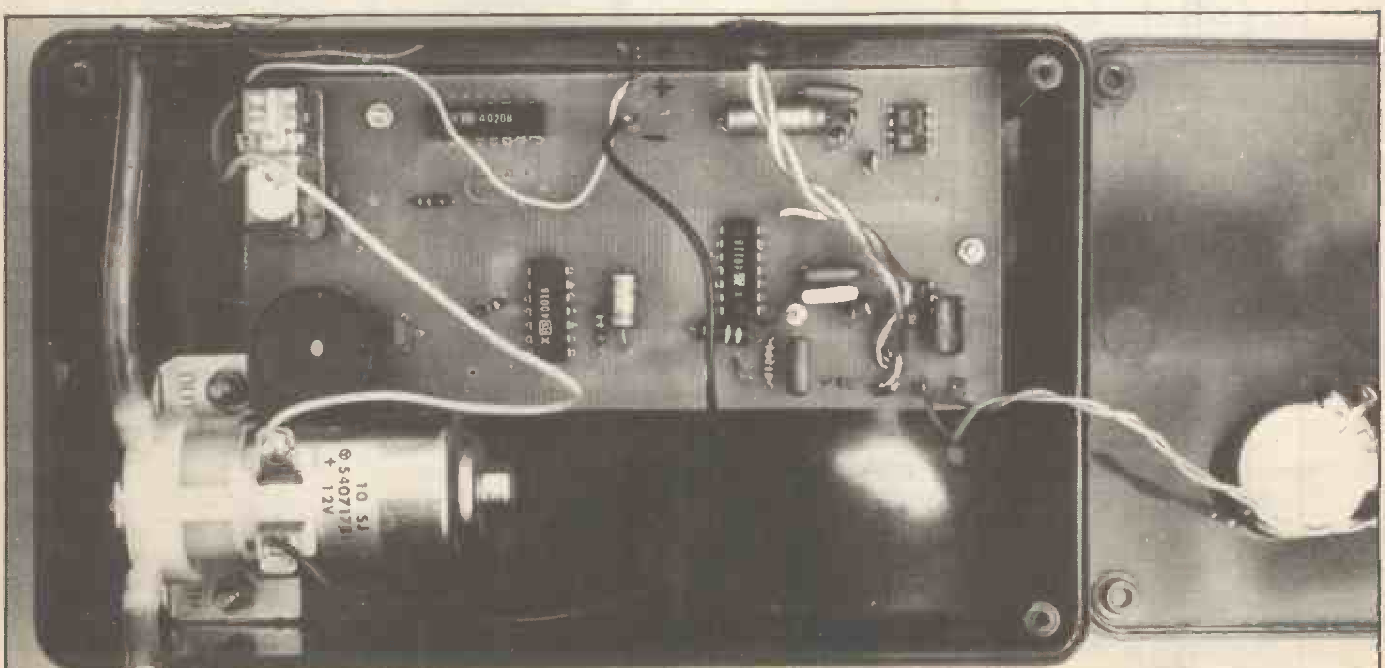
greenhouse, so that the water is at the correct temperature. The tank should be covered, if possible, to exclude light, which encourages the growth of algae, and to exclude soil and dead leaves, which might clog the pump. Alternatively, the pump may be fed from a covered rainwater butt or other tank outside the greenhouse. There could be an application here for those 'water level detector' devices which are so often featured in books of simple electronic projects. Mount one in the tank to warn you when the tank needs topping up!

WARNING: do not run the pump unless it has a supply of water. Without water, it draws excessive current, which could burn out the power supply.

There are several ways in which the water can be distributed to the plants. You may prefer to irrigate from below, in which case the tube from the pump branches to the trays or troughs in which the plants are standing. The trays are flooded repeatedly until the soil becomes saturated to the right amount. If you are using this system, it is advisable to bury the probe nearer to the bottom of its pot. Another method of distribution is to run lengths of tubing above the bench, suspended from the frame of the roof. The tube is perforated at intervals, so that water rains down on the plants beneath. A turbine sprinkler like that illustrated in the drawing scatters the water over a wider area. With all methods, you will probably need to use fine jets on the end of the tube, or screw clips on the tube to restrict the flow. Another point to be considered is what becomes of the water after it has drained away from the pots. If you have troughs on your bench, you could arrange for the water to drain back into the tank. This is more economical of the water and useful, should you want to leave the greenhouse unattended for several days.

Whatever methods you adopt, you will need to experiment with the distributing system to get it just right. You will need to find out which is the best position for the sensor and which is the best setting of the level control (RV1) of the sensor. Eventually you should be able to arrive at just the right system for your greenhouse and the particular plants you are growing.

HE



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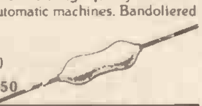

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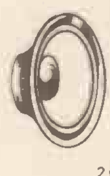

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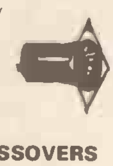

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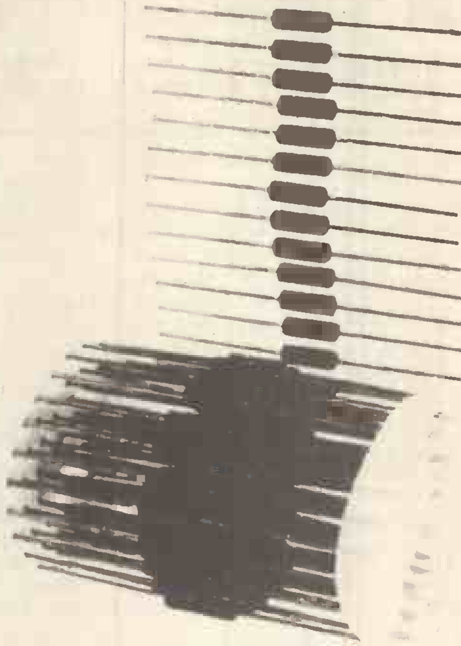
0·001µ 100n OR1 120,150,180 4R7 6p8 1k02

33, 47, 56, 68, 82, 100



To the beginner in electronics, and to quite a few not-so-beginners, the values and units given to electronic components such as resistors, capacitors and RF chokes seem confusing. This article should clarify things for you.

THE DECIMAL point has been almost abolished in electronics. The little dot was so small it often disappeared when things were printed, and in any case not everybody recognises its meaning. The French, who invented the decimal system, use a comma instead and so do most Europeans. Other countries use commas for different purposes, like separating hundreds from thousands in large numbers. So when you see a number written 1,500 you don't immediately know whether it's meant to be fifteen hundred or one-and-a-half to three decimal places! When engineers from all over the world sat down to decide on a standard international numbering system, they decided that the best thing to do with the decimal point/comma was to get rid of it altogether.

It has been replaced by a letter. To show where the decimal point was, any letter would do. For example, you might write one-and-a-half as 1a5 or 1b5 or 1c5, or you could use a capital letter, say 1P5 or 1Q5.

Normally in electronics you're not dealing with pure numbers. You're dealing with numbers of *somethings* — so many volts, so many watts, amps, ohms and so forth. Most of these quantities have letters that are used as abbreviations for them. 5 V means 5 volts, for example, 5 A means 5 amps, 5 W means 5 watts. When you want to express fractional amounts of these quantities you use the abbreviation letter in place of the decimal point, like this: 5V6, 1A5, 3W7. You don't have much trouble seeing that these last three mean 5-point-6 volts, 1-point-5 amps and 3-point-7 watts. Unfortunately, there isn't a letter of our alphabet that stands for ohms, but we're all quite used to seeing a capital R for resistance, so we use that to indicate ohms, like this: 4R7, 2R2, 100R. These mean of course 4-point-7 ohms, 2-point-2 ohms and 100 ohms.

Mini And Maxi Units

Lots of things aren't commonly or conveniently measured in the standard size units. Capacitors, for example, are never measured in Farads, because a whole Farad is an enormous capacitance. Practical capacitors have values measured in thousandths, millionths and even smaller fractions of a Farad. At the other extreme, resistors often have values of thousands and millions of ohms. Now it's obviously inconvient and confusing to write 0F000001 for one microfarad or 100 000R for one hundred kilohms, so what you do is alter the decimal-point-indicating letter to show the size of the units you are using. For example, 1k5. Clearly this means one-and-a-half somethings and from kilograms and kilometres everyone knows that the little letter 'k' indicates a thousand. So 1k5 must mean one-and-a-half thousand that is 1500. Similarly, 4k7 means 4700, 2k2 means 2200 and so forth. It's usually clear enough from the context whether you're talking about resistance or capacitance or frequency or whatever, so you don't need to write ohms or anything afterwards.

As well ask for one thousand, there are a number of other letters that stand for multiples of the basic unit. Here they are:

G (Giga) = 1 000 000 000 (one thousand million, 10^{9})
M (Mega) = 1 000 000 (one million, 10^{6})
k (kilo) = 1 000 (one thousand, 10^{3})
m (milli) = 1/1000 (one thousandth, 10^{-6})
u (micro) = 1/1 000 000 (one millionth, 10^{-6})
n (nano) = 1/1 000 000 000 (one thousand millionth, 10^{-9})
p (pico) = 1/1 000 000 000 000 (one billionth, 10^{-12})

Occasionally you'll come across *tera* (T) which is one million million (10^{12}) and *fento* which is one thousand billionth (10^{-15}).

Armed with this information, you should be able to read almost any printed value of an electronic quality. For practice, here are a few examples of values you might not be too familiar with. A capacitor marked as 47p has a value of 47 picofarads, which is 47 billionths of a Farad. One marked 4p7 has only a tenth the value, 4-point-7 billionths of a Farad. A 100n capacitor is 100 nanofarads or 100 ÷ 1 000 000 000 Farads = 1/10 000 000 farad. At the other end of the scale, a resistor marked as 15M has a value of 15 Megohms, ie: 15 million ohms; one marked 1M5 has a value ten times less at 1-point-5 million ohms.

Translation Problems

The standard international numbering system makes everything simple as long as everybody sticks to it, but unfortunately there are still some occasions when you come across values written in an older style and you have to translate them into a new style. This mainly happens with capacitors.

The first problem is that the old symbol for 'micro' was different. It was a Greek letter called mu, which is pronounced like the noise a pussycat makes, and looks like this: . This symbol caused some confusion in the past, because it sometimes got mistaken for 'm', which has always meant 'milli', a thousand times larger. So was officially replaced by 'u'. If you see a capacitor marked, for example 10 , you can translate that directly into 10u and know that it means 10 microfarads. Nevertheless, is still widely used.

Another confusing thing is the still common practice of marking or specifying capacitor values in *fractions* of a microfarad like 0.001u (1000p, or better, 1n). To convert fractions of a microfarad into modern values, you have to multiply by 1000 to get the answer in nanofarads, or multiply by 1 000 000 and get the answer in picofarads. Don't panic! To save you trouble, here is a list of typical old-style values and how they translate into new style. From this list you should be able to work out very quickly the new-stlye version of any old-style capacitor value.

0.1u = 100n	0.47u = 470n
0.01u = 10n (10 000pl)	0.047u = 47n
0.001u = 1n (1000pl)	0.0047u = 4n7
0.001u = 100p	0.00047u = 470p

Small Resistances

Resistors with small values sometimes cause difficulties. Because small resistances are not very commonly used, most people are not accustomed to thinking in terms of milliohms (thousandths of an ohm), so the little letter 'm' isn't used for resistors. A resistance of one-tenth of an ohm is not written 100m (for one hundred milliohms), but 0R1 (for one-tenth of an ohm). As usual, the letter R indicates the position of the decimal point and shows that the unit of measurement is whole ohms. In the same way, 2R2 means 2-point-2 ohms, 5R6 means 5-point-6 ohms and so forth. Even smaller values are still written as fractions of an ohm, but the 0 before the decimal-point-indicating letter is usually omitted. For instance, R01 means point-01 ohms (one hundreth of an ohm), R001 means point-001 ohms (one thousandth of an ohm), R33 means 33/100ths of an ohm and R068 means 68/1000ths of an ohm.

Zeroes

Some component values are written with a zero before or after the multiplier character to indicate the value quite unambiguously. For example, a 1000 pF capacitor, rather than being written '1n' may be written 1n0. Or a point-1 (0.1) ohm resistor, rather than being written R1, may be written 0R1.

Preferred Values

Why is it that resistors and capacitors only seem to come in certain values? You almost never see a 25R resistor, only 22R or 27R ones. 600k resistors are likewise as rare as hens' teeth, but there are any number of 560k and 680k ones. For one thing, manufacturers can't make every possible value of resistor. If they made resistors in every whole number of ohms between 1R and 10M, they'd be making ten million different products and selling only a few of each. Very capital inefficient, as they say. Resistors would be ridiculously expensive and manufacturers would go bankrupt. Obviously, only a restricted number of values can be produced.

But why these particular values that actually are produced? What's so special about 4k7 or 56R or 820R? Why not stick to simple numbers? The reason is that these particular values allow the least number of different values to be made. How come? Well, resistors are not made with absolute accuracy — that costs too much and isn't usually necessary. Most circuits will accept a variation of 10% in resistor values without problems. So resistors are made with values that are anything up to 10% higher or lower than their marked value. This is called a tolerance of 10% and such a resistor is usually called a 10% resistor. For example, a 100R, 10% resistor might have a value anywhere between 90R and 110R. Given this amount of variation, there would obviously be no point in also making 10% resistors with nominal values like 94R or 107R, because these values are already covered by the ± 10% spread of the 100R resistor.

So in a series of 10% resistors, what should be the next highest value above 100R? A value of, say, 11R would be too low, because the 111R resistor would also have a tolerance of 10%, so its possible values would spread down to below 100R, completely overlapping the upper range of variation of the 100R resistor. To avoid this kind of overlap, the next highest value 10% resistor needs to be about 120R. A 120R 10% resistor has its possible values spread between 108R and 132R. There's still a small overlap, but to get rid of the overlap completely without leaving a gap you'd need a value of one hundred and twenty two and two ninths ohms (work it out for yourself if you like algebra), which is rather an awkward number. 120R is a nice round number, so that's the 'preferred value' next in the series. By similar reasoning, the next value in the series of 10% resistors is 150R, then 220R, 270R, 330R, 390R, 470R, 560R, 680R, 820R and then 1k. It doesn't take much to see that the obvious next preferred value after 1k must be 1k2, then 1k5, 1k8 and so on. In other words, the same sequence of values keeps repeating, multiplied by ten at each repetition. This series of preferred values is known as the *E12 series*, because there are 12 values in the series. For reference, here are two 'decades' of the E12 series:

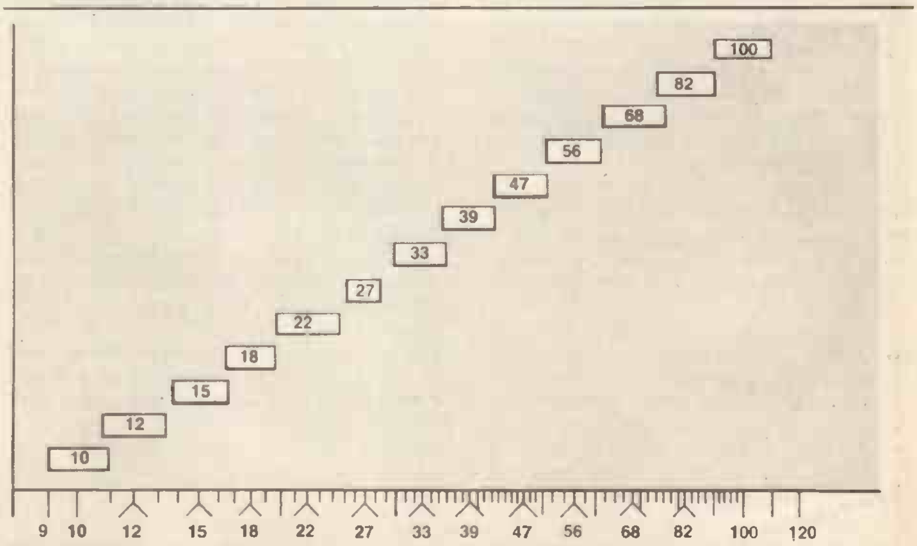
10	100
12	120
15	150
22	220
27	270
33	330
39	390
47	470
56	560
68	680
82	820

Even though resistors are nowadays more commonly made with a tolerance of 5%, the old E12 series of preferred values is still the most widely used. There is a similar series, called E24, which is worked out in just the same way as the E12 series, except that a tolerance of only 5% is assumed.

For closer tolerances, there's the E48 series (2%) and E96 series (1%) with, respectively, 48 and 96 values per decade.

Capacitors are made to wider tolerances than resistors — 20% is not at all uncommon, so they are usually supplied in a restricted range of preferred values. The significant figures in this series are 10, 15, 22, 33, 47 and 68. As there are only six values per decade, it is called the E6 series.

Close tolerance values are written in the same way as we've described previously, so if you come across a 1k02 resistor or a 34p8 capacitor you'll know you're dealing with close tolerance components. In the first case, you have a 1020 ohm resistor, in the second case you have a 34.8 pF capacitor.



This shows the tolerance extremes of all the values in E12 series, represented by a horizontal bar. The left-hand end and right-hand ends of each bar represent, respectively, the lower limit and the upper limit of the value. Most overlap, you will note.

Preferred numbers in decade for the E6, E12, E24 & E96 series

E6 20%	E12 10%	E24 5%	E96 1% and 2%					
10	10	10	10.0	10.2	10.5	10.7		
		11	11.0	11.3	11.5	11.8		
	12	12	12.1	12.4	12.7			
		13	13.0	13.3	13.7	14.0	14.3	14.7
15	15	15	15.0	15.4	15.8			
		16	16.2	16.5	16.9	17.4	17.8	
	18	18	18.2	18.7	19.1	19.6		
		20	20.0	20.5	21.0	21.5		
22	22	22	22.1	22.6	23.2	23.7		
		24	24.3	24.9	25.5	26.1	26.7	
	27	27	27.4	28.0	28.7	29.4		
		30	30.1	30.9	31.6	32.4		
33	33	33	33.2	34.0	34.8	35.7		
		36	36.5	37.4	38.3			
	39	39	39.2	40.2	41.2	42.2		
		43	43.2	44.2	45.3	46.4		
47	47	47	47.5	48.7	49.9			
		51	51.1	52.3	53.6	54.9		
	56	56	56.2	57.6	59.0	60.4		
		62	61.9	63.4	64.9	66.5		
68	68	68	68.1	69.8	71.5	73.2		
		75	75.0	76.8	78.7	80.6		
	82	82	82.5	84.5	86.6	88.7		
		91	90.9	93.1	95.3	97.6		

Top: The 'preferred values' of E6, E12, E24 and E96 series components.
Right: The tolerance spread (possible values, above and below the nominal value) of components in the E6, E12, and E24 preferred value series.

Tolerance extremities for the E6, E12 and E24 preferred series value

−20%	−10%	−5%	nominal value	+5%	+10%	+20%
8	9	9.5	10	10.5	11	12
		10.5	11	11.6		
	10.8	11.4	12	12.6	13.2	
		12.4	13	13.7		
12	13.5	14.3	15	15.8	16.5	18
		15.2	16	16.8		
	16.2	17.1	18	18.9	19.8	
		19.0	20	21.0		
17.6	19.8	20.9	22	23.1	24.2	26.4
		22.8	24	25.2		
	24.3	25.7	27	28.4	29.7	
		28.5	30	31.5		
26.4	29.7	31.4	33	34.7	36.3	39.6
		34.2	36	37.8		
	35.1	37.1	39	41.0	42.9	
		40.9	43	45.2		
37.6	42.3	44.7	47	49.4	51.7	56.4
		48.5	51	53.6		
	50.4	53.2	56	58.8	61.6	
		58.9	62	65.1		
54.4	61.2	64.6	68	71.4	74.8	81.6
		71.3	75	78.8		
	73.8	77.9	82	86.1	90.2	
		86.5	91	95.6		
E6	E12	E24		E24	E12	E6
lower extremities ←				upper extremities →		

HE

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POPULAR COMPUTING

In this issue we present the first instalment of our microcomputer project, especially developed with Hobby Electronics readers in mind. It is more than just a teaching aid — it is also a powerful machine for control applications. In future issues, we'll be presenting a number of projects designed to be controlled by a computer, but first you'll need

THE HE MICROTRAINER . . 60

If any single microcomputer can be said to have started an industry, that computer is Sinclair's ZX81. Add-on extras now available for the ZX81 include ASCII keyboards, controllers and memory packs. In the months to come we'll be reviewing many of these products. We start with

MEMOTECH'S 64K RAM PACK 65

Of course, a computer is only as good as the software — the programs — written for it. A vast number of programs have already been developed for the ZX81 and more are appearing every month. What better place to start than Sinclair Research's own ZX Software, which we've called

THE SINCLAIR TAPES . . . 66

Colour television monitor courtesy of JVC and Which Video?

HE MicroTrainer

A powerful and flexible Hex Trainer/Controller based on the popular 1802 microprocessor also used as the main MPU on board UOSAT, the University of Surrey Satellite). This month we introduce the 1802 and in July, we get down to nuts and bolts with the constructional details.

HOBBY ELECTRONICS, as well as offering projects and features for the more advanced electronics enthusiast, has always been very much a magazine for beginners, too. Whatever direction is taken by the technology of electronics, in industry and commerce, this magazine will always aim at offering the hobbyist a foothold in basic, applied electronics. In this series of articles, covering a major computer project, we present an alternative to the view that microprocessors are of a complexity beyond the abilities of the average hobbyist.

The microprocessor has been around for close to a decade, now, and its success is clearly evident in the vast range of microprocessor-based consumer products that have flooded the market; computers, toys, timers, heating controllers, and cash registers, to name but a few. The very factors that make the device attractive to these applications, namely low cost and high flexibility, equally justify it use by the amateur constructor.

In this article, we present a discussion of the basic principles of microprocessor operation. This will be expanded and illustrated, through applied examples, in later issues and next month we will start the full constructional details of our microprocessor training machine. Later, we will be specifically concerned with interfacing this machine (and machines in general) to the real world in controller-type applications.

A Bit Of This And That

A microprocessor is an electronic device that processes digital information (data). The term 'digital' means that the signal voltages that are being dealt with are in discrete levels, commonly just two levels, a low voltage (0V) and a high voltage (+5V); these are usually referred to as logic 0 and logic 1 respectively. Most of you will already be familiar with simple digital circuitry.

If you pause to think of applications for solid-state electronics, you will see that a large number of them are immediately suited to digital electronic design. In an industrial control system, for example, we may have a number of devices (motor, valves etc) which switch either on or off, open or closed, as a logical function of the state of other devices (switches, sensors etc). Other systems, which use transducers, pick-ups and variable-speed motors, on the other hand, are not immediately adaptable to digital techniques. Nevertheless, even in this latter case digital designs are widely applied, by the method of converting from analogue signals to digital, and from digital to analogue, before and after the signal processing stages, respectively. The reward is improved system reliability and, often, greatly simplified circuitry, which equates with low cost.

Ultimately, we reduce each problem to a set of logic signals, each one of which we term a bit (of information or data). These bits may individually represent the state of an external device (switch, motor etc on or off) or collectively represent a number or variable, such as would be derived from an analogue to digital conversion process. In this latter case, and particularly when using microprocessors, it is usual to collect and process data bits in groups of a fixed number; most of the common microprocessors handle data in groups of eight bits and each group is called a 'byte'. We can use a byte to represent a maximum of 256 numbers, using binary representation. For example, 10010110 is the binary representation of the number 150; it is worked out by assuming that the left most bit (the Most Significant Bit or MSB) has a value of 128 (when set at logic 1) and that bits to the right are half the value of their left-hand neighbours, down to a value of one for the right or Least Significant Bit (LSB) Thus:

$$10010110 = (1 \times 128) + (0 \times 64) + (0 \times 32) + (1 \times 16) + (0 \times 8) + (1 \times 4) + (1 \times 2) + (0 \times 1)$$

There is one other number system that some microprocessors use, in addition to binary, which is called Binary Coded Decimal (BCD). In this system, a byte is notionally separated into two four-bit fragments each of which represents a decimal number, eg 0011, 1001 = 2 + 1, 8 + 1 = 3, 9 = 39. Binary codes higher than 1001 are invalid in BCD and should never occur.

Rarely will you see lists of binary encoded data appearing in print; a much more compact system of notation, called Hexadecimal, is usually applied. In Hexadecimal notation, each of the four bit fragments of the byte are replaced by one of sixteen characters as listed below:

0000	=	0	1000	=	8
0001	=	1	1001	=	9
0010	=	2	1010	=	A
0011	=	3	1011	=	B
0100	=	4	1100	=	C
0101	=	5	1101	=	D
0100	=	6	1110	=	E
0111	=	7	1111	=	F

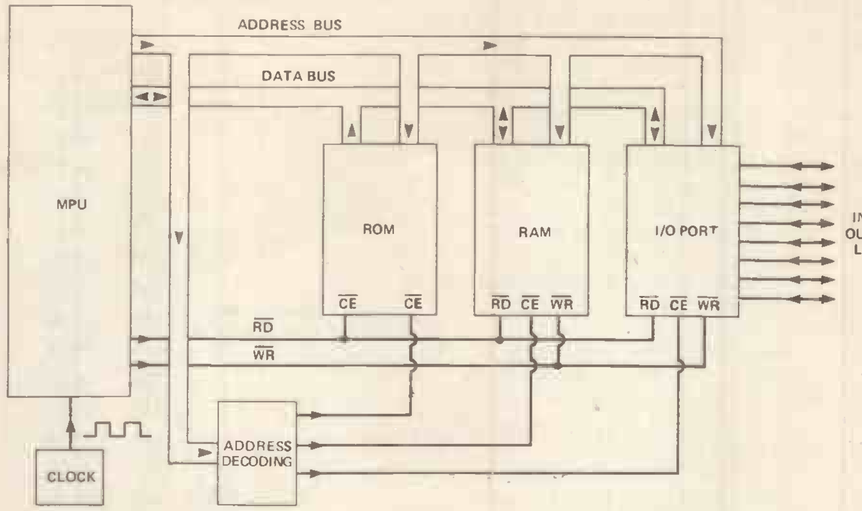

Figure 1. A simple microprocessor system for controller applications.

Hexadecimal and binary are very easily interconverted, eg:

01011101 = 0101 1101 = 5D
10101011 = 1010 1011 = AB.

The Microprocessor

The block diagram, **Figure 1**, shows a minimum-hardware microprocessor system that would be used for industrial controller applications. The main components of the system are a Microprocessor Unit (MPU), a Read Only Memory (ROM), a Random Access Memory (RAM) and an Input/Output device (I/O port).

The RAM is used, essentially, to store the data which is being processed by the MPU. It is internally organised as a number of locations (typically 1024), each of which may store a single byte of data. Any of these locations may be selected at random, ie addressed, so that data may be 'read' from the location without altering it or written into the location, thus changing it. A RAM chip which has 1024 byte capacity (eg, Mostek MK4118) will have ten input terminals called 'address lines' which select between the locations (a ten bit binary number has 2^{10} possible values, ie 1024).

The ROM has a similar organisation to the RAM, except that the stored data has been fixed at the time of manufacture and cannot be altered or written into during normal operation. There is, however, a very popular variation of this device called an EPROM (Electrically Programmable Read Only Memory) which is programmed using a high voltage (+25V) and erased with a source of UV light; there are several machines on the market designed to program these devices. Data which is stored in the ROM, in this application, is called 'Firmware' or, more generally, 'Software'. It is interpreted by the MPU as instructions or commands and therefore controls the operation of the entire system.

Finally, the system has an I/O port — or several I/O ports — which interface the MPU to the outside world. Each of the I/O lines, which are normally programmed as either an input or an output, will connect to any of the external devices (switches, motors, valves etc) devices discussed earlier, via suitable buffering such as a transistor or relay, of course.

All of these components are interconnected by two main busses (a set of lines carrying parallel data), namely the address bus and data bus. Data can be transferred between the MPU and any other device, in both directions (bi-directional), along the data bus. Addresses are placed on to the address bus by the MPU in order to select a particular memory device and location within that device. The address decoding logic uses high-order address bits to determine which of the devices is to be accessed and selects the appropriate device by pulling its Chip Enable (CE) pin to logic zero. This will be explained in detail next month, so for the moment lets just say that each device is selected by a unique range of address numbers. An active low Read Line ($\overline{RD}$) or active low Write Line ($\overline{WR}$) indicates to the selected device the direction of data transfer on the bi-directional data bus. These two signals, together with the chip enable lines, are often referred to as the control bus.

The 1802

The remainder of our discussion on the operation of microprocessors will be with specific reference to the RCA 1802. This device, which is used in our Micro Trainer project, has been chosen as a good MPU for controller applications and, more importantly, for its relatively simple instruction set. Also, it illustrates most of the techniques that apply to the more common eight bit MPUS such as the Z80 and 6502 and, therefore, is an excellent starting point for learning about microprocessors.

Looking firstly at the 1802 pin assignment diagram of Figure 2, you should be able to identify the data bus (D0-D7) the address bus (A0-A7), the control signals $\overline{RD}$ and $\overline{WR}$, the clock input and the power supply connections VDD, VCC and VSS. The address outputs, in fact, provide 16 address lines, giving a total addressing capacity of 65536 (64K) bytes, however, they are time-multiplexed onto just 8 lines. As will be seen later, the most significant byte of the address lines must be first loaded into an 8 bit latch, timed by signal TPA (pin 34), allowing the least significant byte to then appear on pins 25-32. Apart from the CLEAR signal, used to reset the MPU after power-up, the remaining signal lines are not required in the simple design of **Figure 1**, therefore do not worry about them too much, at this stage.

Before describing the sequence of operations that cause the data transfers to and from the MPU (which are called bus cycles, incidentally) we need to take a look inside the 1802 itself.

The model of the 1802 MPU shown in **Figure 3**, reveals everything that the user or programmer needs to know about the internal architecture of the device, ie the registers that store data within the MPU. There are 16 registers of 16 bits, each able to store 2 bytes of data (the high byte is designated R.1 and the low byte R.0). More important than data storage, these registers will also hold 16 bit addresses, pointing to instructions and data stored in the external memory system. There are, additionally, two 4-bit registers X and P, which may contain any value from Hex 00 to Hex 0F, and they assign a special meaning to the register to which they point. The Program Counter, R(P) points to the address from which the MPU fetches data or instructions. After resetting the machine (by a low pulse applied to the CLEAR input) the program counter is always R.0 and has an initial value of 0000H. The index register, R(X), points to data in memory during some arithmetic, logic or transfer operations. All arithmetic and logic operations produce an eight bit result which is placed in the Accumulator (AC). This has an associated Carry Flag (CF), which is a one bit register indicating, for example, an overflow condition arising from certain arithmetic operations. The temporary register (T), the Interrupt Enable flag (IE) and the Q flag will be explained in later issues.

The 1802 MPU carries out instructions in a sequence of two bus cycles, the 'fetch cycle' followed by the 'execute cycle'. A high frequency (2 MHz) clock applied to pin 1 of the MPU provides the timing necessary for these cycles; in fact there are eight clock periods to one bus cycle and all other timed signals, such as WR or RD, are also referenced to the clock. If we assume that the MPU has just been released from a reset condition (CLEAR taken high), the MPU will read its first instruction, from the initial program counter address of 0000H, in the first fetch cycle. This instruction, having been interpreted by the MPU will initiate an execute cycle which will do exactly that which RCA promise it will do, by means of the MPU's internal operation, which is of no real concern to us, the users. In this execute cycle, the MPU may output the address of any of the 16 bit registers to fetch a further data byte from memory, although many of the instructions act on the MPU's internal registers alone and therefore have a so-called non-memory execute cycle.

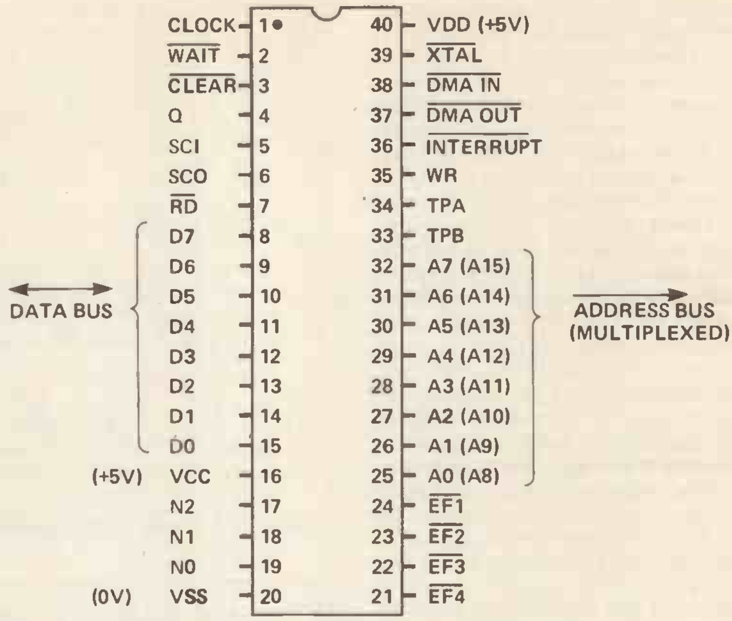

Figure 2. The pin designations of the 1802 microprocessor.

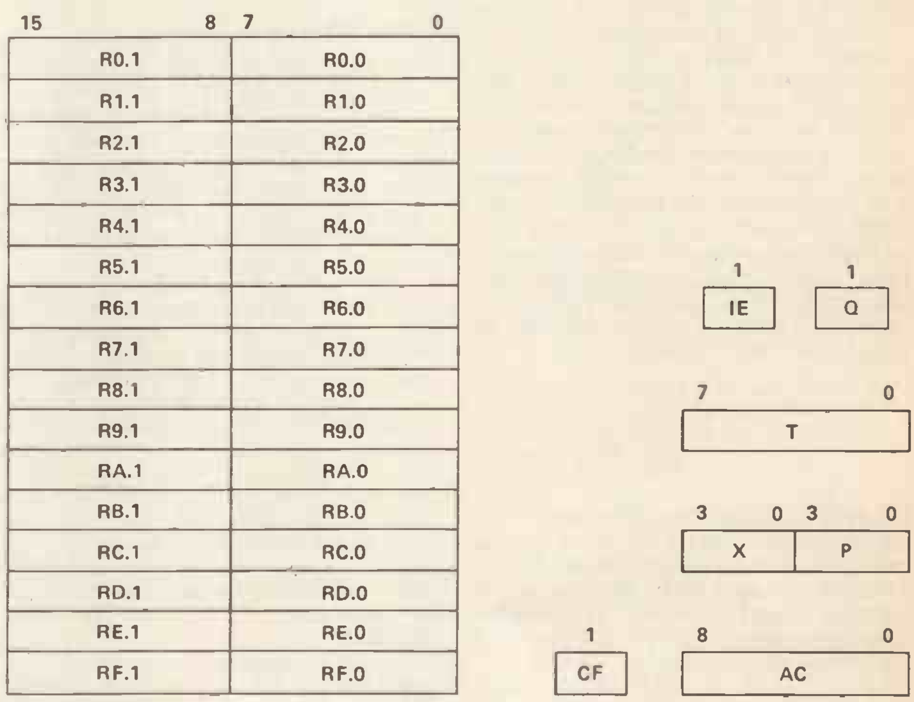

Figure 3. A programming model of the 1802. This is not the 'architecture' of the MPU but a model of how the processor 'appears' to the programmer.

A comprehensive list of the 1802's instruction set appear in Table 1, in which we give the Hexadecimal machine code instruction, functional description of the instruction and the associated mnemonic that one would use in writing machine code programs. The precise meaning of all these will be made clearer in later examples, although we also strongly recommend the purchase of RCA's "User Manual for the CDP1802 COSMAC Microprocessor".

The set includes instructions for tranfers between registers and accumulator and between accumulator and memory, arithmetic and logic operations on data in the accumulator and instructions which alter program flow control (branches) and numerous special instructions. We will discuss all these categories at a later date, however here are a few examples to whet your appetite:

16 (mnemonic, INC R6) when fetched, will cause '1' to be added to the 16 bit value of register 6.

F4 (mnemonic, ADD) will cause the byte of data pointed to in memory, by the index register, to be added to the value stored in the accumulator and the result placed in the accumulator.

32 (mnemonic BZ) followed immediately by a single data byte, will cause that byte to be copied into the low-order half of the program counter if the accumulator has a zero value, otherwise execution will continue with the next instruction.

This latter instruction is used to generate a loop in the program and is termed a 'branch'; in this case a conditional branch. After each instruction execution, the program counter normally advances automatically to the next instruction. The specimen (useless) program below should illustrate these points:

Address	Code	Mnemonics
00000	16	INC R6
0001	30	BR 00
0002	00	

This will cause register six to count from 0000 to FFFF, ad infinitum!

If you have followed all this so far, and are beginning to wonder where the edges of the page merge with reality, do not despair; our applied examples, in later issues, will make things clearer, particularly if you build our Micro Trainer, which will enable you to try things out for yourself.

IDL	00	Wait for interrupt or DMA request
LDN	0N	Load accumulator, via register N
INC	1N	Increment register N
DEC	2N	Decrement register N
BR	30	Branch always
BQ	31	Branch if Q = 1
BZ	32	Branch if accumulator is zero
BPZ	33	Branch if positive or zero
B1	34	Branch if EF1 = 0
B2	35	Branch if EF2 = 0
B3	36	Branch if EF3 = 0
B4	37	Branch if EF4 = 0
BRN	38	Branch never
BNQ	39	Branch if Q = 0
BNZ	3A	Branch if accumulator not zero
BM	3B	Branch if minus
BN1	3C	Branch if EF1 = 1
BN2	3D	Branch if EF2 = 1
BN3	3E	Branch if EF3 = 1
BN4	3F	Branch if EF4 = 1
LDA	4N	Load accumulator, via register N, then increment register N
STR	5N	Store accumulator in memory, via register N
IRX	60	Increment index register
OUT	6N	(N = 1,7) Transfer via index register to output device N, then increment index register
* * *	68	Illegal instruction
INP	6N	(N = 9,F) Transfer to accumulator from input device (N-8), then store via index register
RET	70	Return from interrupt or subroutine
DIS	71	Return from interrupt with interrupts disabled
LDXA	72	Load accumulator, via index register, and increment index register
STXD	73	Store accumulator in memory, via index register, and decrement index register
ADC	74	Add with carry, via index register, to accumulator
SDB	75	Subtract with borrow, accumulator from memory, via index register
SHRC	76	Shift right with carry (accumulator)
SMB	77	Subtract with borrow, memory from accumulator, via index register
SAV	78	Save T register in memory, via index register
MARK	79	Push X, P registers on stack, via index register
REQ	7A	Reset Q flag to zero
SEQ	7B	Set Q flag to one
ADCI	7C	Add with carry, immediate data to accumulator
SDBI	7D	Subtract with borrow, accumulator from immediate data
SHLC	7E	Shift left with carry (accumulator)
SMBI	7F	Subtract with borrow, immediate data from accumulator
GLO	8N	Load accumulator with low order byte of register N
GHI	9N	Load accumulator with high order byte of register N
PLO	AN	Store accumulator in low order byte of register N
PHI	BN	Store accumulator in high order byte of register N
LBR	C0	Long branch always
LBQ	C1	Long branch if Q = 1
LBZ	C2	Long branch if accumulator is zero
LBPZ	C3	Long branch if positive or zero
NOP	C4	No operation (long skip never)
LSNQ	C5	Long skip if Q = 0
LSNZ	C6	Long skip if accumulator not zero
LSMI	C7	Long skip if minus
LSKP	C8	Long skip always
LBNQ	C9	Long branch if Q = 0
LBNZ	CA	Long branch if accumulator not zero
LBMI	CB	Long branch if minus
LSIE	CC	Long skip if IE = 1
LSQ	CD	Long skip if Q = 1
LSZ	CE	Long skip if accumulator zero
LSPZ	CF	Long skip if positive or zero
SEP	DN	Set program counter to register N
SEX	EN	Set index register to register N
LDX	F0	Load accumulator via index register
OR	F1	Logic OR, memory with accumulator, via index register
AND	F2	Logic AND, memory with accumulator, via index register
XOR	F3	Logic XOR, memory with accumulator, via index register
ADD	F4	Add memory to accumulator, via index register
SD	F5	Subtract accumulator from memory, via index register
SHR	F6	Shift right accumulator
SM	F7	Subtract memory from accumulator, via index register
LDI	F8	Load accumulator with immediate data
ORI	F9	Logic OR, accumulator with immediate data
ANI	FA	Logic AND, accumulator with immediate data
XRI	FB	Logic XOR, accumulator with immediate data
ADI	FC	Add to accumulator, immediate data
SDI	FD	Subtract accumulator from immediate data
SHL	FE	Shift left accumulator
SMI	FF	Subtract from accumulator, immediate data

Table 1. 1802 Instruction Set (Mnemonics, Hexadecimal code and operations)

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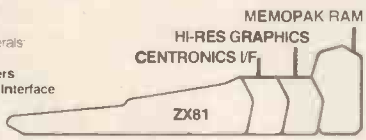

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BREAKDOWN OF MEMORY AREAS

0–8K . . . Sinclair ROM
8–16K . . . This section of memory switches in or out in 4K blocks to leave space for memory mapping, holds its contents during cassette loads, allows communication between programmes, and can be used to run assembly language routines.
16–32K . . . This area can be used for basic programmes and assembly language routines.
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ZX 81 64K RAM PACK

IF there is one indisputable drawback to the ZX-81 it is its lack of memory. The basic machine has a mere 1K of user RAM (Random Access Memory) and this is quickly eaten up by program lines. Ironically, it is the less experienced computer enthusiast who requires the larger amounts of memory. Once you have become a little practised in the art, it is relatively easy to produce more efficient programs, ie those which take up less memory.

The Sinclair add-on pack offers 16K of RAM at a price comparable with that of the computer. For a large number of home users, this amount of memory will suffice for quite a time. Fairly ambitious creations can be undertaken within the confines of 16K! However, anyone who wishes to use his Sinclair for any form of data handling — address lists, stock control, etc, would very quickly run out of space and could end up sending 100 letters to himself — because that's the only address the computer had room to store.

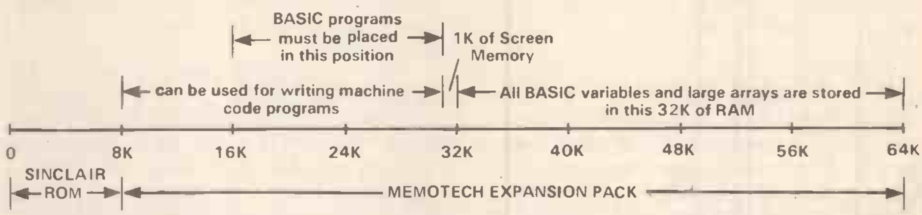


Figure 1. The layout of the 64K of memory available to the ZX-81 when used with the Memotech 64K RAM pack. Note that only about 15K is actually usable for BASIC program text. Note also, however, that 32K more is reserved for storing all the variables used in your programs and for large arrays of information. That 15K is thus actually far more powerful than it might seem!

Memories Are Made Of This

The Memotech 64K RAM is designed to overcome this problem. First let me say that there is only 56K of actual memory present in the box itself. Presumably the 64K legend is derived from the fact that the pack expands the ZX81 *to* 64K and not *by* 64K. Furthermore, the 56K is divided up, to make it more usable for programs requiring large amounts of data. Sinclair complicate things, however, by designing their hardware so that the section of memory that holds all the screen characters has to be positioned somewhere within the first 32K of memory that the ZX-81 finds itself hooked up to. The diagram of **Figure 1** gives an idea of what the various parts of the total 64K can be employed for.

When referring to large amounts of memory it is usual to refer to the position of something within it by the number of locations the computer has to count through to reach it (a 'location' is simply a place to store a byte — eight bits — of information). For example, if the Sinclair stores a particular screen character in the 32,000th location it could have used, then that character "resides" at 32K.

Somewhere A Place For Us?

Using this terminology then, your BASIC programs reside between 16K and 32K, with arrays and variables from 32K upwards. The locations between 8K and 16K can be switched in and out of the overall plan, using little DIL switches on the back of the expansion pack. In addition the top 4K of this, between 12K and 16K, is protected against being cleaned out when you load another program from tape.

Routines can thus be appended together, further extending the possibilities of the computer. As with Sinclair's own expansion, the Memotech plugs directly onto the back of the ZX-81 and requires no leads. It is beautifully made and looks very much at home with the computer. The printer can be connected to the reverse of the pack plug too, making it "stackable".

Included with the box are a couple of the ubiquitous "sticky pads", apparently recommended to attach the machines together. Pretty strong things these, so beware — what Memotech hath joined together, no man shall put asunder. Not easily anyway.

The DIL switches which control the 4K 'blocks' of switchable RAM are accessable through a hole in the back panel of the case. Most users will probably set them to obtain maximum RAM — and leave them there. Business users might be tempted to have a dabble, in which case they're going to need a pretty small screwdriver to keep toggling them back and forth.

Down Memory Lane

In use, the 64K is simple to operate. Upon switch-on, the usual little 'K' appears in the bottom left of the screen. The ZX-81 thinks it has 16K connected to it. This is where it gets a surprise. Type:

```
POKE  16388,  255
POKE  16389,  255
NEW
```

It will now *have* to believe that 56K has, in fact, been added to its capabilities, since you have just modified the locations in the memory where it stores the value of RAM in use.

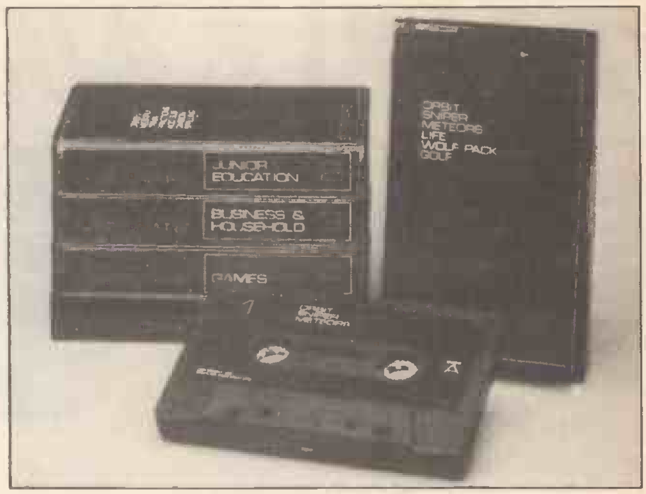
If for some reason you do not wish to use all the memory space available to you, the Sinclair manual notes (Chapter 26) still apply and will work in this case. The available BASIC space is, as previously explained, around 15K-16K but in practise, that 32K of extra storage is brought rapidly into play. It is especially useful for programs such as mailing lists where the information to be handled by the program takes up more space than the actual program listing itself. If you reset the ZX-81, then the machine will lose all knowledge of any memory space beyond 32K. You have to POKE back in again to locations 16388 and 16389 as outlined previously, to remind it that other locations are available.

Conclusions

Whether or not you will find the Memotech 64K RAM value for memory, at £79, will depend largely upon your application for a ZX-81. At £30 more expensive than the Sinclair expansion, it is better engineered, more versatile, and capable of much greater storage. It does not actually contain 64K RAM and I think that title is a little misleading. This is an expansion *to* 64K and is more properly referred to as a 56K RAM pack.

Users wishing to try their hands at some more workman-like applications for the Sinclair will find the Memotech very useful, if not indispensible. The out-and-out home user will have to weigh the added cost very carefully. **HE**

ZX 81 SOFTWARE



THE ZX-81 and the ZX-80 before it have, without question, revolutionised the awareness of the computer in the home: not only as an introduction to computing, but as a teaching tool and also as a fun thing to play with.

Hopefully, we will be looking at software that will enable the ZX-81 to control its external environment — but that still lies a little way in the future. For the present let us look at some of the software available *now*.

ZX Software

Where better to start than with some of the tapes promoted by Sinclair themselves. There are six of these available at the present and we will look at three of them, first of the series is 'Games of Skill', Sinclair Cassette No. 1. This has six programs, three on each side of the tape, and will run in 1K of memory so no extra RAM pack is required.

ORBIT uses fairly simple graphics to represent a spaceship orbiting a star (planet?) and a valuable piece of cargo which the spaceship has to 'capture'. You may manoeuvre your spaceship by altering the distance of the orbit around the star and when you get the ship in the right position over the cargo, the cargo will enter the ship and you will be informed how many days (!) it has taken you to dock. The game can be somewhat frustrating and, because of this, one tends to persevere a number of times, trying to better the previous score. On the whole, the game leaves one with the feeling that control of the situation is not perhaps as easy or definitive as one would like but, although I suspect that I will go back to this game occasionally, I am unlikely to become addicted.

SNIPER displays forty men, one at a time, at different positions across the screen. Your task is to quickly determine at which of the ten possible positions the man is displayed and, within the brief interval that he is visible, 'shoot' him with the appropriate position key (1, 2, 3, 4, 5, 6, 7, 8, 9 and 0). Your score appears continuously throughout the game but not at the end (pity that). The graphics are simple but quite effective; a good game for young kids as speed and coordination are called for. The average adult should be able to master this one very quickly.

METEORS places you in control of a spacecraft that appears at the top of the screen; a storm of meteors approaches you from the bottom of the screen. Your task is to steer your craft through them without collision. Each collision reduces your 'life' and you have five 'lives'. On the fifth collision, the game ends and the distance you have travelled (in light years) is displayed on the screen. A thoroughly enjoyable game to play with simple but effective graphics . . . could be addictive.

Side B of the cassette has LIFE, WOLFPACK and GOLF. LIFE is based on the 'Game of Life' devised by J.H. Conway, in 1970, and represents the growth and decay of cells. Their 'life' is determined by the following rules: 1). If a space is empty and there are three and only three adjacent live cells, a new cell is born in that space. 2). If a cell has two or three neighbours, it survives. 3). any cell with only one neighbour or more than three neighbours dies. The implementation of LIFE on the 1K Sinclair is a credit to the programmer. You may place cells anywhere on a 16 x 16 grid and watch the outcome as generation follows generation. Altogether a fascinating display. Some patterns remain constant but move across the screen; some will develop into stable oscillating patterns while some will die out after only a few generations. A good example, considering the size of memory and the size of the screen.

In WOLFPACK you have control of a destroyer and you may move left or right and drop depth charges. The aim being to hit the enemy submarine travelling below you. Reasonable skill is required to judge when and where to drop the depth charge.

GOLF was a disappointing game that would be much improved if the ball progressed down the fairway, instead of always returning to the tee.

Sinclair cassette No. 5 is entitled 'Junior Education' and has six programs running in 1K.

Kid Stuff?

MATHS gives you the option of problems involving addition, subtraction, multiplication and division. You are then given 10 problems to answer and, after this, your score out of ten is displayed. This is a straightforward program, certainly improving your mental arithmetic (I needed a pencil and paper!).

BALANCE deals with your appreciation of couples and levers. You are offered difficulty levels of 1-3; a graphic representation of a see-saw is displayed with a weight at a distance from the pivot on one side — you have to decide what weight, at a specified distance on the other side, is needed to balance the first weight. Again, a pencil and paper is handy for level three . . . my mental arithmetic isn't what it was!

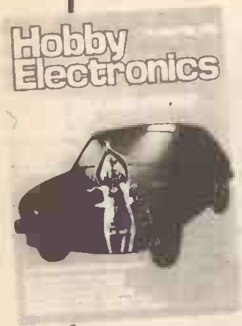
VOLUMES provides a graphic representation of a cube displayed on the screen, with its dimensions; you have to enter the correct volume. There are two levels of difficulty and, on this one, you have to make a note of your score as this is not displayed.

AVERAGES is a program intended to help you understand the concepts of MEAN and MEDIAN and it will draw a bar graph to help you understand! The program will accept up to 50 entries, with the maximum value of any entry being 1,000. The bar graph is crude but the more entries there are, the cleaner the intention of the display becomes. Sadly, this program is not protected against a value outside the previously specified limits and will CRASH so be warned — think before you type. A useful teaching exercise, this one, but one where the data should have been collected before RUNning the program, for it to have maximum impact.

BASES will test your ability to convert from decimal (base 10) to other bases in the range two to nine. My mind is still reeling. I'm glad I tried this one after my son had gone to bed. Base two is reasonable — even I could interpret decimal 17 as 10001 — but when it comes to 72 in base seven (1381) or 69 in base three (2112) I am beginning to flounder without my trusty pencil and paper. But, having put pencil to paper, I found that this program occasionally gave the wrong answers! The two examples above being a case in point: 72 in base seven should be 132 and 69 in base two should be 2120!

The TEMP program displays two barrels full of water. Each barrel has its volume displayed in litres and its temperature in degrees centigrade and you have to calculate the temperature that would result if the two barrels had their contents thoroughly mixed together. Answers have to be correct to 0.001 degrees C for you to be 'correct' . . . well, obviously you need pencil and paper for that . . . don't you?

The Sinclair cassette tapes tried so far all load easily and have given us a great deal of fun, even if I feel I should go back to 'skool' for a refresher course! **HE**



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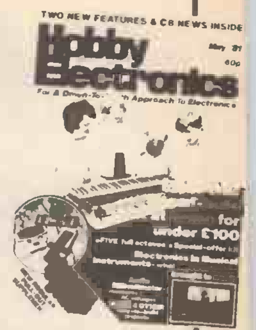

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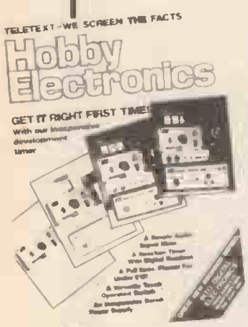

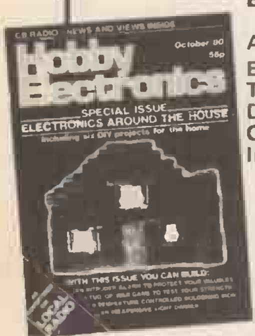

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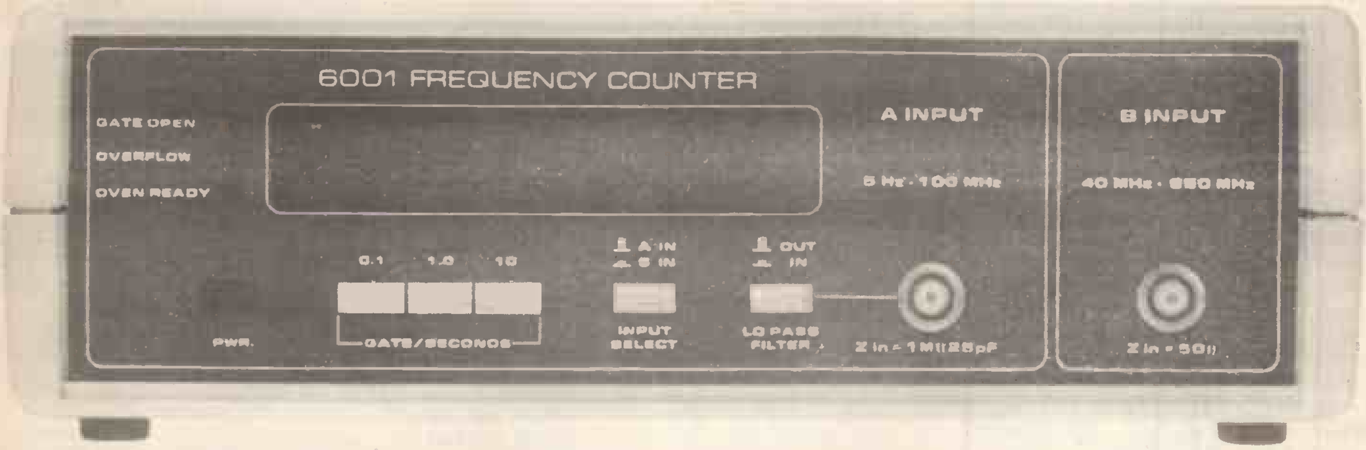
DIGITAL COUNTERS and TIMERS



Several HE projects, recently, have used digital measurement techniques. This article explains the basic principles of digital timers and frequency meters.

MEASURING frequency and time intervals to a known accuracy is often important in many areas of electronics: in communications, broadcasting and audio applications, in digital work and particularly in computer applications — from micros to mainframes. Digital frequency meters (DFMs), or counter/timers as they are also called, have become such an essential item of test equipment that many manufacturers are offering a range of instruments ranging inp rice from a £100 instrument covering the range 20 Hz to 200 MHz to many thousands of pounds for a microprocessor-controlled instrument capable of measuring frequencies well into the gigahertz region and time intervals in the picosecond range.

Frequency and time interval measurement is an area where digital techniques come into their own. The object is to accurately quantify a measurement. Prior to the development of digital instrumentation to do this job, analogue techniques were used — often ingenious and highly refined, but laborious. Heterodyne frequency meters were used widely. These consisted of a stable, accurately calibrated, variable oscillator (VFO) driving one input of a wideband mixer, the unknown frequency being applied to the other input. The output of the mixer was monitored on headphones or an audio amplifer while tuning the VFO. As the unknown frequency was approached an audible 'beat note' would be heard, decreasing in pitch as the VFO was tuned closer to the frequency being measured. At 'zero beat' you could then read off the unknown frequency from the instrument's calibrated dial. The method will no doubt be familiar to many of our older readers. It was laborious, especially when you didn't even know the 'ballpark' of the unknown frequency, and to get a measurement accuracy better than several hundred Hertz (... maybe that's cycles/second!) was tantamount to magic: Top frequency was about 20 MHz.

These days *pocket* DFMs can measure frequency to within ± 50 Hz or better, up to 200 MHz! That's at least a factor often better all round than the old BC221. And readout is obtained in a few seconds or less.

Time interval measurement was, and still is, very much left to that old workhouse — the CRO. But, a CRO has its limitations and quantifying a time measurement to the accuracies required these days is best done with a digital counter.

Frequency Measurement

The block diagram of a basic digital frequency meter is shown in the accompanying illustration. The input signal first encounters a 'trigger' or 'squaring stage' which ensures that the measurement always commences on the same part of the input waveform. The output of the trigger then enters a gate. The gate is 'opened' for a period and allows a number of input cycles through to the counter. The period for which the gate remains open is determined by the output from a divider/scaler driven by a very stable, accurate clock oscillator. A number of outputs from the divider/scaler may be selected to vary the period the gate is open. Usually, a number of decade steps are provided.

The output of the gate drives a counter which provides a binary coded decimal (BCD) output for the display. A 'hold' or 'latch' stage is generally added so that a steady group of numerals is displayed.

The timing diagram below the block diagram illustrates the sequence of events. The input signal, often sinusoidal, is shaped by the trigger stage into a train of rectangular pulses. The gate allows a number of pulses through to the counter, in this case three, during the period it is 'open'. The circuit selects only the positive-going pulses in this example, though negative-going pulses from the trigger stage could equally well be used.

If, say, a gate period of one millisecond (1 mS) were selected the counter would display '3000'. In other words, the input frequency would be 3 kHz.

Practical instruments will have selectable gate periods ranging from one microsecond (1uS) to as much as 10 seconds. The display may have five digits, though eight digit displays are more common.

Many modern digital frequency meters incorporate a high speed divider immediately following the gate, the output of this divider being used to derive the first and second digits of the display. To extend the range of the instrument, a 'prescaler' may be included. This is a high speed divider providing a fixed division ration of ten. Its output may drive either the trigger stage or the gate directly.

Period Measurement

Measuring the period between 'events' is done by re-arranging things a little. The gate, counter and display are used as before but the gate is turned 'on' and 'off' by the input events and the clock signal is passed through to the counter. As the clock is a highly stable, accurate oscillator, the period between input events can be measured with great precision. The accompanying block diagram shows the general arrangement of the instrument for period measurement.

Separate input signals in the arrangement shown are used to trigger the gate on and off. However, a single repetitive input signal may be used to trigger the gate with a slightly different circuit arrangement, The timing diagram with the period counter block diagram shows the sequence of events. If the clock was running at 1 kHz, for example, the time interval between pulses would be one millisecond. As 17 pulses passed through the gate in the example, the period between the A input event and the B input event was 17 mS and the display would read, say, 17 000 (resolution of one microsecond).

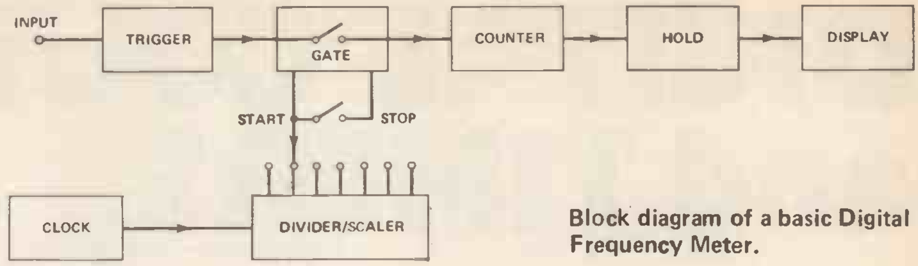
Pulse widths can be measured with a period counter, too. In this instance, the gate is triggered on the positive-going and negative-going edges of the input pulse. However, some difficulties arise. If the input pulse had a perfectly 'square' shape, the on and off gating points would always give an accurate result because the triggering transitions would occur precisely on the rise and fall of the pulse. Trigger level would not affect the interval measured. Real-life pulses however, are seldom perfect, the edges having definite rise and fall times. In this case, the trigger level becomes critical in determining the width of a pulse. The diagram here shows why and how it is overcome. Counters are usually provided with a 'slope selection' control which determines whether the trigger operates on the positive or negative slope — (a), or (b) respectively in the diagram.

Noise Error Reduction

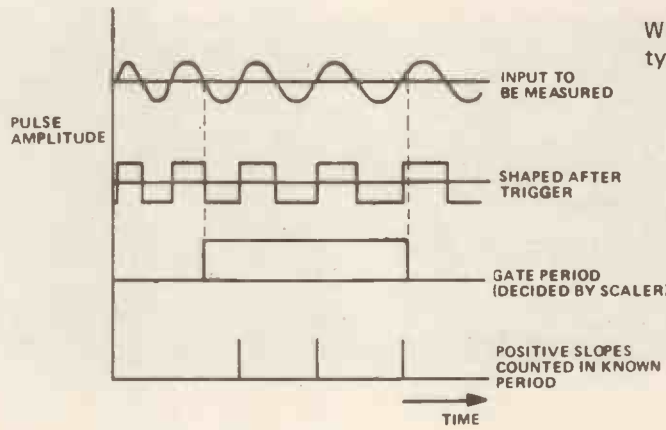
The above descriptions give the basic operating modes of the various counter/timer/frequency-meter combinations. In practice, a number of refinements may be incorporated to obtain better practical performance.

Noise can be reduced by incorporating a fixed amount of backlash in the trigger circuit; this produces what is called the 'trigger window'. On the way up the trigger level is at a higher level than on the way down, as shown in the Trigger Window Diagram here. Provided the noise added to the signal has an amplitude smaller than the window width, the counter will only trigger once on the way up and once on the way down. This method works well for high-frequency measurements where the noise is usually a small percent of the signal-plus-noise amplitued.

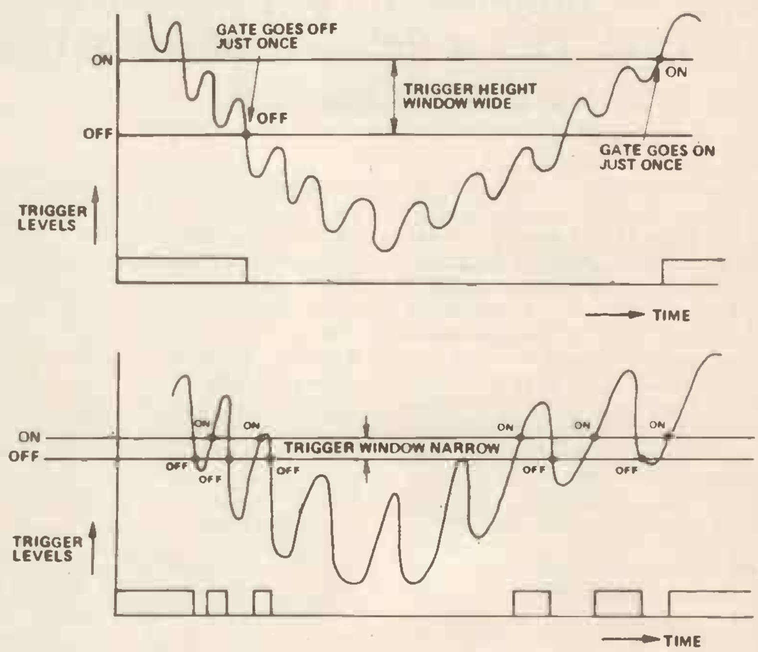
Low frequency measurements can often involve interference sources that



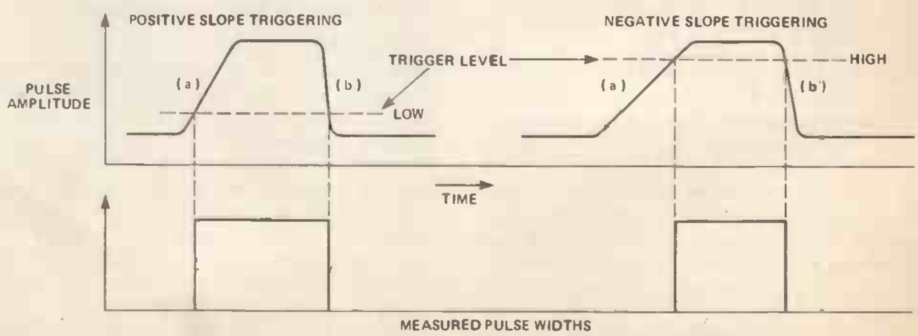
Block diagram of a basic Digital Frequency Meter.



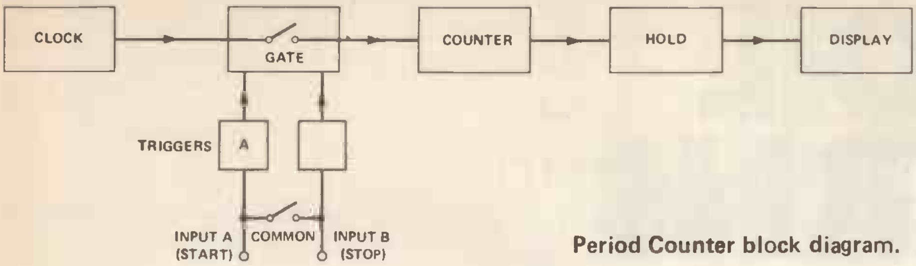
Waveforms produced by a typical DFM.



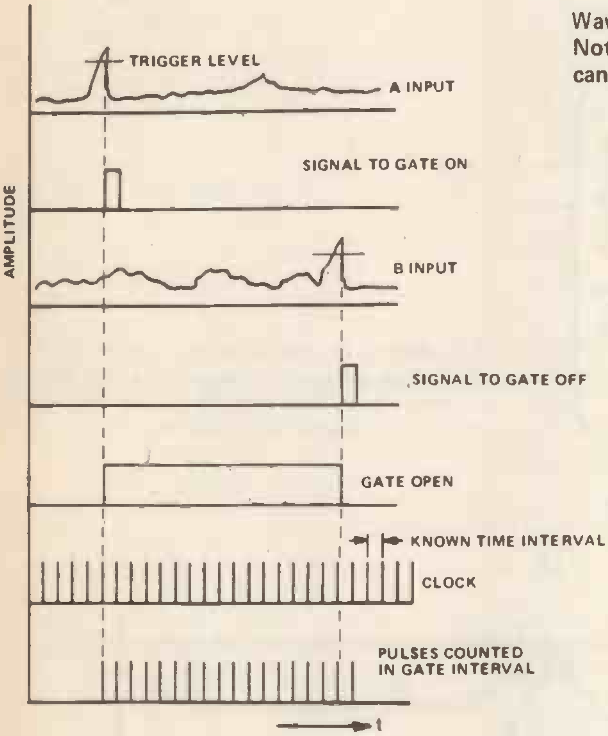
The Trigger Window diagram. Setting the Window too low (below) will cause inaccurate measurements.



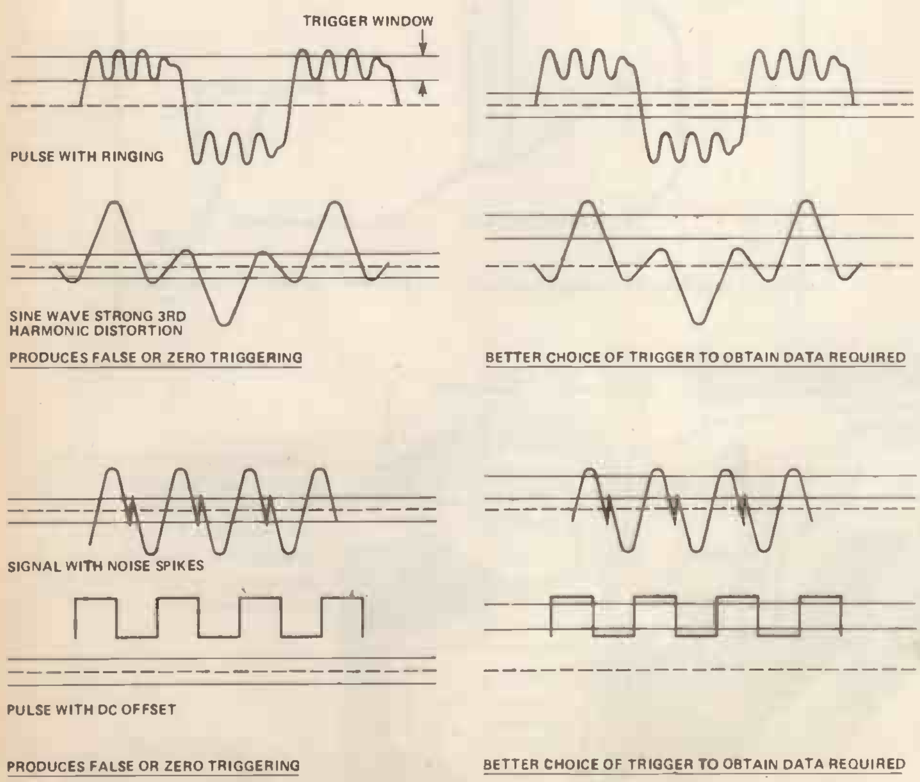
When measuring pulse widths, the accuracy will depend on whether positive or negative slope triggering is selected, and on the trigger level setting.



Period Counter block diagram.



Waveforms of a Period Counter. Note that input signals A and B can be the same.



The Trigger Window level can be set to reject false triggering caused by spurious signals (noise, harmonic distortion, ringing etc.) on the main signal.

produce rapid spike transients. One simple method of reducing this is to use filters. Advanced designs contain filter systems that reject all frequencies higher than that being tested, the appropriate filter being automatically selected by the counter itself after it has made a determination of the frequency of the signal.

A recent approach to the noise problem is to set up a time-window (as opposed to the trigger height window) that, once the counter gate is on, inhibits the off-state chance until after a time just shorter than the expected interval. This is known as trigger masking. It is very useful in eliminating contact-bounce retriggers.

Before using a counter/timer on an unknown waveform, it is good practice where ever feasible to look at the waveshape on an oscilloscope in order to decide the best strategy for trigger-level and height-window width settings.

As the readout is in digital form it is necessary to hold the display at the determined value for a period long enough to allow the value to be read. Some units incorporate a control that gives the operator a choice of hold time.

How To Choose

First, look in your piggybank! Prices for a straight digital frequency meter start at around £70. Next step in the price/features bracket for a DFM is around £125. Instruments range right up to several thousand pounds, which is beyond most hobbyists!

Next step is to look at your applications. But, keep in mind future applications and get something a little better — if your budget will stretch that far. The number of digits in the display will certainly be a deciding factor, depending on your applications. The majority of instruments available have either six- or eight-digit displays. Next consideration is the number of ranges offered (gate time selection). Resolution is important and is related to the display, an eight-digit instrument has a better resolution than a six-digit instrument, naturally enough.

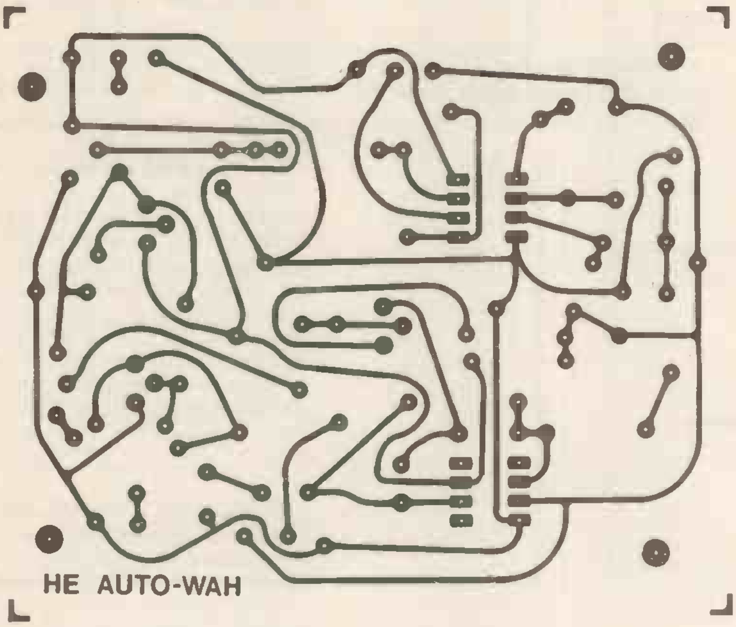
The clock oscillator stability determines the inherent accurancy of the instrument and it is instructive to compare the specifications of different makes and mdoels when considering this parameter. Generally, a temperature range over which the accuracy is maintained will be quoted along with this specification. Accuracy will be quoted in parts-per-million (ppm) or parts in 10^n. A reasonable figure for accuracy, for most hobbyist applications, would be one ppm (one in 10^6) over a temperature range of 15°C to 50°C.

Whether you get a battery operated or a mains/battery operated instrument will depend largely on your applications.

Refinements like filters, trigger window control, gate time delays, frequency ratio, totalizing etc depend entirely on your application — and your budget!

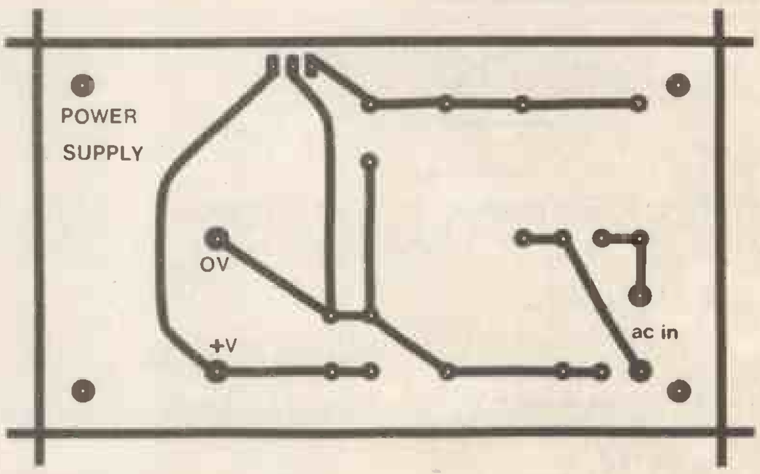
HE

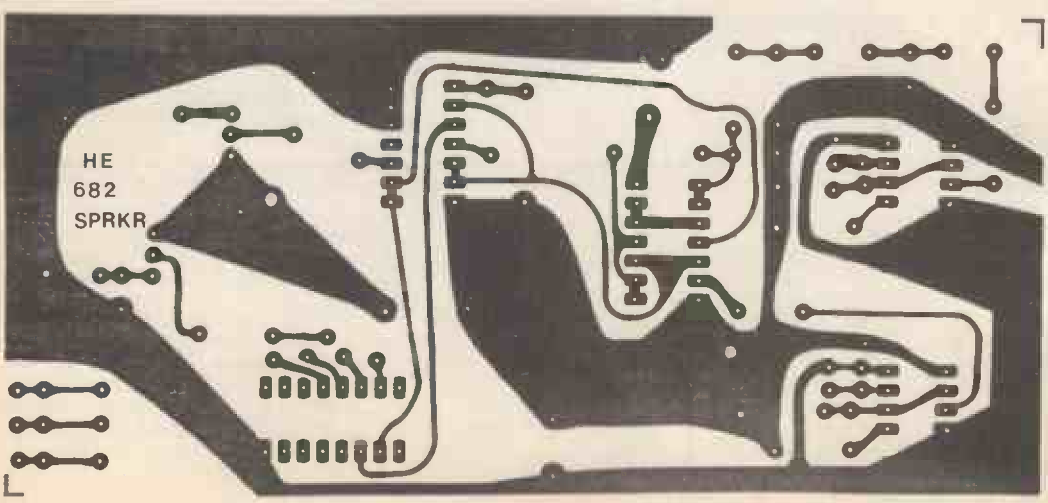
PCB FOIL PATTERNS



Foil pattern for the Auto-Wah (left). The large spots are to locate the PCB pillars — make sure the holes are the correct size, so that the board clips in place.

The Power Supply Design PCB pattern (right). This board should present no problems, as the layout Is not critical.





The HE Auto Greenhouse Sprinkler PCB pattern (left). The large areas of copper are present to improve stability — they can be omitted if you include C9 on the board.

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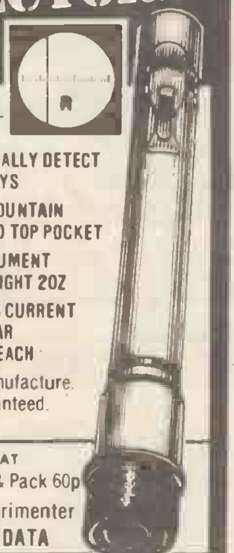

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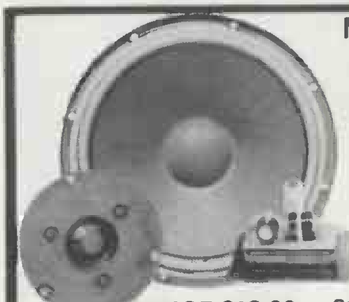

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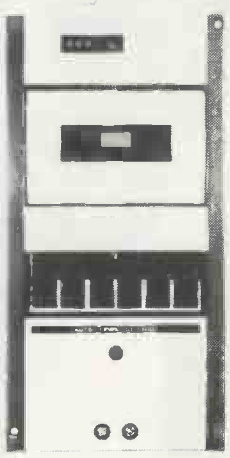

6 piano type keys

STEREO CASSETTE TAPE DECK MODULE. Comprising of a top panel and tape mechanism coupled to a record/play back printed board assembly. Supplied as one complete unit for horizontal installation into cabinet or console of own choice. These units are brand new, ready built and tested.
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Price £26.70 + £2.50 postage and packing.
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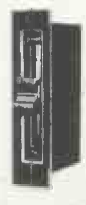

- Controls loads up to 1KW
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General purpose full range loudspeaker, ideal for mini systems etc.
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BSR P256 TURNTABLE

P256 turntable chassis ● S shaped tone arm ● Belt driven ● Aluminium platter ● Precision calibrated counter balance ● Anti-skate (bias device) ● Damped cueing lever ● 240 volt AC operation (Hz) ● Cut out template supplied ● Completely manual arm. This deck has a completely manual arm and is designed primarily for disco and studio use where all the advantages of a manual arm are required.
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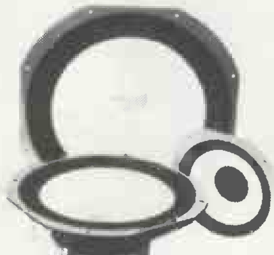
Specification and Price:–



15" 100 watt R.M.S. Impedance 8ohm 59 oz. magnet. 2" aluminium voice coil. Resonant Frequency 20Hz. Frequency Response to 2.5KHz. Sensitivity 97dB. **Price £32 each.** £2.50 Packing and Carriage each.

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Vu Meter

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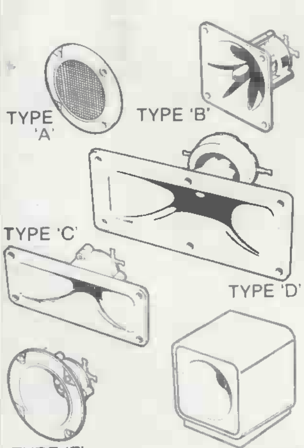

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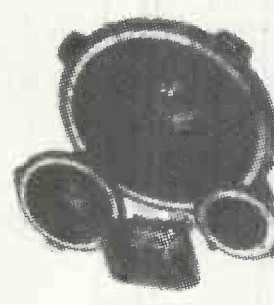

Fitted with attractive cast aluminium fixing escutcheons and mesh protective grills which are removable enabling a unique choice of cabinet styling. Can be mounted directly on to baffle with or without conventional speaker fabrics. All three units have aluminium centre domes and rolled foam surround. Crossover combines spring loaded loudspeaker terminals and recessed mounting panel.
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12" 80 watt R.M.S. loudspeaker.
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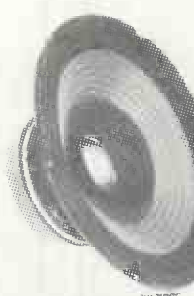

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