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TEN PROJECT ISSUE

MEMORY SCOPE DISPLAY

SOUND SAMPLER

CYMBAL SYNTH

CHORUS UNIT

RHYTHM CHIP

AND MORE

19 A.. 800 SARAWAT

SAW DEVICES

HOW TO DESIGN SIMPLE TRANSISTOR STAGES

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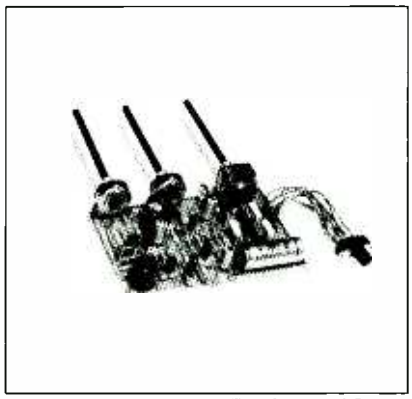

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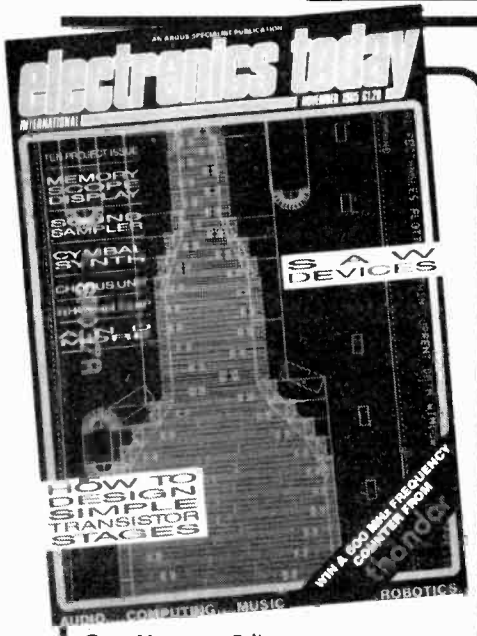

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ELECTROLYTIC CAPACITORS: (Values in uF) 500v 10uf 52 47 78p 63V 0.47 1.0 1.5 2.2 3.3 4.7 8p 10 10p. 15 22 12p 33 15p 47 12p 68 20p 100 19p 220 26p 1000 70p 2200 99p: 50V 68 20p 100 17p 220 24p 40V 22 9p 33 12p 330 47 32p 1000 48p 2200 90p 25V 1.5 4.7 10 22 47 8p 100 11p 150 12p 220 15p 330 22p 470 25p 680 1000 34p 1500 42p 2200 50p 3300 76p 4700 92p 16V 47 68 100 9p. 125 12p. 330 16p 470 20p 680 34p 1000 27p 1500 31p 2200 26p 4700 72p

TAG-END CAPACITORS: 64V. 2200 120p: 3300 145p: 4700 245p: 50V: 2200 95p: 3300 155p: 40V: 4700 160p: 25V: 2200 70p. 3300 85p. 4000 4700 75p: 10 000 250p: 15 000 270p: 16V: 22 000 200p.

POLYESTER CAPACITORS: Axial Lead Type
400V: 1nF 1n5 2n2 3n3 4n7 6n8 11p: 10n 15n 18n 22n 12p, 33n 47n 68n 16p: 150n 20p: 220n 30p: 330n 42: 470n 52p; 680n 1uF 68p. 2u2 82p 1000V: 1nF 17p: 10nF 30p: 15n 40p: 22n 36p: 33n 42p: 47n 100n 42p.

SIEMENS pcb Type Miniature poly Capacitors

250V
1nF 1n5, 2n2 3n3 4n7 6n8 10n 15n 7p 18n, 22n 27n 33n 39n 47n 8p 39n 56n 12p 82n 100n 11p

100V
100n 120n 10p 150n 180n 12p 220n 270n 15p 330n 390n 20p 470n 560n 26p 680n 30p 1uF 34p 2u2 50p

POLYESTER RADIAL LEAD CAPACITORS: 250V
10n 15n 22n 27n 6p, 33n 47n 68n 100n 8p; 150n 220n 10p: 330n 470n 15p; 680n 19p: 1u5 40p: 2u2 48p.

FEED-THROUGH CAPACITORS
1000pF/450V 10p

TANTALUM BEAD CAPACITORS
35V: 0.1uF 0.22 0.33 15p 0.47 0.68. 1.0 1.5 16p; 2.2 3.3 18p; 4.7 6.8 22p 10 28p: 16V: 2.2 3.3 16p: 4.7 6.8, 10 18p: 15 36p: 22 45p; 33 47 50p; 100 95p; 10V: 15 22 26p; 33 47 50p; 100 80p, 6V: 100 55p.

POTENTIOMETERS: Carbon Track. Rotary 0.25W Log & LIN Values 470R, 1K & 2K (Linear only)
Single Gang 35p
5K — 2M Single Gang Log & Lin 35p
5K — 2M Single Gang DP Switch 95p
5K — 2M Double Gang 99p

MYLAR FILM CAPACITORS
100V: 1nF 2.4 4nF 10 6p: 15nF 22n 30n 40n 47n 7p: 56n 100n 200n 9p: 50V: 470nF 12p.

SLIDER POTENTIOMETERS
0.25W log and linear values 60mm
5K — 500K single gang 80p
Graduated Bezels for above 45p

CERAMIC CAPACITORS 50V:
Range 0.5pF to 10nF 4p
15nF, 22nF 33nF, 47nF 5p
100nF/20V 7p 100nF/20V 7p

PRESET POTENTIOMETERS
0.1W Miniature Vertical or Horizontal 100R to 4M7 8p
0.25W Larger 100R to 3M3 Horz 12p
0.25W Larger 200R to 4M7 Vertical 12p

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POLYSTYRENE CAPACITORS
10pF to 1nF 8p: 1.5nF to 12nF 10p.

SILVER MICA (Values in pF)
2.3.3.4.7 6.8 8.2 10 12 15 18 22 27 33 39 47 50 56 68 75 82 85, 100 120 150 180pF 15p each
200 220 250 270 300 330 360 390 470 800 800 820 21p each
1000 1200 1800 2200 30p each
3300, 4700pF 80p

MINIATURE TRIMMERS Capacitors
2-6pF 2-10pF 22p, 2-25pF 5-65pF 30p; 10 88pF 36p.

RESISTORS Carbon Film miniature Hi-Stab 5%

	RANGE	Val	1-99	100 +
0.25W	2Ω2 — 10M	E24	3p	1p
0.5W	2Ω2 — 4M7	E12	3p	1p
1W	2Ω2 — 10M	E12	6p	4p
2% Metal Film	51Ω — 1M	E24	6p	4p
1% Metal Film	51Ω — 1M	E24	5p	4p

100+ price applies to Resistors of each type not mixed

RESISTORS NETWORK S.I.L.
7 Commoned (8 pins) 100Ω 680Ω 1K 2k2 4K7 10K, 47K 100K 18p
8 Commoned (9 pins) 150Ω 180Ω 270Ω 330Ω 1K 2K2 4K7 6K8 10K 22K 47K & 100K 20p.

TRANSISTORS

AC126/7	35	BC547/8	12	BFX81	45	OC75/76	55	ZTX501/2	15	2N4286	25
AC141/2	35	BC549C	15	BFX84	35	OC81/82	50	ZTX503	18	2N4289	25
AC176	35	BC556/7	15	BFX85/6	35	OC83/84	70	ZTX504	25	2N4314	78
AC187	35	BC558/9	15	BFY50/51	30	OC170/71	75	ZTX531	125	2N4400	25
AC188	35	BCY39/40	85	BFY52	30	OC70	40	ZTX550	25	2N4427	80
ACY19/21	75	BCY41/42	30	BFY53	35	OC200	75	2N697	23	2N4871	55
ACY22/41	75	BCY45	50	BFY55/56	56	TIP29A	32	2N698	40	2N5135/6	30
AD142	120	BCY58/59	38	BFY64	40	TIP29C	38	2N699	48	2N5138	25
AD149	79	BCY70/71	18	BFY81	120	TIP30A	35	2N706A	25	2N5172	25
AD161	42	BCY72	25	BFY90	80	TIP30C	37	2N708	25	2N5179	45
AD162	42	BCY78	30	BRY39	50	TIP31A	38	2N918	40	2N5180	45
AF115/6	80	BD114	190	BSX20	30	TIP31B	39	2N1131/2	40	2N5190/1	75
AF188	80	BD121	95	BSX26/29	45	TIP31C	45	2N1302	45	2N5194	80
AF124/26	70	BD124	115	BSY26	35	TIP32A	43	2N1307	70	2N5305/8	30
AF139	40	BD131/32	65	BSY95	35	TIP32C	45	2N1671B	160	2N5457/8	30
AF178	75	BD133	70	BU105	180	TIP33A	70	2N2160	325	2N5459	30
AF186	70	BD135	45	BU205	180	TIP33C	75	2N2219A	28	2N5485	36
AF239	55	BD136/37	40	BU208	200	TIP34A	85	2N2220A	28	2N5777	45
BC107	12	BD138/39	40	BUY69C	225	TIP34C	105	2N2221A	25	2N5879	160
BC107B	14	BD140	40	MD8001	250	TIP35A	120	2N2222A	25	2N6027	32
BC108	12	BD144/45	198	MJ2955	90	TIP35C	140	2N2368	25	2SA671	250
BC108B	14	BD158	88	MJE170	150	TIP36A	130	2N2369A	18	2SA715	75
BC108C	14	BD205/6	110	MJE180	150	TIP36C	140	2N2483/4	27	2SC495	85
BC109	12	BD245	65	MJE340	54	TIP41A	50	2N2646	48	2SC496	85
BC109B	14	BD378	70	MJE350	100	TIP41B	52	2N2904/5	28	2SC1061	250
BC109C	14	BD434	70	MJE371	100	TIP42A	55	2N2906/7	28	2SC1096	85
BC114/5	30	BD517	75	MJE520	85	TIP42B	58	2N2907A	28	2SC1162	45
BC117/8	25	BD645	80	MJE521	96	TIP120	70	2N2926G	10	2SC1173	125
BC137/9	40	BD695A	150	MJE2955	98	TIP121/2	73	2N3053	25	2SC1306	100
BC140	38	BD696A	150	MJE3055	70	TIP141/2	120	2N3054	55	2SC1307	150
BC142/3	38	BF115	45	MPF102	40	TIP147	150	2N3055	50	2SC1449	95
BC147	12	BF154/8	30	MPF103	30	TIP2955	70	2N3252	48	2SC1678	140
BC147B	15	BF167	35	MPF104	30	TIP3055	70	2N3441/2	140	2SC1679	180
BC148	12	BF173	35	MPF105	30	TIS43	50	2N3614/5	180	2SC1923	85
BC148B	15	BF177	35	MPF106	40	TIS44/5	45	2N3663	20	2SC1945	225
BC149	12	BF178	35	MPSA05	30	TIS88A	50	2N3702/3	10	2SC1963	80
BC149C	15	BF179	40	MPSA08	30	TIS90/91	30	2N3704/5	10	2SC1957	80
BC182L	10	BF184/5	38	MPSA12	32	UC734	99	2N3706/7	10	2SC1969	180
BC183L	10	BF194/5	12	MPSA55	30	VK1010	99	2N3708/9	10	2SC2028	85
BC184	10	BF198/9	18	MPSA56	30	VN10KM	70	2N3713	140	2SC2029	200
BC184L	10	BF200	80	MPSA67	40	VN66AF	95	2N3771	179	2SC2078	125
BC186/7	28	BF224A	40	MPSU02	58	VN67AF	110	2N3772	195	2SC2091	85
BC188 6 7	25	BF224B	40	MPSU05	60	VN88AF	120	2N3773	210	2SC2314	86
BC12	10	BF245	50	MPSU06	60	VN89AF	120	2N3819	35	2SC2166	105
BC212L	12	BF256A	45	MPSU52	65	ZTX107/8	12	2N3820	60	2SC2335	200
BC213	10	BF256B	50	MPSU55	60	ZTX109	12	2N3822/3	60	2SC2547	40
BC213L	12	BF257/8	32	MPSU56	60	ZTX212	28	2N3866	90	2SC2612	200
BC214	10	BF259	40	OC26	170	ZTX300	13	2N3903/4	18	2SD234	74
BC214L	12	BF275	55	OC28	220	ZTX302	18	2N3905/6	15	2SK45	80
BC237/8	15	BF336/7	35	OC35	50	ZTX303	25	2N3906	17	2SK288	225
BC256B	35	BF394	40	OC36/41	75	ZTX304	17	2N4037	60	2SJ81	225
BC307B	15	BF451	40	OC42/75	75	ZTX326	30	2N4058	15	2SJ85	225
BC308	18	BF494/5	40	OC71/72	50	ZTX451	23	2N4061/2	15	3N128	115
BC318	80	BF594/5	30			ZTX500	14	2N4264	30	3N140	115
BC327	15	BFR39/40	30								
BC337/8	15	BFR41/79	25								
BC441/61	34	BFR80/81	25								
BC477	40	BFR98	105								
BC516/7	40	BFX29	35								

74HC

HC00	55
HC02	55
HC08	55
HC10	55
HC20	55
HC32	55
HC42	135
HC51	55
HC74	70
HC86	60
HC107	70
HC109	75
HC139	120
HC153	35
HC160	35
HC161	135
HC164	135
HC165	270
HC173	120
HC174	120
HC175	120
HC240	195
HC249	195
HC241	195
HC242	135
HC244	195
HC245	195
HC259	270
HC373	225
HC374	225
HC393	225
HC640	240
HC645	240

RF CHOKES Miniature PCB type

1uH, 2u2, 4u7, 10uF, 22u 33u, 47u, 100u, 220u, 330u, 470u..... 35p
1mH, 1m5, 2m2, 4m7 10mH..... 40p
22mH 33mH, 43mH, 47mH..... 60p
100mH, 220mH..... 75p

DIODES

AA119	8	BY100	15	1N4001/2	5
AA129	10	BY126	12	1N4003	6
AAY30	8	BY127	20	1N4004/5	6
BA100	10	CR033	198	1N4006/7	7
BA102	10	OA9	10	1N4148	4
BY100	15	OA47	10	1N5401	12
BY126	12	OA70	9	1N5404	16
BY127	20	OA79	10	1N5406	1
CR033	198	OA81	10	1N5408	19
OA9	10	OA85	10	1S44	9
OA47	10	OA90	8	1S921	9
OA70	9	OA91	8	6A 100V	40
OA79	10	OA95	8	6A/400V	50
OA81	10	OA200	8	6A/800V	60
OA85	10	OA202	8		
OA90	8	1N914	4		
OA91	8	1N916	5		

VARICAPS

BB105B	40	BB109B	45
BB106	40		

BRIDGE RECTIFIERS

1A/50V	18	1A/400V	25
1A/100V	20	1A/600V	30
1A/200V	25	2A/50V	28
2A/100V	40	2A/200V	42
2A/400V	50	2A/600V	60
6A/100V	83	6A/400V	98
10A/200V	215	10A/400V	298
10A/600V	298	25A/200V	240
25A/400V	396	BY164	58

ZENERS

Range 2V7 to 39V 400mW 8p each
Range 3V3 to 33V 1.3W 15p each

TRIACS

3A200V	54	8A100V	80
3A400V	58	8A400V	89
8A800V	115	12A100V	78
12A400V	98	12A600V	130
12A800V	136	16A100V	103
16A400V	106	16A800V	220
25V500V	220	25A800V	296
T2800	125		

TO-3 TYPES

5A/40V	32	8A300V	80
5A400V	40	8A600V	90
5A600V	48	12A100V	78
8A300V	60	12A400V	96
8A600V	90	12A800V	188
12A100V	78	BT106	150
12A400V	96	BT116	180
12A800V	188	C106D	36
BT106	150	TIC44	24
BT116	180	TIC45	29
C106D	36	TIC47	36
TIC44	24	2N5062	32
TIC45	29	2N5064	38
TIC47	36	2N4444	130
2N5062	32		
2N5064	38		
2N4444	130		

DIAC

ST2	25

75 SERIES

75107/8	95	75451/2	50
75110	90	75454	70
75114	150	75491/2	65
75121/2	130		
75150	125		
75154	125		
75158	150		
75159	195		
75160	350		
75162	650		
75182	99		
75188/9	100		
75322	140		
75324	360		
75365	165		
75361/3	150		
75365	185		
75450	85		

COMPUTER ICs

2102L	160	8202	£25	8279	750
2114	275	8205	225	8282	450
2147	300	8212	220	8283	450
2516	300	8214	495	8284	550
2532	300	8216	150	8288	£11
2L32	450	8224	300	8748	£55
2564	600	8226	300	8T26A	99
256 K Dram	495	8228	300	8T27	150
26501	75	8236	00	8131	350
2716-5V	300	8243	290	8195	90
27128-250	400	8250	£11	8197N	90
2732A	585	8251A	350	9602	220
2732-4	350	8253	1370	9637A	250
2764-250	295	8255	350	AM26LS31C	125
27C64	800	8256AC	£15	AM26LS32A	125
27128-250	695	8257-5	400	AM26LS 33	150
27256-2	1055	8259	400	AM7910	£19
3242	675	8272	£15	AY-3-1015	300
4027	95	8279	750	AY-5-1013	300
4116-200n	100	8282	450	CD4714	150
4164-150n	200	8283	450	COM8017	275
4416-2	299	8284	550	D8748	£33
4532-3	250	8288	£11	DM8131	275
4816-100ns	100	8748	£55	DP8303	450
4864-15	200	8T26A	99	DP8304	350
6116-150	200	8T27	150	DS3647	600
6116L-120	220	8131	350	DS3691N	350
6117-100n	575	8195	90	DS88LS120	300
6167-6	795	8197N	90	DS8820	110
6264L-15	580	Z80 DMA	795	DS8830	140
63A03	£14	Z80ADMA	925	DS8831	125
65C02	650	Z80 PIO	250	DS8832	200
6502CPU	325	Z80A PIO	315	E9364	800
6502A	545	Z80A SIO	£9	E9365	£28
6503	350	Z80ASIO-2	£9	FD1691	£15
6503	650			FD1771	£15
6504 250	550			FD1791	£22
6505	650			FD1795	£28
6520PIA	175			MD2601	75
6522A	545			HD4315	250
6522VIA	340			HD6301	225
6530	£11			HD63A03RP	700
6532RRIOT	650			HM6845SP	755
6545RTC	899			IM6402	380
6551ACIA	650			INS8060N	1250
6545RTC	899			MC14B8	100
6551ACIA	650			MC1489	100
6592PC	£20			MC14411	675
6800	220			MC14412	725
68000	£20			MC3242	590
6802	275			MC3446	250
68A02	345			MC3447P	315
6803	850			MC3486	225
6805	670			MC3487	225
6808	520			MC6845	625
6809E	550			MC8646	625
6810	150			MK3886-2M	£7
6820	150			MM5280D	696
6821	150				
6BB21	220				
6840	375				
6843	800				
6845	650				
6845SP	750				
6847	650				
6850	120				
6852	250				
6854	625				
6BB54	750				
6859	£4				
68000	530				
8017	275				
8035	350				
8080A	425				
8085	£8				
8085A	950				
8088	895				
8123	160				
8131	475				
8150	800				
8154	750				
8155	400				
8156	400				
81LS95	175				

LINEAR ICs

555Cmos	80	LM307	45	LM3900	70
702	50	LM308T	75	LM3909	95
709C 8 pin	35	LM311	45	LM3911	175
710	50	LM318	135	LM3914	300
741 8 pin	16	LM319	180	LM3915	345
747C 14 pin	60	LM2aA	45	LM3916	300
748C 8 pin	35	LM334Z	85	LM13600	150
7358 8 pin	185	LM335Z	130	LS7220	295
810	160	LM337	250	M7068J	150
9400CJ	375	LM339	40	M51513L	230
ADC0808	1000	LM348	60		
AY-1-1320	225	LM349	125		
AY-1-5050	99	LM358	50		
AY-1-5051	160	LM377	210		
AY-1-6720	210	LM379	495		
AY-3-1270	720	LM380	95		
AY-3-1458	350	LM381N	150		
AY-3-8910	390	LM382	130		
Booklet for AY-3-8910	150	LM384	140		
AY-3-8912	450	LM386	90		
AY-5-1317A	630	LM387	120		
AY-5-1350	366	LM389	160		
AY-5-8100	650	LM393	60		
AY-5-3500	650	LM394CH	380		
AY3011	130	LM556	170		
AY3012	175	LM725CN	300		
AY3014	275	LM733	65		
AY3018	85	LM1458	35		
AY3019	90	LM1871	300		
AY3020	210	LM1889	400		
AY3023	210	LM2907	395		
AY3028A	110	LM2917	300		
AY3035	255	LM3900	70		
AY3036	270				

TTL/LS

7400	25	74107	50	74293	80
7401	25	74109	50	74297	175
7402	25	74110	50	74298	160
7403	25	74111	50	74351	180
7404	30	74112	50	74365	70
7405	30	74113	50	74366	70
7406	40	74114	50	74367	70
7407	40	74116	150	74368	70
7408	25	74118	100	74376	1120
7409	25	74119	160	74390	100
7410	25	74120	90	74393	100
7411	25	74121	45	74426	60
7412	25	74122	65	74490	100
7413	40	74123	75		
7414	40	74125	60		
7416	35	74126	55		
7417	35	74128	55		
7420	25	74132	70		
7421	50	74136	65		
7422	35	74141	85		
7423	35	74143	235		
7425	35	74144	250		
7426	40	74145	100		
7427	35	74147	160		
7428	35	74148	130		
7430	25	74150	170		
7432	30	74151	85		
7433	30	74153	70		
7437	30	74154	130		
7438	40	74155	75		
7440	30	74156	90		
7441	90	74157	75		
7442	85	74159	170		
7443	100	74160	100		
7444	100	74161	100		
7445	110	74162	100		
7446	110	74163	100		
7447	95	74164	110		
7448	110	74165	100		
7450	30	74166	130		
7451	30	74167	170		
7454	35	74170	190		
7460	30	74172	400		
7470	50	74173	130		
7472	50	74174	100		
7473	50	74175	100		
7474	45	74176	100		
7475	55	74177	110		
7476	45	74178	130		
7480	60	74179	130		
7481	175	74180	300		
7482	100	74181	300		
7483	100	74182	120		
7484	110	74190	120		
7485	100	74191	120		
7486	40	74192	120		
7489	200	74193	120		
7490	55	74194	120		
7491	70	74195	120		
7492	110	74196	120		
7493	50	74197	120		
7494	100	74198	200		
7495	60	74199	200		
7496	75	74200	1000		
7497	200	74221	150		
74100	60	74246	250		
74104	70	74247	150		
74105	70	74248	150		
74107	45	74249	150		
74109	70	74251	90		
74110	55	74259	150		
74111	55	74263	75		
74112	170	74265	60		
74116	160	74273	180		
74118	110	74276	130		
74119	160	74279	130		
74120	90	74283	130		
74121	45	74284	300		
74122	65	74285	300		
74123	75	74286	80		
74125	60	74290	120		
74126	55				
74128	55				
74132	70				
74136	65				
74141	85				
74143	235				
74144	250				
74145	100				
74147	160				
74148	130				
74150	170				
74151	85				
74153	70				
74154	130				
74155	75				
74156	90				
74157	75				
74159	170				
74160	100				
74161	100				
74162	100				
74163	100				
74164	110				
74165	100				
74166	130				
74167	170				
74170	190				
74172	400				
74173	130				
74174	100				
74175	100				
74176	100				
74177	110				
74178	130				
74179	130				
74180	300				
74181	300				
74182	120				
74184	170				
74185	170				
74190	120				
74191	120				
74192	120				
74193	120				
74194	120				
74195	120				
74196	120				
74197	120				
74198	200				
74199	200				
74221	150				
74246	150				
74247	150				
74248	150				
74249	150				
74251	90				
74259	150				
74263	75				
74265	60				
74273	180				
74276	130				
74278	160				
74279	80				
74283	100				
74284	440				
74285	300				
74286	80				
74290	120				

74C

74C244	150	74C373	180
74C245	150	74C374	425
74C922	420	74C923	600
74C925	650		

74S

S00	45	S38	70	S86	100
S02	40	S40	40	S87	150
S03	40	S51	40	S112	150
S04	40	S53	40	S113	120
S05	40	S64	40	S114	120
S08	40	S65	40	S124	300
S09	40	S74	70	S132	90
S10	40	S85	295	S133	50
S11	50	S86	100	S134	60
S12	60	S87	150	S135	110
S13	35	S112	150	S138	170
S14	50	S113	120	S139	170
S15	45	S114	120	S140	75
S20	40	S124	300	S151	140
S22	60	S132	90	S153	140
S30	50	S133	50	S157	200
S32	50	S134	60	S158	190
S37	50	S135	110	S162	300
S38	70	S138	170	S163	300
S40	40	S139	170	S174	250
S51	40	S140	75	S175	300
S64	40	S151	140	S188	180
S65	40	S153	140	S189	1125
S74	70	S157	200	S194	280
S85	295	S158	190	S197	300
S86	100	S162	300	S201	250
S87	150	S163	300	S225	500
S112	150	S174	250	S226	350
S113	120	S175	300	S240	375
S114	120	S188	180	S241	375
S123	80	S189	225	S244	475
S124	125	S194	280	S251	225
S125	125	S197	300	S253	225
S132	90	S201	250	S257	225
S133	50	S225	500	S258	225
S134	60	S226	350	S260	70
S135	110	S240	375	S261	1500
S138	60	S241	375	S287	200
S139	60	S244	475	S288	180
S140	75	S251	225	S289	200
S151	140	S253	225	S301	350
S153	140	S257	225	S365	250
S157	200	S258	225	S373	375
S158	190	S260	70	S374	375
S162	300	S261	1500	S412	380
S163	300	S287	200	S470	325
S174	250	S288	180	S472	600
S175	300	S289	200	S473	400
S188	180	S301	350	S474

SWITCHES

TOGGLE 2A 250V
SPST **35p** DPDP **48p**
SUB-MIN TOGGLE
SPST on-off **58p**
SPDT c/over **84p**
SPDT centre off **85p**
SPDT biased both ways **105p**
DPDT 6 tags **80p**
DPDT centre off **88p**
DPDT biased both ways **145p**
DPDT 3 positions on-on-on **185p**
4 pole 2 way **220p**

SLIDE 250V
DPDT 1A **14p**
DPDT 1A c/off **15p**
DPDT ½A **13p**

PUSHBUTTON 6A
with 10mm Button
SPDT latching **150p**
DPDT latching **200p**
DPDT moment **200p**

Mini Non Locking
Push to Make **15p**
Push to Break **25p**

DIGITAST Switch
Assorted Colours
75p each

DIP SWITCHES

(SPST) 4 way **65p**, 6 way **80p**, 8 way **85p**; 10 way **125p** (SPDT) 4 way **190p**

ROTARY SWITCHES

(Adjustable Stop type)
1 pole/2 to 12 way 2 pole/2 to 6 way 3 pole/2 to 4 way 4 pole/2 to 3 way **48p**

ROTARY: Mains DP 250V 4 Amp on/off **68p**

ROTARY: (Make-a-switch)
Make a multiway switch. Shafting assembly has adjustable stop. Accommodates up to 6 wafers (max 6 pole/12 way + DP switch). Mechanism only **90p**

WAFERS: (make before break) to fit the above switch mechanism. 1 pole/12 way, 2 pole/6 way, 3 pole/4 way, 4 pole/3 way, 6p/2 Way **65p**
Mains DP 4A Switch to fit **45p**
Spacers **4p**. Screen **6p**

ROCKER SWITCHES

ROCKER 5A/250V SPST **28p**
ROCKER 10A/250V SPDT **38p**
ROCKER 10A/250V DPDT c/off **95p**
ROCKER 10A/250V DPST with neon **85p**

THUMBWHEEL Mini front mounting switches
Decade Switch Module **275p**
B.C.D. Switch Module **298p**
Mounting Cheeks (per pair) **75p**

JUMPER LEADS (Ribbon Cable Assembly)

Length	14 pin	16 pin	24 Pin	40 pin
Single ended DIP (Header/Plug) Jumper				
24 inches	**145p**	**185p**	**240p**	**380p**
Double ended DIP (Header Plug) Jumper				
12 inches	**198p**	**215p**	**315p**	**480p**
24 inches	**210p**	**235p**	**345p**	**540p**
36 inches	**290p**	**370p**	**480p**	**525p**

IDC Female Header Socket Jumper Leads 36"

	20pin	26 pin	34 pin	40 pin
Single ended	**180p**	**200p**	**260p**	**300p**
Double ended	**290p**	**370p**	**480p**	**525p**

VEROBOARD 0.1"

2½" × 1"	30p
2½" × 3¾"	95p
2¼" × 5"	110p
3¾" × 3¾"	110p
3¾" × 5"	125p
3¾" × 17"	420p
4¾" × 17"	590p
VQ Board	195p
DIP Board	395p
Vero Strip	95p

VERO PINS per 100
Single Ended **55p**
Double Ended **60p**
Wire Wrape S/E **155p**
Wire Wrape D/E **255p**

FERRIC CHLORIDE
1lb bag Anhydrous
125p + 50p p&p

VERO WIREING
Pen + Spool... **380p**
Spare spool ... **75p**
Combs ... **8p**
Pen + Spool + Combs ... **599p**

PROTO OECs

Veroblock	480p
S-Dec	350p
Edrobreadboard	590p
Bimboard	575p
Superstrip SS2	1350p

Vero Tools
Spot face Cutters **150p**
Pin insertion tool **185p**

OALO ETCH RESIST PEN
Plus spare tip **100p**

COPPER CLAD BOARDS

Fibre glass	Single sided	Double sided
6" × 6"	100p	125p
6" × 12"	175p	225p

DIL SOCKETS

	Low Prof	Wire Wrap
8 pin	**8p**	**25p**
14 pin	**10p**	**35p**
16 pin	**10p**	**42p**
18 pin	**16p**	**52p**
20 pin	**20p**	**60p**
22 pin	**22p**	**65p**
24 pin	**25p**	**70p**
28 pin	**28p**	**80p**
40 pin	**30p**	**90p**

EDGE CONNECTORS

	.1"	.156"
2×6 way	—	**75p**
2×12 way	—	**160p**
2×15 way	—	**165p**
2×18 way	**175p**	**180p**
2×22 way	**200p**	**170p**
2×23 way	**150p**	—
2×25 way	**250p**	**245p**
2×28 way	**180p**	—
2×30 way	**280p**	—
2×36 way	**300p**	—
2×40 way	**320p**	—
2×43 way	**400p**	—
2×75 way	**800p**	—

SIL SOCKET 0.1" Pitch 20 way **65p**

ANTEX SOLDERING IRONS

C15W	**525p**	CS17W	**545p**
C18W	**550p**	XS25W	**570p**
Spare Bits	**85p**	Elements	**230p**
Iron Stand	**175p**	Heat Shunt	**30p**

IDC CONNECTORS

	PCB with Pins Strt	Plugs latch Pins Angle	Female Header Plug	Female Card Edge Conct
10 way	**90p**	**99p**	**85p**	**120p**
16 way	**130p**	**150p**	**110p**	—
20 way	**145p**	**166p**	**125p**	**195p**
26 way	**175p**	**200p**	**150p**	**240p**
34 way	**200p**	**236p**	**160p**	**320p**
40 way	**220p**	**250p**	**180p**	**340p**
50 way	**238p**	**270p**	**200p**	**380p**
60 way	—	—	**230p**	**495p**

EURO CONNECTORS

Gold Flashed Contacts	Female Socket Strt Pins	Female Socket Angle Pins	Male Strt Pins	Plug Angle Pins
DIN41617 31 way	**125p**	—	—	**175p**
DIN41612 2 x 32 A + B	**200p**	-	**175p**	**220p**
DIN41612 2 x 32 A + C	**225p**	-	**185p**	**230p**
DIN41612 3 x 32 A + B + C	**280p**	**290p**	**295p**	**300p**

DIL PLUG (Header)

Solder IDC

14 pin	**40p**	**95p**
16 pin	**45p**	**100p**
24 pin	**85p**	**135p**
28 pin	**150p**	**200p**
40 pin	**200p**	**255p**

RIBBON CABLE

price per foot

	Grey	Color
10 way	**15p**	**28p**
16 way	**25p**	**40p**
20 way	**30p**	**50p**
24 way	**40p**	**65p**
28 way	**55p**	**80p**
34 way	**60p**	**85p**
40 way	**70p**	**90p**
50 way	**100p**	**135p**
64 way	**120p**	**160p**

ZIF TEXTOOL DIL SOCKETS

24 pin	**550p**
28 pin	**650p**
40 pin	**800p**

'D' CONNECTORS

	9 way	15 way	25 way	37 way
Male				
Solder lugs	**55p**	**80p**	**120p**	**150p**
Angle pins	**110p**	**175p**	**225p**	**300p**
PCB pins	**100p**	**100p**	**160p**	**250p**
Female				
Solder lugs	**90p**	**125p**	**180p**	**275p**
Angle pins	**150p**	**200p**	**260p**	**390p**
PCB pins	**100p**	**125p**	**195p**	**355p**
Covers	**75p**	**70p**	**70p**	**85p**

IDC 25 way 'D' Plug **385p**, Socket **450p**

25 way 'D' CONNECTOR (RS232) Jumper Lead Cable Assembly

18" long, Single end, Male	**475p**
18" long, Single end, Female	**510p**
36" long, Double Ended, M/M	**995p**
36" long, Double Ended, F/F	**£10**
36" long, Double Ended, M/F	**995p**

AMPHENOL PLUGS

	IDC	SOLDER
24 way IEEE plugs	**465p**	**460p**
24 way IEEE skt	**485p**	**480p**
36 way Centronics plug	**375p**	**390p**
36 way Centronics skt	**480p**	**450p**

PANEL METERS

FSD
60 × 46 × 35mm

0-50uA	
0-100uA	
0-500uA	
0-1mA	
0-5mA	
0-10mA	
0-50mA	
0-100mA	
0-500mA	
0-1A	
0-2A	
0-25V	
0-50V	
0-300V	**465p each**

CRYSTALS

32.768KHz	**100**
100KHz	**400**
200KHz	**370**
455KH	**370**
1MHz	**265**
1.008M	**275**
1.28MHz	**450**
1.6MHz	**200**
1.8MHz	**545**
1.8432M	**220**
2.0MHz	**225**
2.4576M	**200**
3.12MHz	**240**
3.276M	**150**
3.5794M	**98**
3.6864M	**300**
4.0MHz	**150**
4.032MHz	**290**
4.19430M	**200**
4.433619M	**100**
4.608MHz	**200**
4.80MHz	**200**
5.0MHz	**150**
5.185MHz	**300**
5.24288M	**390**
6.0MHz	**140**
6.144MHz	**140**
6.5536MHz	**225**
7.0MHz	**150**
7.168MHz	**175**
7.7328MHz	**250**
7.68MHz	**200**
8.0MHz	**150**
8.089333M	**395**
8.86723M	**175**
9.00MHz	**200**
10.0MHz	**175**
10.24MHz	**200**
10.5MHz	**250**
10.7MHz	**150**
12.0MHz	**150**
12.528M	**300**
14.31814M	**170**
15.0MHz	**155**
16.0MHz	**200**
18.0MHz	**150**
18.432M	**150**
19.968MHz	**150**
20.0MHz	**150**
24.0MHz	**150**
24.930MHz	**325**
26.69M	**150**
27.648M	**170**
27.145M	**180**
38.6667M	**240**
48.0MHz	**240**
100.0MHz	**295**

RELAYS

Miniature, enclosed, PCB mount

SINGLE POLE Changeover
RL-91 205R Coil, 12V DC (10V5 to 19.5V), 10A at 30V DC or 250V AC **195p**

DOUBLE POLE Changeover, 6A 30V DC or 250V AC
RL-113 53R Coil, 6V DC (5V4 to 9V9) **190p**
RL8-111 205R Coil, 12V DC (10V7 to 19V5) **195p**
RL8-114 740R Coil, 24V DC (22V to 37V) **200p**

ASTEC UHF MODULATORS

Standard 6MHz **375p**
Wideband 8MHz **450p**

BUZZERS

miniature, solid-state 6V, 9V & 12V **70p**
PIEZO TRANSDUCERS PB2720 **70p**
ULTRASONIC TRANSDUCERS 40KHz **475p**

LOUDSPEAKERS

Miniature, 0.3W, 8Ω
2in, 3"x1in, 2"x1in, 3in 2"x1in, 40Ω 64Ωor 80Ω **80p**
6" × 4" 8Ω **£5**
7" × 5" 8Ω **£4.25**
8" × 5" 8Ω **£5.50**

MONITORS

- ZENITH — 12" Green, Hi-Resolution Popular **£66**
- MICROVITEC 1431, Standard Res. Colour RGB input 14" incl cable **£185**
- MICROVITEC 1451, 14" Medium resolution **£229**
- KAGA 12" Med-res RGB Colour. Has flicker-free characters. Ideal for BBC, Apple, VIC, etc **£225** (car £7)
- KAGA 12" As above but Hi-Resolution **£310** (car £7)
- Connecting Lead for KAGA **£5**

Carriage £7 Securicor

SPECIAL OFFER

	1+	10+
2764-250nS	**240p**	**200p**
27128-250nS	**390p**	**385p**
6116LP-120nS	**195p**	**190p**
6264LP-150nS	**560p**	**550p**

GAS/SMOKE DETECTORS

TGS812 or TGS813
£6 each
Holders for above **40p**

TRANSFORMERS

3·0-3V 6·0-6V 9·0-9V 12·0-12V 15·0-15V @ 100mA **130p**

PCB mounting. Miniature. Split bobbin
3VA: 2×6V/0.25A 2×9V/0.15A 2×12V/0.12A 2×15V/0.2A **235p**
6VA: 2×6V/0.5A 2×9V/0.3A *2×12V/0.25A 2×15V/0.2A **280p**

Standard Split Bobbin type
6VA: 2×6V/0.5A 2×9V/0.4A 2×12V/0.3A 2×15V/0.25A **250p**
12VA: 2×4.5V/1A3, 2×5V/1A, 2×9V/0.6A 2×12V/0.5A, 2×15V/0.4A, 2×20V/0.3A **345p** (35p p&p)
24VA: 2×6V/1.5A, 2×9V/1.2A, 2×12V/1A, 2×15V/0.8A, 2×20V/0.6A **385p** (60p p&p)
50VA: 2×6V/4A, 2×9V/2.5A, 2×12V/2A, 2×15V/1.5A, 2×20V/1.2A, 2×25V/1A, 2×30V/0.8A **520p** (60p p&p)
50VA: Outputs +5V/5A, +12V, +25V, −5V, −12V at 1A **620p** (60p p&p)
100VA: 2×12V/4A, 2×15V/3A, 2×20V/2.5A, 2×25V/2A, 2×30V/1.5A, 2×50V/1A **955p** (75p p&p)

P&P charge to be added over and above our normal postal charge

VOLTAGE REGULATORS

1A TO220 Plastic Casing

	+ve		-ve	
5V	7805	**45p**	7905	**50p**
12V	7812	**45p**	7908	**50p**
15V	7815	**45p**	7912	**50p**
18V	7818	**45p**	7915	**50p**
24V	7824	**45p**	7918	**50p**
			7924	**50p**

100mA TO92 Plastic package

5V	78L05	**30p**	79L05	**45p**
6V	78L06	**30p**	-	-
8V	78L08	**30p**	-	-
12V	78L12	**30p**	79L12	**45p**
15V	78L15	**50p**	79L15	**45p**

ICL7660	**245p**	TAA550	**50p**
RC4194	**375p**	TDA1412	**50p**
RC4195	**160p**	TL497	**185p**
LM309K	**135p**	78H05+5V/5V	**550p**
LM317K	**250p**	78H12+12V/5A	**695p**
LM317KP	**450p**	78HG+5V to + 25V 5A	**585p**
LM323K	**450p**		
LM337	**175p**	79HG-2.25V to -24V 5A	**785p**
LM723 Var	**30p**		
78S40	**225p**		

SOLDERCON PINS

Ideal for making S/L or DIL Sockets

100 pins	**45p**
500 pins	**195p**

ALUM BOXES

3" × 2" × 1"	**85p**
4" × 2½" × 2"	**100p**
4" × 2½" × 2½"	**103p**
4" × 4" × 2"	**105p**
4" × 4" × 2½"	**120p**
5" × 4" × 1½"	**99p**
5" × 4" × 2½"	**120p**
5" × 2¾" × 1½"	**90p**
5" × 2¾" × 2½"	**130p**
6" × 4" × 2"	**120p**
6" × 4" × 3"	**150p**
7" × 5" × 3"	**180p**
8" × 6" × 3"	**210p**
10" × 4" × 3"	**240p**
10" × 7" × 3"	**275p**
12" × 5" × 3"	**280p**
12" × 8" × 3"	**295p**

CMOS

4000	20	4075	25	4541	95
4001	20	4076	60	4543	85
4002	20	4077	25	4548	40
4006	70	4078	25	4549	390
4007	20	4081	20	4553	210
4008	60	4082	20	4554	180
4009	40	4085	60	4555	50
4010	40	4086	60	4556	50
4011	20	4089	120	4557	250
4012	20	4093	25	4558	120
4013	30	4094	70	4559	340
4014	50	4095	70	4560	110
4015	40	4096	100	4561	104
4016	25	4097	260	4562	350
4017	45	4098	70	4566	160
4018	55	4099	110	4568	250
4019	35	4160	95	4569	175
4020	50	4161	96	4572	45
4021	55	4162	96	4580	255
4022	60	4163	96	4581	125
4023	20	4174	96	4582	99
4024	35	4175	105	4583	100
4025	20	4194	105	4584	40
4026	90	4408	850	4585	65
4027	30	4409	850	4597	330
4028	40	4410	725	4599	155
4029	45	4411	750	40085	90
4030	20	4412	805	40097	45
4031	125	4415	590	40098	42
4032	65	4419	280	40100	215
4033	130	4422	770	40101	130
4034	145	4435	850	40102	140
4035	75	4440	900	40103	412
4036	250	4450	360	40104	120
4037	115	4451	350	40105	220
4038	75	4490	450	40106	40
4039	270	4500	395	40107	55
4040	45	4501	40	40108	325
4041	55	4502	50	40109	100
4042	45	4503	45	40110	235
4043	45	4504	100	40114	240
4044	50	4505	350	40161	194
4045	110	4506	100	40163	75
4046	60	4507	45	40173	100
4047	50	4508	115	40174	75
4048	50	4510	50	40175	75
4049	25	4511	50	40181	220
4050	25	4512	50	40182	80
4051	50	4513	150	40192	75
4052	50	4514	115	40193	90
4053	60	4515	115	40194	70
4054	70	4516	50	40195	75
4055	70	4517	275	40244	196
4056	85	4518	50	40245	196
4057	1000	4519	35	40257	196
4059	400	4520	50	40373	220
4060	70	4521	110	40374	220
4061	560	4522	125	45106	586
4062	986	4526	70		
4063	80	4527	60		
4066	25	4528	45		
4067	230	4529	80		
4068	20	4530	90		
4069	20	4531	120		
4070	25	4532	85		
4071	20	4534	365		
4072	20	4536	250		
4073	20	4538	70		
		4539	80		

OPTO

OCP71	120
ORP12	85
ORP61	86
BPX25	250
BPW21	320
TIL139	225

OPTO ELECTRONICS

LEDs with clips

TIL 209	10
TIL211 GRN	14
TIL212 Yel	14
TIL220.2 Red	12
2 Green Yellow or Amber	14
0.2" Bi-colour Red/Green	100p
Green/Yellow	115p
0.2" Tri-colour Red/Green/Yellow	85
Hi-Brightness Red	58
High-Bri Green or Yel	68
Flashing red	55
0.2" red Square LEDs Red	30
Green Yellow	
Rectangle Stackable LEDs	
Red Green or Yellow	19
Triangular LEDs Red	18
Green or yellow	22
LD271 Infra Red	48
SFH205 Detector	118
TIL32 Infra Red	52
TIL78 Detector	55
TIL38	50
TIL100	75
BARGRAPH Red 10 segments	275

ISOLATORS

IL74	145
ILD74	145
ILQ74	275
TIL111/2/4	70
ILCT6 Darlington	135
TIL117	125
4N33 Photo Darlington	136

7 Segment Displays

TIL312 .3" CA	120
TIL313 .3" CC	120
TIL321 .5" CA	140
TIL322 .5" CC	140
TIL729/730	140
DL704 .3" CC	125
DL707 .3" CA	125
FND357 Red	120
FND500	130
.3" Green CA	150
.6" Green CA	215
.3" ± 1 Red CA	150
.3" ± 1 Green CA	150
LCD .3½ Digits	496
LCD 6 Digits	625
Reflective Switch	225
SLOTTED Optical Switch similar to RS Comp's	295

TURNED PIN Low Profile

Professional DIL SOCKETS

8 pin	**25p**
14 pin	**40p**
16 pin	**42p**
18 pin	**47p**
20 pin	**60p**
22 pin	**70p**
24 pin	**72p**
28 pin	**90p**
40 pin	**120p**

BT TELEPHONE CONNECTOR

LJU 1/4A	Mini Line Master	430p
LJU 1/6A	Mini Line Slave	295p
LJU 2/4A	Line Master	370p
LJU 2/6A	Line Slave	250p
LJU 3/4A	Flush Master	370p
LJU 3/6A	Flush Slave	240p
LJU 10/3A	Dual Splitter	550p
4 WAY	BT Plug	65p

COMPUTER CORNER

- EPSON RX80 F/T Printer **£219**
- EPSON FX80 Printer **£316**
- EPSON FX100 Printer **£429**
- KAGA/TAXAN KP810 Printer **£239**
- KAGA/TAXAN KP910 Printer **£339**
- BROTHER HR15 Daisywheel **£329**

Cable for above printers to interface with BBC Micro **£7**

- TEX EPROM ERASER — Erases up to 25 Eproms. Has a built-in safety switch **£30**
- SPARE UV Lamp Bulb **£8**
- C12 Computer CASSETTES in Library cases **35p**
- 8½" & 9½" Fan Fold paper (1000 sheets) **£7 (Carr 150p)**

(Securicor Carriage charge on printers is £7)

CALL IN AT OUR SHOP FOR A DEMONSTRATION ON ANY OF THE ABOVE ITEMS. BE SATISFIED BEFORE YOU BUY OR WRITE IN FOR OUR DESCRIPTIVE MICRO PERIPHERALS LEAFLET.

5¼" DISC DRIVES for the BBC Micro

(All Drives are supplied cased with Power Supply and Utilities Disc)

- **CS200** – Epson Single 200K, 40 track, Double sided **£107**
- **CS400S** – Mitsubishi Single 400K, 80T, Double sided 40 track switchable **£130**
- **CD400** – Epson Twin 400K, 40 track, Double sided drive **£175**
- **CD800S** – Mitsubishi Twin 800K, 80T, 40/80 track switchable Drive **£235**
- **TWIN Disc drive case** with Power supply and Cables to house ones own drives **£35**
- All Single Drives with Power supply are supplied in a twin case for later inclusion of a second drive

(Securicor Carriage on Drives £7)

- **DISC INTERFACE KIT** complete **£65**
- **DFS Manual** (comprehensive) (NO VAT) **£7**

SPECTRUM 32K UPGRADE

Upgrade your 16K Spectrum to full 48K with our RAM Upgrade Kit. Very simple to fit. Fitting instructions supplied.

£18

BBC MICRO WORDPROCESSING PACKAGE

A complete wordprocessing package (which can be heavily modified to your requirements, maintaining large discount). We supply everything you need to get a BBC Micro running as a word-processor. Please call in for a demonstration.

Example Package:
BBC Micro, with DFS Interface, Wordwise, Twin 400K TEC Disc Drives, 12" High-res green monitor, Brother HR15 Daisywheel printer, Beebcalc & Database software on Disc, 10 3M Discs, 500 sheets of paper, 4-way mains trailing socket, manuals and all cables

BBC Model B Only £299

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BBC Model B **Only £289**

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Rapid Electronics

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Boxted, Colchester, Essex CO4 5RD.
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Telex: 987756.

ACCESS AND BARCLAYCARD WELCOME

MIN. D CONNECTORS

	9 way	15 way	25 way	37 way
Plugs solder lugs	35p	40p	56p	100p
Right angle PCB	85p	130p	200p	260p
Sockets solder lugs	45p	50p	65p	120p
Right angle PCB	115p	170p	290p	350p
Covers	70p	80p	80p	95p

CONNECTORS

	Plug	Skt	Jack	Plug	Skt
DIN	8p	8p	2.5mm	10p	9p
3 pin	13p	13p	3.5mm	10p	9p
5 pin	14p	13p	Standard	17p	20p
Phono	10p	14p	Stereo	25p	25p
1mm	12p	9p	4mm	12p	12p

UHF (CB) Connectors.
PL259 Plug 40p. Reducer 14p.
SO239 square chassis skt 40p.
SO239S round chassis skt 40p.
IEC 3 pin 250V/6A.
Plug chassis mounting . . . 55p
Socket free hanging . . . 90p
Socket with 2m lead . . . 125p

SWITCHES

Submin toggle:
SPST 55p. SPDT 60p. DPDT 65p.
Miniature toggle.
SPDT 60p. SPDT centre off 65p.
DPDT 70p. DPDT centre off 75p.
Standard toggle.
SPST 35p. DPDT 48p.
Miniature DPDT slide 14p.
Push to make 15p.
Push to break 22p.
Rotary type adjustable stop.
1P12W, 2P6W, 3P4W, 4P3W 53p
DIL switches:
4SPST 70p 6SPST 80p 8SPST 90p.
BCD rotary Hexadecimal 180p.
Decimal 170p

SOCKETS

	Low profile	Wire wrap
8 pin	4p	28p
14 pin	7p	48p
16 pin	8p	55p
18 pin	9p	65p
20 pin	10p	75p
22 pin	12p	80p
24 pin	12p	85p
28 pin	13p	100p
40 pin	18p	140p

Professional ZIF sockets
24 pin 430p 28 pin 480p
40 pin 595p

SOLDERING IRONS

Antex CS 17W Soldering iron	480
2.3 and 4.7mm bits to suit	85
Antex XS 25W soldering iron	500
3.3 and 4.7mm bits to suit	85
Solder pump desoldering tool	480
Spare nozzle for above	70
10 metres 22 swg solder	100
0.5kg 22 swg solder	750
Iron stand for CS/XS irons	170

VERO

Protobloc 1 breadboard	395
Veroboard Size 0.1 in matrix	
2.5 x 1	26
2.5 x 3.75	95
3.75 x 5	120
3.75 x 17	390
4.75 x 17	495
VQ board	190
Veropins per 100	
Single sided	55
Double sided	65
Spot face cutter	150
Pin insertion tool	190
Wiring pen	375
Spare spool 75p	Combs 6

MICRO

2716	310	27128-250	290	6800	200	6522	330
2532	380	6116P3	150	6802	280	6532	520
2732 one time programmable		6264P15	320	6809	600	6551	540
	280	4164-15	160	6810	140	8085A	320
2732	280	41256-15	320	6821	140	8156	380
2764-250	220	Z80A CPU	270	6840	360	8251	350
2764-BBC	220	Z80A P10	270	6850	165	8253	370
		Z80A CTC	270	6852	240	8255	320
		Z80A S10	700	6875	500	8259	400
		Z80A DMA	700	6880	100	MC1488	60
				6502	370	MC1489	60

COMPONENT KITS

0.25W Resistor Kit. Contains 1000 0.25W 5% resistors from 4.7 ohms thru to 10M. Quantities depend upon popularity i.e. 10x10R, 30x470R, 30x10K, 25x470K. Just £7.90
Ceramic capacitor Kit. Total of 250 miniature ceramic capacitors from 22p to 0.1u. Just £6.90
Polyester capacitor Kit. Total of 110 miniature polyester capacitors from 0.01u to 0.47u. Just £6.90
Preset Kit. Total of 110 miniature preset resistors from 100R to 1M. Horizontal mounting type. Just £6.90
Radial Electrolytic Capacitor Kit. A pack containing a total of 93 miniature caps from 1u to 2200u Just £7.50
Nut and Bolt Kit. Contains 800 assorted items. 100 each 6BA ¼in, ⅛in, nuts and wshrs, 4BA ¼in, ⅛in, nuts and wshrs. Just £3.20

CABLES

20 metre pack single core connecting cable ten different colours.	75p
Speaker cable	10p/m
Standard screened	16p/m
Twin screened	24p/m
2.5A 3 core mains	23p/m
10 way rainbow ribbon	26p/ft
20 way rainbow ribbon	47p/ft
10 way grey ribbon	14P/ft
20 way grey ribbon	28p/ft

REGULATORS

78L05	30	79L05	50
78L12	30	79L12	50
78L15	30	79L15	50
7805	40	7905	45
7812	45	7912	45
7815	45	7915	45
LM317K	230	LM723	40
LM317T	90	78H05	550
LM323K	420		

DIODES

		▶1N4001	3
BY127	12	1N4002	5
OA47	10	1N4006	7
OA90	8	1N4007	7
OA91	7	1N5401	12
OA200	8	1N5404	16
OA202	8	1N5406	17
1N914	4	400mWzen	6
▶1N4148	3	1.3W zeners	13

OPTO

3mm red	8	5mm red	8
3mm green	11	5mm green	11
3mm yellow	11	5mm yellow	11

Clips to suit - 3p each.

Rectangular:		TIL32	40
red	10	TIL111	55
green	12	TIL78	40
yellow	12	ORP12	85
ILD74	95	ILQ74	185
TIL38	35	TIL100	75
2NS777	45	Tri-color Led	30

Seven segment displays:

Com cathode:		Com anode.	
DL704 0.3"	95	DL707 0.3"	95
FND6000.5"100		FND5070.5"100	
10 bar DIL LED display			140
5mm highbright 10		Superbright	30

HARDWARE

PP3 battery clips	6
Red or black crocodile clips	6
Black pointer control knob	15
Pr Ultrasonic transducers	396
▶6V Electronic buzzer	70
▶12V Electronic buzzer	70
▶PB2720 Piezo transducer	75
▶64mm 64 ohm speaker	70
▶64mm 8 ohm speaker	75
20mm panel fuseholder	25
Red or black probe clip	30
4mm terminals	36
12 way 'chocolate' block	21
ultra-min. 6 or 12v rel. SPDT	130
ditto, but DPDT	195

EURO CONNECTORS

Gold flashed contacts:	Rt. angle plug	Wirewrap socket
64 way A+B	195	230
64 way A+C	220	270
96 way A+B+C	320	330

TRIACS

	400V 8A	65	
	400V 16A	95	
400V 4A	50	BR100	25

NEW 1986 CATALOGUE

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Rapid Electronics Electronics Components Catalogue

CAPACITORS

Polyester, radial leads. 250v. C280 type: 0.01, 0.015, 0.022, 0.033 - 6p; 0.047, 0.068, 0.1 - 7p; 0.15, 0.22 - 9p; 0.33, 0.47 - 13p; 0.68 - 20p; 1u - 23p.
Electrolytic, radial or axial leads: 0.47/63V, 1/63V, 2.2/63V, 4.7/63V, 10/25V - 7p; 22/25V, 47/25V - 8p; 100/25V - 9p; 220/25V - 14p; 470/25V - 22p; 1000/25V - 30p; 2200/25V - 50p.
Tag end power supply electrolytics: 2200/40V - 110p; 4700/40V - 160p 2200/63V - 140p; 4700/63V - 230p
Polyester, miniature Siemens PCB: 1n, 2n2, 3n3, 4n7, 6n8, 10n, 15n, 7p, 22n, 33n, 47n, 68n, 8p; 100n, 9p; 150n, 11p; 220n, 13p; 330n, 20p; 470n 26p; 680n, 29p; 1u 33p.

Tantalum bead:
0.1, 0.22, 0.33, 0.47, 1.0 @ 35V - 12p. 2.2, 4.7, 10 @ 25V - 20p; 15/16V - 30p; 22/16V - 27p, 33/16V - 45p; 47/6V - 27p; 47/16V - 70p; 68/6V - 40p; 100/10V - 90p.
Cer. disc. 22p-0.01u 50V, 3p each.
Mullard miniature ceramic plate: 1.8pF to 100pF 6p each.
Polystyrene, 5% tol: 10p-1000p, 6p; 1500-4700, 8p; 6800 0.012u, 10p.
Trimmers. Mullard 808 series. 2-10 pF, 22p; 2-22pF, 30p; 5.5-65pF, 35p

BRIDGE RECTIFIERS

	2A 200V		40
	2A 400V		45
	6A 100V		80
	6A 400V		95
1A 50V	20	VM18 DIL	0.9A
1A 400V	35	200V	50

IDC CONNECTORS

	PCB Plug St.	PCB Plug Rt. ang.	Socket	Edge Conn.
10 way	70	70	70	–
16 way	75	80	80	–
20 way	90	90	95	130
26 way	105	110	115	155
34 way	115	130	130	180
40 way	140	140	145	210
50 way	165	165	170	240
60 way	195	195	200	–

COMPUTER CONNECTORS

ZX81 2 x 23 way edge connector wire wrap for ZX81 . . . 150
SPECTRUM 2 x 28 way edge connector wire wrap. . . . 200
AMPHENOL PLUGS
24 way IEEE IDC. . . . 450
36 way Centronix IDC . . . 490

RIBBON CABLE

Grey Ribbon cable. Price per foot

10 way	14	34 way	58
16 way	25	40 way	68
20 way	28	50 way	90
26 way	38	60 way	100

LINEAR

	IC7611	100	LM358	40	LM3915	190	NE567	100	TDA1024	90
	ICL7621	200	LM377	210	LM1360C	100	NE570	230	TL061	40
555CMOS	55	ICL7622	190	LM380	80	MC1310	150	NE571	195	TL062	65
556CMOS	150	ICL8038	395	LM381	130	MC1496	70	NE5532	160	TL064	105
709	35	ICL8211A	200	LM382	130	MC3302	75	NE5534	105	TL071	32
741	16	ICM7555	55	LM384	160	MC3340	130	RC4136	65	TL072	55
748	35	ICM7556	150	LM386	85	MF10CN	330	RC4558	45	TL074	105
AY38910	390	LF347	90	LM387	90	ML922	415	SL486	240	TL081	28
AY38912	430	LF351	40	LM393	45	ML924	290	SL490	280	TL082	45
CA3046	60	LF353	70	LM710	48	ML925	290	SN76018	150	TL084	90
CA3080E	65	LF356	90	LM711	48	ML926	275	SN76477	380	TL170	50
CA3089	200	LM10C	325	LM725	270	ML927	275	SP8629	250	UA2240	130
CA3090AQ	375	LM301A	30	LM733	70	ML928	275	SP0256AL2	425	ULN2003	80
CA3130E	75	LM311	45	LM741	16	ML929	275	Speech data	50	ULN2004	80
CA3140E	38	LM318	110	LM747	60	NE529	225	TBA800	70	XR2206	395
CA3160	95	LM324	40	LM748	35	NE531	135	TBA810	65	ZN414	75
CA3136	100	LM334Z	85	LM1458	35	NE544	170	TBA820M	60	ZN423	100
CA3189	260	LM335Z	130	LM2917N8	170	NE565	20	TBA950	220	ZN424P	70
CA3240E	100	LM339	40	LM3900	50	NE556	45	TCA940	165	ZN425E	340
ICL7106	680	LM348	60	LM3909	85	NE565	95	TDA1008	250	ZN426E	200
				LM3914	190	NE566	95	TDA1022	270	ZN427E	580
										ZN428E	435
										ZN459	190
										ZN1034E	190

RESISTORS

Carbon film	1+	25+
¼W 5% 4.7ohm - 10M	2p	1p
½W 5% 4.7ohm - 4M7	3p	2p
Metal film		
¼W 1% 100hm - 1M	4p	3p
25+ Price applies to 25+ per value not mixed.		

CRYSTALS

100KHz	235	5.008MHz	240
1MHz	275	6.0MHz	140
1.8432M	200	6.144MHz	150
2.0MHz	225	7.0MHz	150
2.4576M	200	8.0MHz	140
3.276M	150	10.0MHz	170
3.579M	95	12.0MHz	170
4.0MHz	140	16.0MHz	200
4.194MHz	150		
4.43MHz	100		

BOXES

	Aluminium	
	3 x 2 x 1"	65
Plastic with lid	4 x 2¾ x 1¼"	95
& screws	4 x 2¾ x 2"	95
71x46x22mm	50 6 x 4 x 2"	120
95x71x35mm	86 7 x 5 x 2¼"	165
140x90x55mm	140 8 x 6 x 3"	205

TRANSISTORS

		BC548	5	BFR40	23	2N1613	30	2N3906	10		
		BC549	10	BFR80	23	2N2218A	45	2N4037	45		
		BC557	10	BFR81	23	2N2219A	28	2N4058	10		
AC125	35	BC558	10	BFX29	30	2N2221A	25	2N4060	10	TIP35C	125
AC126	30	BC158	10	BFX84	30	2N2222A	20	2N4061	10	TIP36A	115
AC127	30	BC159	10	BFX85	30	2N2368	25	2N4062	10	TIP36C	130
AC128	30	BC160	40	BFX86	30	2N2369	18	40360	40	TIP41A	45
AC176	25	BC168C	10	BFX87	30	2N2484	27	40361	50	TIP42A	45
AC187	25	BC169C	10	BFX88	30	2n2646	60	40362	50	TIP120	60
AC188	25	BC170	8	BFY50	27	2N2904	28	40408	50	TIP121	60
AD142	120	BC171	10	BFY51	27	2N2904A	28	2N5457	30	TIP122	60
AD161	42	BC172	8	BFY52	27	2N2905	28	2N5458	30	TIP141	110
AD162	42	BC177	16	BFY53	30	2N2905A	28	2N5459	30	TIP142	120
AF124	60	BC178	16	BFY55	30	2N2906	28	2n5485	35	TIP147	120
AF126	50	BC179	18	BFY56	30	2N2906A	28	2N5777	45	TIP2955	70
AF139	40	BC182	10	BFY39	50	2N2907	24	2N697	20	TIP3055	60
AF186	70	BC182L	10	BSX20	22	2N2907A	24	2N698	40	TIS43	40
AF239	55	BC183	10	BSX29	35	2N2926	10	2N706A	20	TIS43	40
BC107	10	BC183L	10	BSY95A	30	2N3053	28	2N708	25	TIS44	45
BC107B	12	BC184	10	BU205	160	2N3054	55	2N918	35	TIS45	45
BC108	10	BC184L	10	BU206	200	2N3055	50	TIP29	35	TI590	30
BC108B	12	BC212	10	BU208	170	2N3442	120	TIP29A	35	TI591	30
BC108C	12	BC212L	10	MJ2955	99	2N3702	9	TIP29B	35	VN10KM	65
BC109	10	BC213	10	MJE340	50	2N3703	10	TIP29C	35	VN66AF	94
BC109C	12	BC213L	10	MJE520	50	2N3704	9	TIP30	35	VN66AF	110
BC114	22	BC214	10	MJE521	90	2N3705	10	TIP30A	35	VN88AF	120
BC115	22	BC214L	10	MJE3055	70	2N3706	10	TIP30B	35	ZTX107	11
BC117	22	BC237	7	MPF102	40	2N3707	10	TIP30C	40	ZTX108	11
BC119	35	BC238	7	MPF104	40	2N3708	10	TIP31A	35	ZTX109	11
BC137	40	BC308	10	MPSA05	23	2N3709	10	TIP31B	35	ZTX300	14
BC139	38	BC327	8	MPSA06	25	2N3772	170	TIP31C	40	ZTX301	16
BC140	29	BC328	8	MPSA12	29	2N3773	195	TIP32A	35	ZTX302	16
BC141	30	BC337	8	MPSA55	30	2N3819	32	TIP32B	38	ZTX304	20
BC142	28	BC338	12	MPSA56	30	2N3820	50	TIP32C	40	ZTX341	20
BC143	30	BC477	22	MPSU05	55	2N3823	65	TIP33A	65	ZTX500	13
BC147	10	BC478	22	MPSU06	55	2N3866	90	TIP33C	75	ZTX501	18
BC148	10	BC479	22	MPSU55	55	2N3903	10	TIP34A	70	ZTX502	18
BC149	10	BC517	30	MPSU56	55	2N3904	10	TIP34C	80	ZTX503	18
BC157	11	BC547	5	BFR40	35	2N118L	22	2N3905	10	TIP35A	105	ZTX504	25

TTL

		7412	28	7440	28	7476	40	74107	40	74157	70	74180	90
		7413	38	7442	70	7480	50	74109	50	74160	80	74181	240
		7414	48	7444	105	7483	48	74121	40	74161	80	74182	80
7400	25	7416	38	7446	130	7485	80	74122	50	74162	80	74190	70
7401	28	7417	38	7447	88	7486	38	74123	50	74163	80	74191	75
7402	25	7420	28	7448	88	7489	140	74125	45	74164	110	74192	75
7403	28	7421	50	7450	28	7490	40	74126	45	74165	80	74193	70
7404	25	7422	28	7451	28	7491	70	74132	50	74167	200	74194	75
7405	28	7427	30	7453	28	7492	55	74141	80	74170	170	74195	75
7406	40	7428	30	7454	28	7493	45	74145	75	74173	90	74196	75
7407	40	7430	28	7460	28	7494	80	74147	130	74174	90	74197	75
7408	28	7432	30	7472	35	7495	60	74148	105	74175	80	74198	160
7409	28	7433	38	7473	35	/496	80	74150	135	74176	80	74199	160
7410	28	7437	30	7474	35	7497	150	74153	70	74177	80		
7411	28	7438	35	7475	45	74100	120	74154	135	74179	90		

CMOS

		4016	20	4034	145	4054	70	4081	15	4502	50	4529	55
		4017	35	4036	270	4055	70	4082	15	4503	45	4532	50
		4018	40	4039	270	4059	400	4085	35	4507	45	4534	390
4000	15	4019	30	4040	40	4060	45	4086	50	4508	95	4538	40
4001	15	4020	40	4041	50	4063	75	4089	120	4510	45	4543	40
4002	15	4021	40	4042	30	4066	25	4093	22	4511	50	4549	390
4006	40	4022	40	4043	45	4067	230	4094	55	4512	50	4553	215
4007	15	4023	15	4044	45	4068	18	4095	80	4514	85	4555	35
4008	45	4024	30	4046	48	4069	15	4097	260	4515	85	4556	35
4009	25	4025	18	4047	50	4070	20	4098	50	4516	45	4559	290
4010	25	4026	90	4048	35	4071	18	40106	35	4518	45	4560	110
4011	15	4027	22	4049	23	4072	18	40109	100	4520	45	4584	35
4012	15	4028	35	4050	23	4073	18	40163	75	4521	110	4585	50
4013	24	4029	40	4051	45	4075	18	40173	100	4526	45	4724	140
4014	40	4030	20	4052	45	4076	50	40175	75	4527	35		
4015	40	4031	125	4053	45	4077	30	40193	90	4528	40		

LS TTL

		LS20	20	LS75	30	LS123	45	LS161	55	LS221	70	LS365	40
		LS21	20	LS76	30	LS125	38	LS162	55	LS240	65	LS366	40
		LS22	20	LS78	28	LS126	38	LS163	55	LS241	60	LS367	40
LS00	18	LS26	20	LS83	45	LS132	45	LS164	55	LS242	60	LS368	40
LS01	20	LS27	20	LS85	50	LS136	35	LS165	65	LS243	60	LS373	60
LS02	20	LS30	20	LS86	22	LS138	38	LS166	85	LS244	55	LS374	60
LS03	20	LS32	20	LS90	25	LS139	38	LS170	100	LS245	55	LS375	40
LS04	18	LS37	20	LS92	35	LS145	75	LS173	45	LS247	60	LS377	80
LS05	20	LS38	20	LS93	30	LS147	100	LS174	45	LS251	45	LS378	65
LS08	20	LS40	20	LS95	50	LS148	100	LS175	45	LS257	45	LS390	55
LS09	20	LS42	35	LS96	75	LS151	35	LS190	60	LS258	45	LS393	55
LS10	20	LS47	60	LS107	25	LS153	35	LS191	55	LS259	70	LS399	95
LS11	20	LS48	65	LS109	26	LS154	120	LS192	55	LS266	32	LS541	95
LS12	20	LS51	20	LS112	30	LS155	45	LS193	55	LS273	55	LS670	110
LS13	25	LS55	20	LS113	30	LS157	35	LS195	55	LS279	50		
LS14	35	LS73	33	LS114	30	LS158	35	LS196	55	LS283	60		
LS15	20	LS74	25	LS122	45	LS160	50	LS197	55	LS353	75		

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DIGEST

Industry Hampered By Lack Of Qualified Staff

A shortage of qualified staff is the main constraint on the development and use of new technologies, according to a recent survey of top businessmen.

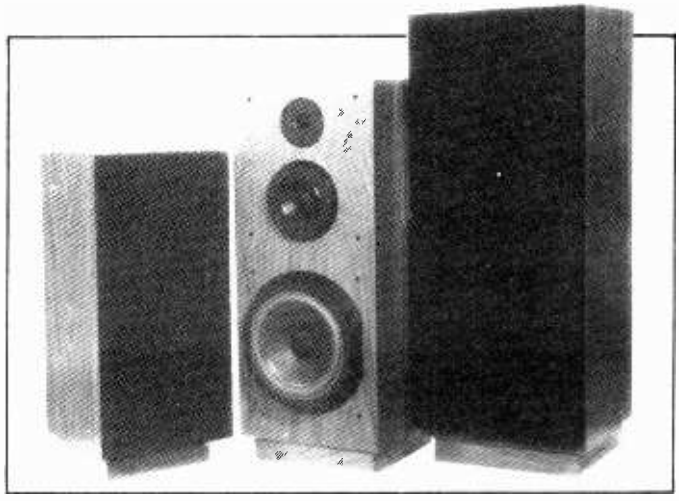
And while this problem affects most industrial countries, including Japan, British businessmen seem less ready to invest in research and development than do their foreign counterparts and see the benefits of new technology in narrower terms.

The poll was carried out by the management consultants PA Technology, and involved 176 chief executives and company directors from Britain, Japan, the United States, Germany and the Benelux countries. Twenty-two percent of those surveyed cited shortage of qualified staff as a major constrain while none of them felt that high interest rates or trade union activity were barriers to innovation.

The Japanees, it appears, are worried about both the quantity and the quality of the skilled staff they produce. Britain was not thought to have any problem with the quality of staff, particularly graduates, but was not felt to be making the most effective use of them.

On research, a third of all businessment interviewed outside the UK said that the emergence of new technologies had led them to invest more, whereas in the UK the figure was only 6%. More than half the British businessmen admitted to knowing little or nothing about the services offered by universities and other research institutions while their Japanese counterparts were well informed and highly satisfied with the effectiveness of their research bodies. The Japanese also placed more importance on pure research than any of their competitors.

None of the Japanese respondents mentioned technology as a means of reducing production costs or increasing production rates. By contrast, the Western countries all placed more importance on this factor.



Scanspeak Loudspeakers In Kit Form

Wilmslow Audio can now supply kits of parts to enable constructors to build any of the loudspeakers in the Scanspeak DIY range.

The kits are based on designs in The Scanspeak Handbook, which describes a number of loudspeaker systems which can be constructed using Scanspeak drive units. Among the features of these designs are the use of phase correction rings to space each drive unit the correct distance away from the front of the cabinet and the incorporation of a vented loading system.

The drive units are said to employ a symmetrical drive system which ensures that cone excursions in each direction are identical, removing the rise in impedance at high frequencies and thus simplifying crossover design, and they also use hexagonal cross-section wire in the voice coil. This is said to remove the tiny airgap that normally exists between windings, improving heat transfer and hence the power handling.

The cabinet panels are machined from Medium Density Fibre (MDF) board and Wilmslow can also supply a variety of iron-on wood veneer finishes. They will supply The Scanspeak Handbook free-of-charge.

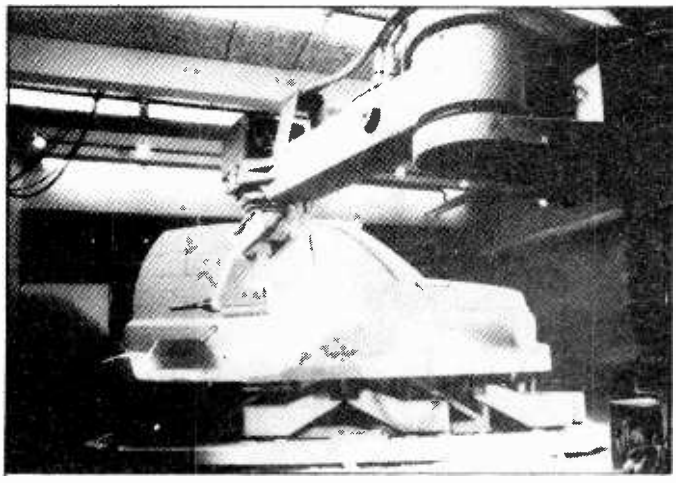
Wilmslow Audio Ltd, 35-39 Church Street, Wilmslow, Chesire SK9 1AS, tel 0625 — 529599.

Micro Chips Off The Old Block

Renault have cut in half the time taken to produce a life-size model of a new car by using a computer-controlled robot. An articulated arm cuts the required shape out of a giant block of plastic and the model can be ready for finishing and painting in just two days.

Traditionally, it took twelve to sixteen weeks to progress from the initial rough sketches of a new car body to the stage where a life-size, three dimensional model was ready. Part of the time was taken up in the prodiction of 1/5th scale models to enable the three-dimensional effect to be appreciated before moving on to the full size model.

With modern computer aided design techniques, this intermediate stage is no longer required. The stylist can create an image on a touch sensitive screen and then rotate and manipulate it to assess the design and make any changes necessary. When everyone is satisfied, the program can be used to control the robot and life-size model quickly produced.



The process is being developed at Renault's Technical Centre at Rueil, near Paris. They claim that it has reduced the time required for the initial stages of the design process to between six and eight weeks, with consequent reductions in the cost. It also frees designers to work on more valuable tasks.

Renault UK Ltd, Western Avenue, London W3)RZ, tel 01-992 3481.

ETI Printed Circuit Board Service

We are pleased to be able to announce that we have at last appointed a new supplier and will shortly be able to resume this service

We expect to be able to start clearing the backlog of boards on order in the next week or two and would hope to have everything back to normal by the time the next issue comes out.

However, we would be grateful if readers who are thinking of ordering boards would hold on for a little longer and let us get things straightened out first. For this reason we have not printed the PCB Service page again this month but hope to include it, with any price changes occasioned by the change of supplier, in the December issue.

We would like to thank our readers for their forebearance during this difficult period.

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DECCA 80 16" COLOUR monitor. RGB input.

Little or hardly used manufacturer's surplus enables us to offer this special converted **DECCA RGB** Colour Video TV Monitor at a super low price of only **£99.00**, a price for a colour monitor as yet unheard of!! Our own interface, safety modification and special 16" high definition **PIL** tube, coupled with the tried and tested **DECCA 80** series TV chassis gives 80 column definition and picture quality found only on monitors costing **3 TIMES OUR PRICE**. In fact, **WE GUARANTEE** you will be delighted with this product, the quality for the price, has to be seen to be believed. Supplied complete and ready to plug direct to a **BBC MICRO** computer or any other system with a **TTL RGB** output. Other features are: internal speaker, Modular construction, auto degaussing circuit, Attractive **TEAK CASE**, compact dimensions only 52cm W x 34 H x 24 D, 90 day guarantee. Although used, units are supplied in **EXCELLENT** condition, **ONLY £99.00** + Carr.
DECCA 80, 16" COLOUR monitor. Compositve video input. Same as above model but fitted with Composite Video input and audio amp for **COMPUTER**, VCR or **AUDIO VISUAL** use. **ONLY £99.00** + Carr.
REDIFFUSION MARK 3, 20" Colour monitor. Fitted with standard 75 ohm composite video input and sound amp. This large screen colour display is ideal for shops, schools, clubs and other **AUDIO VISUAL** applications. Supplied in AS NEW or little used condition **ONLY £145.00** + Carr.

BUDGET RANGE EX EQUIPMENT MONOCHROME video monitors.

All units are fully cased and set for 240v standard working with composite video inputs. Units are pre tested and set up for **80** column use on **BBC** micro etc. Even when MINOR screen burns exist – normal data displays are unaffected.
12" KGM 320-1 B/W high bandwidth input, will display up to 132 x 25 lines. **£32.95**
12" GREEN SCREEN version of **KGM 320-1** Only **£39.95**
9" KGM 324 GREEN SCREEN fully cased very compact unit Only **£55.00**
9" HITACHI VM-906E/K Black and White screen **£49.95**

Carriage and insurance on all monitors **£10.00**

D.C. POWER SUPPLY SPECIALS

GOULD OF443 enclosed, compact switch mode supply with DC regulated outputs of +5v @ 5.5a, +12v @ 0.5a, –12v @ 0.1a and –23v @ 0.02a. Dim 18 x 11 x 6 cm. 110 or 240v input. **BRAND NEW** only **£14.95**
GOULD G6-40A 5v 40 amp switch mode supply NEW £130.00
GREENDALE 19A-BOE Switch mode 60 watt open PCB with a fully regulated DC output of 5v @ 6 amps, and three semi regulated outputs of +12V, –12V +15V @ upto 1 amp. Dim only 11 cm x 20 cm x 5.5 cm. Similar to RS 591-994. 110 or 240v AC input. **TESTED** ex equipment. **Only £24.95**
AC-DC Linear **PSU** for **DISK** drive and **SYSTEM** applications. Constructed on a rugged ALLOY chassis to continuously supply fully regulated DC outputs of +5V @ 3 amps, –5V @ 0.6 amps and +24v @ 5 amps. Short circuit and overvoltage protected. 110 or 240 V AC input. Dim 28 x 12.5 x 7 cm **NEW £49.95.**

Carriage on PSU's £3.00

SPECIAL 300 BAUD MODEM OFFER

Another **GIGANTIC** purchase of these **EX BRITISH TELECOM, BRAND NEW** or little used 2B data modems allows US to make the **FINAL REDUCTION**, and for **YOU** to join the exciting world of data communications at an **UNHEARD OF PRICE OF ONLY £29.95**. Made to the highest **POST OFFICE APPROVED** spec at a cost of hundreds of pounds each, the 2B has all the standard requirements for data base, business or hobby communications. All this and more!!

- 300 baud full duplex
- Full remote control
- CCITT tone standards
- Supplied with full data
- Modular construction
- Direct isolated connection
- CALL, ANSWER and AUTO modes
- Standard RS232 serial interface
- Built in test switching
- 240v Mains operation
- 1 year full guarantee
- Just 2 wires to comms line

NOW ONLY £29.95

BT 600 Jack plug and cable £2.25 Carriage and Ins. £10.00

VDU TERMINALS

Standard VDU data entry terminals at give away prices!!
QUME QVT108. Current product, state of the art terminal with detachable keyboard, 12" green screen, 2 page RAM, **TVI 925** emulation, 25 x 80, Clock, Swivel and tilt base, Printer port, Function keys etc. **BRAND NEW** and BOXED AT ALMOST **HALF PRICE** Only **£425.00**
AJ510 – EX RENTAL Z80 controlled, 15" green screen 24 x 80 display, graphics, cursor addressing, printer port etc. Very good condition **TESTED** complete with manual only £225.00.
ADDS 520 – Dumb terminal, used, 12" b/w screen RS232 interface and printer port. **TESTED. ONLY £125.00**
Carriage on terminals £10.00
100's of other terminals in stock.
CALL for more details.

DISPLAY ELECTRONICS

All prices quoted are for U.K. Mainland, paid cash with order in Pounds Sterling PLUS VAT. Minimum order value **£2.00**. Minimum Credit Card order **£10.00**. Minimum BONA FIDE account orders from Government Depts., Schools, Universities and established companies **£20.00**. Where post and packing not indicated please ADD £1.00 + VAT. Warehouse open Mon-Fri 9.30-5.30. Sat 10.30-5.30. We reserve the right to change prices and specifications without notice. Trade, Bulk and Export

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DIARY

Offshore Computers Conference & Exhbition — October 8-10th
Aberdeen Exhibition & Conference Centre. Conference devoted to the use of computers in petroleum exploration. Thirty-seven papers from seven countries will be presented and the costs range from £160.00 + VAT for one day to £390.00 + VAT for the full event. Entry to the association exhbition is free. Contact Offshore Exhibitions and Conferences Ltd, Rowe House, 55-59 Fife Road, Kingston upon Thames, Surrey KT1 1TA, tel 01-549 5831.

Technology Engineering Fair — October 8-11th
NEC, Birmingham. For details see August '85 ETI or contact Cahners at the address below.

Internepcon UK — October 10/11th
Metropole Hotel and Brighton Centre, Brighton. For details see August '85 ETI or contact Cahners at the address below.

Computer Graphics '85 — October 15-18th
Wembley Conference Centre, London. For details see August '85 ETI or contact Online at the address below.

Electronic Displays '85 — October 29-31st
Kensington Exhibition Centre, London. For details see September '85 ETI or contact Network Events at the address below.

Cellular Communications International — November 5-7th
Wembley Conference Centre, London. For details see September '85 ETI or contact Online at the address below.

Programming In Ada: A Hands-On Workshop — November 12-15th
London: venue to be announced. Course designed to enable programmers, engineers and technical managers to write, debut, test and execute Ada programs and interface between Ada and programs written in other codes. Paritipants ideally should be familiar with either Pascal, C, Fortran or PL/1. The cost is £675.00 + VAT and details are available from ICS at the address below.

Compec '85 — Novemer 12-15th
Olympia, London. Exhibition of professional computer hardware and software. For details contact Reed Exhibitions, Surrey House, 1 Throwley Way, Sutton Surrey SM1 4QQ, tel 01-643 8040.

International Test And Measurement Exhibition (ITAME) — November 27-29th
Olympia 2, London. Exhibition and conference covering all areas of electronic test and measurement. For details see February '85 ETI or contact Network at the address below.

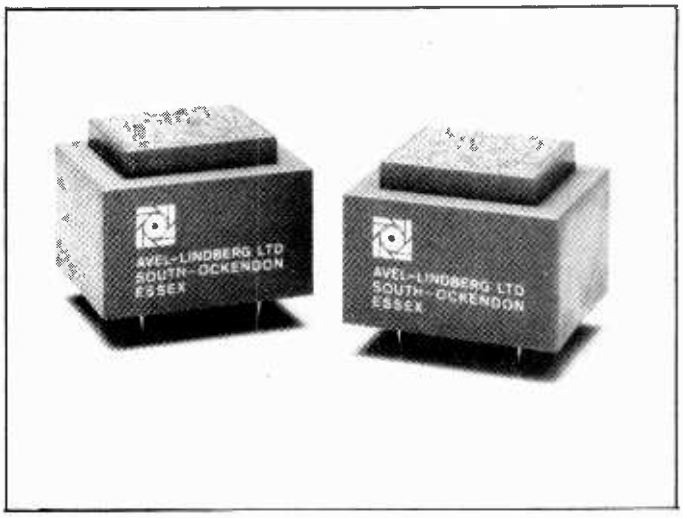
Satellite Communications — December 3/4th
Tara Hotel, London Conference which aims to cover all aspects of the subject including DBS SMATV, interactive services, navigation, broadcasting, technology transfer, etc. The cost is £465.00. Contact Online at the address below.

The Which Computer? Show — January 14-17th 1986
NEC, Birmingham. Exhibition of business computers and word processors. For details contact Cahners at the address below.

Electronics In Oil And Gas — February 4-6th 1986
Barbican, London. Exhibition and conference devoted to electronic equipment for surveying, drilling, pumping, processing and testing in the oil and gas industries. Contact Cahners at the address below.

Electronic Production Efficiency Exposition (EPEE) — March 11-13th 1986
Olympia, London. Exhibition and conference on computer aided design, manufacture and test (CADMAT) in the electronics industry. Contact Network at the address below.

Addresses:
Cahners Exhibition Ltd Chatsworth House 59 London Road, Twickenham Middlesex TW1 3SZ, tel 01-891 5051.
ICS Publishing Co (UK) Ltd 3 Swan Court, Leatherhead, Surrey KT22 8AD, tel 0372-379211.
Network Events Ltd Printers Mews, Market Hill, Buckingham MK18 1JX tel 0280-815226
Online Conferences Ltd, Pinner Green House Ash Hill Drive, Pinner, Middlesex HA5 2AE, tel 01-868 4466.



Short Circuit Proof Transformers

Avel Lindberg have introduced a range of miniature printed circuit mounting transformers which are internally protected against short circuits.

The transformers incorporate a positive temperature co-efficient thermal cut-out which breaks the primary circuit if an overload causes them to heat up. The advantage of this system then compared with conventional fuses is that the circuit will be restored as soon as the transformer has cooled sufficiently.

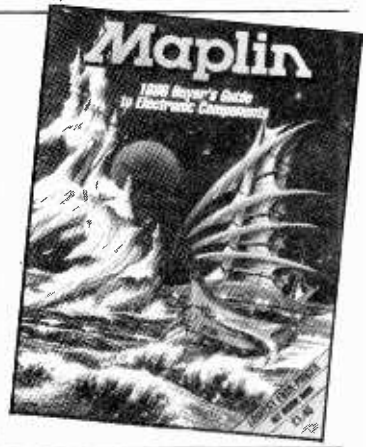
All the transformers in the range have single 240V, 50/60Hz primary windings and either one or two secondary windings. Those with single windings are rated at 1VA and are available in 6, 8, 9, 12, 15, 18 and 24V versions. The dual winding types are rated at 2VA and are available in 6, 7, 9, 12, 25 and 28V versions. The manufacturers claim that the windings can be connected in parallel as well as in series.

The overall dimensions of the transformers are 44 x 37mm x 33mm high and they are designed for direct soldering to a printed circuit board. Extra rigidity can be achieved by inserting self-tapping screws through the board and into holes moulded in the underside of the plastic case.

The transformers conform to BS415 class 2 and to the relevant IEC and VDE standars. For further details contact Avel-Lindberg Ltd. South Ockendon, Essex RM15 5TD, tel 0708-53444.

New Maplin Catalogue

Due out soon is the 1986 Buyer' Guide to Electronic Components from Maplin. It will contain details of a wide range of electronic components and, as our picture shows, carries the sort of cover illustration we have come to expect from Maplin. It will be available from high street newsagents for £1.45 or by post for £1.85 direct from Maplin Electronic Supplies Ltd, PO Box 3, Rayleigh, Essex SS6 8LR tel 0702 — 552911.



After 29 years, Quad have announced that they are ceasing production of their famous Electrostatic loudspeaker, the ESL. Some 54,000 have been built since they were first demonstrated in 1956 and Quad claim that just about every loudspeaker manufacturer, reviewer and serious recording studio has used them at some time and that many still do. They were suceeded a few years ago by the ESL 63, but Quad say that parts for the original ESL will continue to be available until the year 2,000

● Cosser have published a 12-page full colour brochure which describes their capabilities in fibre optics and optical signal processing. Copies are available from the Publicity Department, Cossor Electronics Ltd, The Pinnacles, Harlow, Essex CM19 5BB, tel 0279 - 26862.

ETI

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01-208 1177 TECHNOMATIC LTD 01-208 1177

BBC Micro Computer System

ACORN COMPUTER SYSTEMS
BBC Model B Special offer ..... £299 (a)
BBC Model B+Econet ..... £335 (a)
BBC Model B+DFS ..... £346 (a)
BBC Model B+DFS +Econet ..... £399 (a)
BBC B Plus ..... £409 (a)

UPGRADE KITS
DFS Kit ..... £80 (d)
Econet Kit ..... £55 (d)
1770 DFS Kit ..... £49 (d)
ADFS ROM ..... £29 (d)

ACORN ADD-ON PRODUCTS
Z80 2nd Processor ..... £348 (a)
6502 2nd Processor ..... £175 (a)
Teltext Adaptor ..... £190 (b)
IEEE Interface ..... £282 (b)
Music 500 ..... £173 (b)
RH Light pen ..... £29 (c)

BBC FIRMWARE
Basic II ROM ..... £22.50 (d)
View 12.1 Word Processor ROM ..... £48.00 (c)
Wordwise Plus ..... £49.00 (d)
BCPL ROM/Disc ..... £52.00 (b)
Disc Doctor/Gremlin Debug ROM £26 (d)
EXMON/TOOL KIT ROM ..... £23 ea (d)
Printmaster (FX80)/Graphics ..... £28 ea (d)
ULTRACALC spreadsheet ROM £50 ea (c)
VIEW STORE/VIEW SHEET ..... £52 ea (c)
ISO PASCAL/LOGO ..... £60 ea (c)
Oxford PASCAL/G-FORTH/LISP ROM ..... £43 ea (c)
ACCELERATOR (BASIC Compiler) ..... £56 (c)

COMMUNICATION ROM
Termi II ..... £26 (d)
Communicator ..... £57 (d)
Commstar ..... £27 (d)
DATABEEB ..... £25 (d)

TORCH UNICORN products including the IBM Compatible GRADUATE in stock
For detailed specification on any of the BBC Firmware/Peripherals listed here or information on our complete range please write to us.

DISC DRIVES

These are fully cases and wired drives with slim line high quality mechanisms. Drives supplied with cables manuals and formatting disc suitable for the BBC computer. All 80 track drives are supplied with 40/80 track switching as standard. All drives can operate in single or dual density format.

Single Drives:
1 x 100K 40T SS :TS100 ..... £79(b)
1 x 400K 40/80T DS :T400 ..... £85(b)

Dual Drives: (with integral psu)
Stacked Version:
PD200 2 x 100K 40T SS ..... £179 (a)
PD800 2 x 400K 80/40T DS ..... £235 (a)

With integral psu:
PS100 with psu ..... £99 (b)
PS400 ..... £105 (b)

Plinth Versions:
PD200 ..... £205 (a)
PD800P ..... £260 (a)

3.5" Drives
TS35 1 x 400K 80T DS ..... £99(b)
TD35 2 x 400K 80T DS ..... £175 (b)

3M FLOPPY DISCS

High quality discs that offer a reliable error free performance for life. Each disc is individually tested and guaranteed for life. Ten discs are supplied in a sturdy cardboard box.

5¼" DISCS		3½" DISCS
40 SS DD £13 (c)	40T DS DD £18 (c)	80T SS DD £39 (c)
80T SS DD £22 (c)	80T SS DD £24 (c)	80T DS DD £38 (d)

DRIVE ACCESSORIES

FLOPPICLENE Disc Head Cleaning Kit with 20 disposable cleaning discs ensures continued optimum performance of the drives ..... £14.50 (c)
Single Disc Cable ..... £6 (d)
Dual Disc Cable ..... £8.50 (d)
10 Disc Library Case ..... £1.80(c)
b0130 Disc Case ..... £6 (c)
40 Disc Lockable Box ..... £14 (c)
100 Disc Lockable Box ..... £19 (c)

PRINTERS

EPSON
RX80T+ £210 (a)
LX80 the new NLQ printer £219 (a)
FX80T £315 (a) RX100+ £345 (a)
FX100 £430 (a)
JX80 4 Colour Printer £429 (a)
HI80 4 Colour Plotter £375 (a)

KAGA TAXAN:
KP810 £235 (a) KP910 £339 (a)

DAISY WHEELS:
JUKI 6100 £295 (a)
BROTHER HR15 £315 (a)

Paper:
2000 Sheets Fanfold:
9.5" x 11" £13 (b)
14.5" x 11" £17.50 (b)
Labels: (per 1000)
3.5" x 17/16" Single row £5.25(d)
27/16" x 17/16" Triple row £5.00 (d)

ACCESSORIES

EPSON
32K Internal Buffer Parallel £75 (b)
Serial Interface: 8143 £28 (c);
8148 with 2K £59 (c)
Paper Roll Holder £17 (d);
FX80 Tractor Attachment £37 (c)
Ribbons: FX/RX/MX80 £5 (d)
FX/RX/MX100 £10 (d)
RX/FX80 Dust Cover £4.50 (d)

KAGA TAXAN
RS232 with 2K Buffer £85 (c)
KP810/910 Ribbon £6.00 (d)

JUKI 6100
RS232 with 2K Buffer £65 (c)
Ribbon £2.50 (d)
Tractor Attachment £129 (a)
Sheet Feeder £180 (a)
BBC Parallel Lead £7 (d)
Serial Lead £7 (d)

BROTHER HR15
Sheet Feeder £199 (a)
Tractor Feed £99 (a)
Ribbons Carbon or Nylon £4.50 (a)

MONITORS

MICROVITEC 14" RGB:
1431 Standard Resolution ..... £190 (a)
1451 Medium Resolution ..... £240 (a)
1441 Hi Resolution ..... £395 (a)
1431 AP Std Res PAL/AUDIO ..... £205 (a)
1451 AP Med Res PAL/AUDIO ..... £280 (a)
1451 DQ3 Med Res for QL ..... £239 (a)
1456 DI — IBM Compatible RGB Monitor ..... £395 (a)
MITSUBISHI 14" Med Res. IBM/BBC Compatible RGB ..... £299 (a)
Above monitors are now available in plastic or metal cases.
KAGA Super Hi Res Vision III RGB ..... £325 (a)
Hi Res Vision II ..... £225 (a)

MONOCHROME MONITORS 12":
Kaga Green KX1201 G Hi Res ..... £99 (a)
Kaga Amber KX1201 A Hi Res ..... £105 (a)
Sanyo Green DM8112CX Hi Res ..... £90 (a)
Swivel Stand for Kaga Monochrome ..... £21 (c)

MODEMS

— All modems listed below are BT approved

MIRACLE WS2000:
The ultimate world standard modem coverall all common CCITT standards (BELL standards outside the UK) up to 1200 Baud. Allows communication with virtually any computer system in the world. The optional AUTO DIAL and AUTO ANSWER boards enhance the considerable facialities already provided on the modem. Mains powered £129(b). Auto Dial Board/Auto Answer Board £30(c) each. (awaiting BT approval) Software lead £4.50.

NEW WS3000 SERIES
WS3000 V2123 (V21E V23) £295 (a)
WS3000 V22 (as above plus 1200 baud fall duplex £495 (a)
Ask for details on WS3000

BUZZ BOX:
This pocket sized modem complies with V21 300/300 Baud and provides an ideal solution for communications between users, with main frame computers and bulletin boards at a very economic cost. Battery or mains operated, £62(c). Mains adaptor £8(d).
BBC to Modem data lead £7.

SPECIAL OFFER

2764-25 ..... £2.40
27128-25 ..... £2.90
6264LP-15 ..... £4.50

ATTENTION

All prices in this double page advertisement are subject to change without notice.

ALL PRICES EXCLUDE VAT
Please add carriage 50p unless indicated as follows:
(a) £8 (b) £2.50 (c) £1.50 (d) £1.00

GANG OF EIGHT

INTELLIGENT FAST EPROM COPIER

Copies up to eight eproms at a time and accepts all single rail eproms up to 27256. Can reduce programming time by 80% by using manufacturer's suggested algorithms. Fixed Vpp of 21 & 25 volts and variable Vpp factory set at 12.5 volts. LCD display with alpha moving message. £395(b).

SOFTY II

This low cost intelligent eprom programmer can program 2716, 2516, 2532, 2732, and with an adaptor, 2564 and 2764. Displays 512 byte page on TV — has a serial and parallel I/O routines. Can be used as an emulator, cassette interface.
Softy II ..... £195(b)
Adaptor for 2764/2564. £25.00(c)

UV ERASERS

All erasers with built in safety switch and mains indicator.
UV1B erases up to 6 eproms at a time. ... £47(c)
UV1T as above but with a timer ..... £59(c)
UV140 erases up to 14 eproms at a time. £71 (b)
UV141 as above but with a timer. ..... £88 (b)

CONNECTOR SYSTEMS

I.D. CONNECTORS

(Speedblock Type)

No of ways	Header Plug	Receptacle	Edge Conn.
10	90p	85p	120p
20	145p	125p	195p
26	175p	150p	240p
34	200p	160p	320p
40	220p	190p	340p
50	235p	200p	390p

D CONNECTORS

No of Ways	9	15	25	37
MALE:				
Ang Pins	120	180	230	350
Solder	60	85	125	170
IDC	175	275	325	-
FEMALE:				
St Pin	100	140	210	380
Ang pins	160	210	275	440
Solder	90	130	195	290
IDC	195	325	375	-
St Hood	90	95	100	120
Screw Lock	130	150	175	-

TEXTOOL ZIF

SOCKETS 24-pin £7.50
28-pin £9.00 40-pin £12

EDGE CONNECTORS

	0.1"	0.156"
2 x 6-way (commodore)	—	300p
2 x 10-way	150p	—
2 x 12-way (vic 20)	—	350p
2 x 18-way	—	140p
2 x 23-way (ZX81)	175p	220p
2 x 25-way	225p	220p
2 x 28-way (Spectrum)	200p	—
2 x 36-way	250p	—
1 x 43-way	260p	—
2 x 22-way	190p	—
2 x 43-way	395p	—
1 x 77-way	400p	500p
2 x 50-way(S100conn)	600p	—

EURO CONNECTORS

DIN 41612	Plug	Socket
2 x 32 way St Pin	230p	275p
2 x 32 way Ang Pin	275p	320p
3 x 32 way St Pin	260p	300p
3 x 32 way Ang Pin	375p	400p
IDC Skt A + B		400p
IDC Skt A + C		400p

For 2 x 32 way please specify spacing (A + B, A + C).

MISC CONNS

21 pin Scart Connector 200p
8 pin Video Connector 200p

AMPHENOL CONNECTORS

	Solder	ZDC
36 way plug	500p	475p
36 way skt	550p	500p
24 way plug IEEE	475p	475p
24 way skt IEEE	500p	500p

PCB Mtg Skt Ang Pin
24 way 700p 36way 750p

GENDER CHANGERS 25 way D type

Male to Male £10
Male to Female £10
Female to Female £10

RS 232 JUMPERS

(25 way D)

24" Single end Male	£5.00
24" Single end Female	£5.25
24" Female Female	£10.00
24" Male Male	£9.50
24" Male Female	£9.50

DIL SWITCHES

4-way 90p 6-way 105p
8-way 120p 10-way 150p

RIBBON CABLE

(grey/metre)

10-way	40p	34-way	160p
16-way	60p	40-way	180p
20-way	85p	50-way	200p
26-way	120p	64-way	280p

DIL HEADERS

	Solder	IDC
14 pin	40p	100p
16 pin	50p	110p
18 pin	60p	-
20 pin	75p	-
24 pin	100p	150p
28 pin	160p	200p
40 pin	200p	225p

TECHNOLINE VIEWDATA SYSTEM

Using 'Prestel' type protocols for information and orders phone 01-450 9764. 24 hour service, 7 days a week.

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74 SERIES

7400	30p	74181	340p	74LS162A	75p	74S08	50p	4063	85p
7401	30p	74182	140p	74LS163A	75p	74S10	50p	4066	40p
7402	30p	74184	180p	74LS164	75p	74S11	75p	4067	230p
7403	30p	74185A	180p	74LS165A	110p	74S20	50p	4068	25p
7404	36p	74190	130p	74LS166A	150p	74S22	50p	4069	24p
7405	30p	74191	130p	74LS168	130p	74S30	50p	4070	24p
7406	40p	74192	110p	74LS169	100p	74S32	50p	4071	24p
7407	40p	74193	115p	74LS170	140p	74S37	50p	4072	24p
7408	30p	74194	110p	74LS173A	100p	74S38	60p	4073	24p
7409	30p	74195	80p	74LS174	75p	74S40	50p	4075	24p
7410	30p	74196	130p	74LS175	75p	74S51	45p	4076	65p
7411	30p	74197	110p	74LS181	200p	74S64	45p	4077	25p
7412	30p	74198	220p	74LS183	190p	74S74	70p	4078	25p
7413	50p	74199	220p	74LS190	75p	74S85	300p	4081	24p
7414	70p	74221	110p	74LS191	75p	74S86	100p	4082	25p
7416	36p	74251	100p	74LS192	80p	74S112	150p	4085	60p
7417	40p	74259	150p	74LS193	80p	74S113	120p	4086	75p
7420	30p	74265	380p	74LS194A	75p	74S114	120p	4089	120p
7421	60p	74273	200p	74LS195A	75p	74S124	300p	4093	35p
7422	36p	74276	140p	74LS196	80p	74S132	100p	4094	90p
7423	36p	74278	170p	74LS197	80p	74S133	60p	4095	90p
7425	40p	74279	90p	74LS221	90p	74S138	180p	4096	90p
7426	40p	74283	105p	74LS240	80p	74S138	180p	4097	270p
7427	40p	74285	320p	74LS241	80p	74S139	180p	4098	75p
7428	43p	74290	90p	74LS242	90p	74S140	100p	4099	90p
7430	30p	74293	90p	74LS243	90p	74S151	150p	4501	36p
7432	36p	74298	180p	74LS244	80p	74S153	150p	4502	55p
7433	30p	74351	200p	74LS245	110p	74S157	200p	4503	36p
7437	30p	74365A	80p	74LS247	110p	74S158	200p	4504	95p
7438	40p	74366A	80p	74LS248	110p	74S163	300p	4505	380p
7439	40p	74367A	80p	74LS249	110p	74S169	550p	4506	90p
7440	40p	74368A	70p	74LS251	75p	74S174	300p	4507/4030	
7441	90p	74376	160p	74LS253	75p	74S175	320p		35p
7442A	70p	74390	110p	74LS256	90p	74S188	180p	4508	120p
7443A	100p	74393	112p	74LS257A	70p	74S189	180p	4510	55p
7444	110p	74490	140p	74LS258A	70p	74S194	300p	4511	55p
7445	100p	**74LS SERIES**		74LS260	75p	74S195	300p	4512	55p
7446A	100p			74LS261	120p	74S196	350p	4513	150p
7447A	100p	74LS00	24p	74LS266	60p	74S200	450p	4514	110p
7448	120p	74LS01	24p	74LS273	125p	74S201	320p	4515	110p
7450	36p	74LS02	24p	74LS279	70p	74S225	520p	4516	55p
7451	35p	74LS03	24p	74LS280	190p	74S240	400p	4517	220p
7453	38p	74LS04	24p	74LS283	80p	74S241	400p	4518	48p
7454	38p	74LS05	24p	74LS290	80p	74S244	500p	4519	32p
7460	55p	74LS08	24p	74LS292	900p	74S251	250p	4520	60p
7470	50p	74LS09	24p	74LS293	80p	74S257	250p	4521	115p
7472	55p	74LS10	24p	74LS295	140p	74S258	250p	4522	80p
7473	55p	74LS11	24p	74LS297	£8	74S260	100p	4526	70p
7474	50p	74LS12	24p	74LS298	100p	74S261	300p	4527	80p
7475	60p	74LS13	34p	74LS299	220p	74S283	270p	4528	65p
7476	45p	74LS14	50p	74LS321	370p	74S287	225p	4529	100p
7480	65p	74LS15	24p	74LS323	300p	74S288	200p	4531	75p
7481	180p	74LS20	24p	74LS324	320p	74S289	225p	4532	65p
7483A	105p	74LS21	24p	74LS348	200p	74S299	550p	4534	380p
7484A	125p	74LS22	24p	74LS352	120p	74S373	400p	4536	250p
7485	110p	74LS24	50p	74LS353	120p	74S374	400p	4538	75p
7486	42p	74LS26	24p	74LS356	210p	74S387	225p	4539	75p
7489	210p	74LS27	24p	74LS363	180p			4541	90p
7490A	55p	74LS28	24p	74LS364	180p	[illegible]		4543	70p
7491	70p	74LS30	24p	74LS365	50p			4551	100p
7492A	70p	74LS32	24p	74LS366	50p	4000	20p	4553	240p
7493A	55p	74LS33	24p	74LS367	50p	4001	24p	4555	36p
7494	110p	74LS37	24p	74LS368A	50p	4002	25p	4556	50p
7495A	80p	74LS38	24p	74LS373	90p	4006	70p	4557	240p
7496	80p	74LS40	24p	74LS374	90p	4007	25p	4560	140p
7497	210p	74LS42	50p	74LS375	75p	4008	50p	4566	140p
74100	190p	74LS43	150p	74LS377	130p	4009	45p	4568	240p
74107	50p	74LS47	80p	74LS378	95p	4010	60p	4569	170p
74109	75p	74LS48	90p	74LS379	130p	4011	24p	4572	45p
74110	75p	74LS49	100p	74LS381	450p	4012	25p	4583	90p
74111	55p	74LS51	24p	74LS385	325p	4013	36p	4584	48p
74116	170p	74LS54	24p	74LS390	60p	4014	60p	4585	60p
74118	110p	74LS55	24p	74LS393	100p	4015	70p	4724	150p
74119	170p	74LS73A	30p	74LS395A	100p	4016	36p	14411	750p
74120	100p	74LS74A	35p	74LS399	140p	4017	55p	14412	750p
74121	55p	74LS75	45p	74LS445	180p	4018	60p	14416	300p
74122	70p	74LS76A	36p	74LS465	120p	4019	60p	14419	260p
74123	80p	74LS83A	70p	74LS467	120p	4020	80p	14490	420p
74125	65p	74LS85	75p	74LS490	150p	4021	60p	14495	450p
74126	55p	74LS86	35p	74LS540	100p	4022	70p	14500	650p
74128	55p	74LS90	48p	74LS541	100p	4023	30p	14599	200p
74132	75p	74LS91	90p	74LS608	700p	4024	48p	22100	350p
74136	70p	74LS92	55p	74LS610	1900p	4025	24p	22101	700p
74141	90p	74LS93	54p	74LS612	1900p	4026	90p	22102	700p
74142	250p	74LS95B	75p	74LS624	350p	4027	40p	40014/4584	
74143	270p	74LS96	90p	74LS626	225p	4028	60p	40106	48p
74144	270p	74LS107	40p	74LS628	225p	4029	75p	40085	120p
74145	110p	74LS109	40p	74LS629	125p	4030	35p	40097	36p
74147	170p	74LS112	45p	74LS640-1	200p	4031	125p	40098	40p
74148	140p	74LS113	45p		300p	4032	100p	40100	150p
74150	175p	74LS114	45p	74LS641	150p	4033	125p	40101	125p
74151A	70p	74LS122	70p	74LS642-1		4034	250p	40102	130p
74153	80p	74LS123	80p		300p	4035	70p	40103	200p
74154	140p	74LS124/		74LS643	250p	4036	70p	40104	120p
74155	80p	629/140p		74LS643-1		4037	110p	40105	150p
74156	100p	74LS125	50p		300p	4038	100p	40106	48p
74157	80p	74LS126	50p	74LS644	350p	4039	260p	40107	55p
74159	175p	74LS132	65p	74LS645	200p	4040	60p	40108	320p
74160	110p	74LS133	50p	74LS645-1		4041	55p	40109	20p
74161	80p	74LS136	45p		400p	4042	50p	40110	225p
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74164	120p	74LS145	95p	74LS670	170p	4045	100p	40163	100p
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74175	105p	74LS156	65p			4053	60p	40257	180p
74176	100p	74LS157	50p	74S00	50p	4504	80p	40373	180p
74178	150p	74LS158	65p	74S02	50p	4055	80p	40374	180p
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75115	140p
75121	140p
75122	140p
75150P	120p
75154	220p
75159	220p
75160	500p
75161	350p
75162	400p
75172	300p
75182	90p
75188	60p
75189	60p
75365	150p
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75453	70p
75454	70p
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75492	85p
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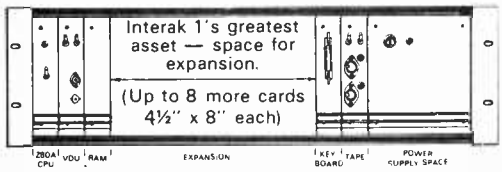

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6. 'Here's the pitch,' said the prof., feeling alright,
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SUPER COMPETITION

In conjunction with Thandar Electronics, ETI is offering three superb frequency meters as prizes in this simple to enter competition.

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The first prize will be awarded to the person who gets all the answers correct and, in the event of a tie, provides the wittiest phrase. The two second prizes will be awarded to the runners-up. If no completely correct answers are received, the prizes will be awarded on a points basis — 2 points for each correctly answered quiz question and one point for providing the correct seven-letter word. Employees of Argus Specialist Publications and Thandar Electronics or their relatives are not eligible for the competition. The competition judges will be Gary Herman (ETI) and Tony Starling (Thandar) and the results will be announced in the January 1986 issue of ETI, on sale on December 6th, 1985.

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READ/WRITE

Silly Old Buffer

Dear ETI,

I feel that I must object to your inclusion of a particular addendum in the service sheet section of the September issue, It concerns the use of the TMS4416 dynamic RAMS in my printer buffer project which was published in the July and August issues.

While it is true that the Z80 will only provide seven bits of refresh, it is possible to use software to simulate the use of all eight bits. Two methods are commonly used:
1) Regularly toggle bit 7 of the refresh register.
2) Execute continuous op-codes located between XX80 and XXF0 in the memory map, at least once every 4mS.

Either of these methods will provide satisfactory refresh for the TMS4416 and the second is, in fact, incorporated in the design of the printer buffer. The use of the Hitachi IC mentioned is definitely not required.

I did not mention this aspect of the refresh mechanism in the original article, but I do feel I should have been consulted before publication of this erroneous addendum. My thanks for this opportunity to set the record straight.

Yours faithfully,
Nick Sawyer,
London N13.

Literary Sources

Dear Sir,

I was not surprised to learn from a letter in your magazine that Motorola are not very helpful (Read/Write, ETI September 1985). I also have had no reply from them when I asked for some literature. But I wrote to STC Electronics Services, Edinburgh Way, Harlow, Essex CM20 2DF who were very helpful and sent about twelve data sheets, all Motorola. I can also recommend Gothic Crellon, 380 Bath Road, Slough, Berkshire SL1 6JE who have been very helpful.

Yours faithfully
P.D. Yates
Chelmsford

Goth, ic's eaSy To C that Motorola aren't terribly interested in the home constructor. — Ed.

Fine Print

Dear Editor,

I thought I'd drop you this line after reading my August copy of ETI.

I use a BBC-B computer, Wordwise and an EX42 typewriter as a printer. The interface allowing me the printer mode came from ETI October 1983. I have had no trouble with it since setting it up.

As a writer my unit is in constant use and not to print listings! Over the last couple of days I have down loaded around twenty thousand words to the EX42 . . . no problem.

The only complaint I have about the system is speed. I find 10cps too slow for my needs so I will soon be buying a printer. As the system stands at the moment it is completely trouble free, so I have no complaints with it or the interface. Thus it did surprise me a little to see in the August issue an 'EX42 Interface for the BBC'B'.

*When using Wordwise all one need do to get 'CT' is to direct command *FX6 when in the WW edit mode.*

This letter is produced using Wordwise, the EX42 and your interface. . . .OK!

Yours sincerely
J.M. Stevenson
Brentwood

First someone calls us 'reputable', now a reader says he's actually persuaded one of our projects to work! Where will it all end?

The original interface was designed for use with the Microtan 65, but many of our readers wanted to use it with a BBC B or other microcomputer. It is quite possible to re-write the software to provide the necessary control signals for other machines, but apparently some people aren't quite sure how to go about it. Hence the dedicated BBC B version. However, it's good to hear that someone has got the original version to work with a Beeb. — Ed.

AUNTIE STATIC'S PROBLEM CORNER

Dear Auntie,

I have often wondered why 2's complement arithmetic works in binary but not with ordinary numbers. I don't expect you will know the answer.

S. Lister,
Salisbury.

Since you have the bloomin' cheek to question Auntie's omniscience, I don't think you deserve an answer at all. However, being a kind and understanding Auntie and since I don't get paid unless I answer a question or two, I'll overlook it just this once.

Two's complement arithmetic obviously doesn't work for decimals because you can't form the 2's complement of a decimal (ordinary?) number. However, you can form the 10's complement by subtracting each digit of the number from 9, and then adding 1 to the final result, so −1111 would become 8889, −2634 would become 7366, and so on.

Suppose you are faced with the horrible prospect of doing a subtraction having just discovered that your calculator batteries are flat. 7342–4186= ????? You don't want to get involved with all the nursery school business of borrowing and such like, so what do you do? Faint? Break out in a cold sweat? Go and change your library book? No! With dignity and poise you scribble all over the second number and replace it with its 10's complement equivalent so you are left with: 7342+5814= ????? This is nowhere near as complicated as having to do a subtraction, and with your family and friends looking on in admiration you skillfully add the numbers together to give 13156.

At this point you realise that your answer can't possibly be right because its bigger than the number you started with. Don't panic! Just keep your thumb over the initial 1 and show your answer with a flourish: 3156. When you get used to this method you can avoid getting an inky thumb by starting your addition as close as possible to the left hand side of the paper. The extra 1 will then overflow onto the tablecloth and you can quickly slide your paper over to cover it up.

The only thing to remember is that if you are faced with something like 37373737−66, where the numbers are not both the same length, you must put a load of 9s in front of your 10's complement number until they are the same length. In this case you will end up with: 27272727+99999934 = THUMB3737671 (by the beginners' thumb method). Oh yes, and if the number you are subtracting is bigger than the one you're taking it away from, the answer will be in 10's complement form. For more advanced students there are also Chinese subtractions, or takeaways, but these are outside the scope of this reply. — Auntie.

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SURFACE ACOUSTIC WAVES

Does your knowledge of SAW devices need sharpening up? Andy Armstrong looks at the cutting edge of the new technology.

Filters, resonators and delay lines are essential elements in a wide range of electronic equipment and a great deal of time and effort has been devoted to improving them, either by perfecting existing techniques or developing new ones. Filters and resonators have traditionally relied upon the frequency-selective properties of reactive networks and much has been written about the best ways of combining reactive components (capacitors, inductors and crystals) to obtain the desired results. Delays produced by passing the signal from a transmitting transducer to a receiving transducer and placing between them some substance which slows down the passage of the wave. Examples range from the glass block and piezo-electric transducers used in television receivers to the coil-spring and magnetic transducers used in some audio effects units.

These techniques remained largely unchanged until the development of the field effect transistor (FET) with its excellent switching characteristics, and the introduction of integrated circuitry which made it possible to build circuits of previously unimaginable complexity. The devices which resulted were the switched capacitor filter and the bucket brigade delay line, or charge couped device (CCD), both of which use linear circuit elements controlled by electronic switching. The advantages in each case include greater flexibility: the break frequency of the filter and the delay period of the bucket brigade device can both be altered simply by changing the frequency of the external clock.

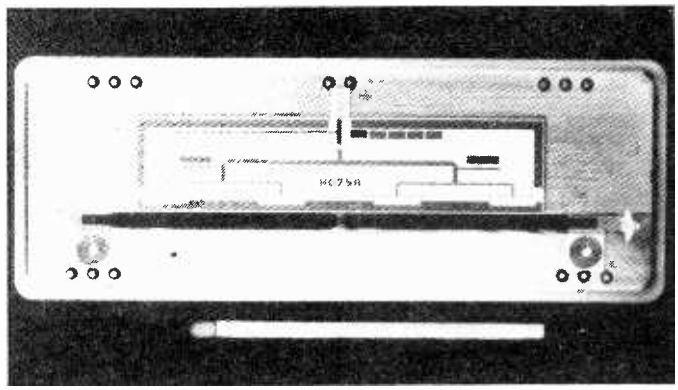
The development of complex digital integrated circuits has taken this flexibility several stages further. It is now possible to convert an analogue signal into digital form and then carry out a wide range of filtering operations, if necessary under software control so that the parameters can readily be changed to meet specific requirements. Delay can be obtained simply by using readily-available memory chips, allowing longer periods to be achieved without attendant degradation of the signal. Unlike linear systems, in which phase and frequency are heavily interdependent and it is not easy to design for one without affecting the other, digital filtering allows many different parameters to be specified to a high level of accuracy.

The last few years have seen the emergence of another new signal processing technology which combines many of the advantages of linear and digital techniques. Surface Acoustic Wave (SAW) devices use a tiny transducer to launch a wave across the surface of a piezo-electric crystal and another transducer to pick the wave up again. In this respect they are not unlike conventional glass delay lines, but the crucial difference is that the behaviour of the wave can be modified by the use of complex transducers which work, in effect, as multiple taps on the delay line. The result is a filter whose characteristics can be controlled almost as well as can those of a digital system but which can be produced at a fraction of the cost.

The Nature Of The Wave

Before going any further, we shall look at what a surface acoustic wave actually is and how they are generated.

The easiest way to understand what is involved is to consider a very simple crystal structure — a cubic lattice with identical atoms at each vertex. An ordinary wave set up in the structure simply involves compression and rarefaction of the atoms forming the structure. To put it crudely, one could imagine the little model atoms bouncing back and forth on their springs. The atoms are fairly stiffly supported, being anchored by six bonds. This type of wave is called a *bulk* wave, and is of the type generated in conventional glass delay lines.



A SAW convolver manufacturered by Siemens. The lithium niobate SAW chip is the thin, dark strip in the lower half of the case and the reminder of the area is occupied with matching elements.

A *surface* wave, on the other hand, involves atoms on the surface swinging about in an arc rather than a straight line. Atoms on a face of the crystal are less firmly anchored, with only five bonds attached, so the

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propagation speed of a surface wave is lower than that of a bulk wave. This means that a surface wave is confined to the surface, and does not tend to excite bulk waves. It is possible to launch bulk waves when trying to launch surface waves, and vice-versa, but they are different entities and there is limited interchange between the two. The rate of propagation of these acoustic waves is very much less than that of electromagnetic waves, so a relatively long delay line may be made in a small space.

Surface acoustic wave devices are made on crystals of particular types, the main ones being quartz, lithium niobate, and lithium tantalate, all of which are piezoelectric crystals. This is essential, because the transducers which launch the wave consist of interleaved strips or fingers of metalisation which are energised with an electrical signal to excite a piezoelectric response and hence launch a wave.

Figure 1 shows the layout of a typical SAW filter. The transducers are symmetrical, so acoustic waves are radiated in both directions. The acoustic absorber on the far side is there to prevent the reverse wave from either propagating around the crystal or being

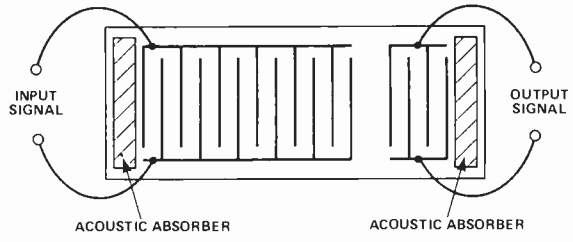

Fig. 1 The layout of a typical SAW filter. The two transducers consist of a number of fingers of metallisation on the surface of the crystal.

reflected from the edge. Either event would interfere mightily with the intended function of the device. Similar reasoning applies to the presence of the absorber behind the receiving transducer.

In this simple example, the waves launched by each pair of fingers in the transducer may either reinforce or cancel the waves from other pairs, depending on the acoustic wavelength. The even spacing of the fingers shown would give rise to a flat-topped filter response.

LC filters can provide a good approximation to any reasonable amplitude response characteristic, but the resulting phase response is likely to be less than ideal. An enormous complexity is required to achieve a particular phase response as well, and it is normally quite impractical. A SAW filter, on the other hand, can meet this kind of requirement because phase and amplitude response may be determined separately.

The example in Figure 1 shows a transducer which has evenly spaced, fully overlapping fingers. The spacing may be varied to adjust the phase response, and the degree of overlap may be varied to control the intensity of the wave. Figure 2 shows a Sin(x)/x transducer which will give a bandpass response showing some resemblance to the square response beloved of textbook writers. Real transducer patterns have many more fingers, of course.

The method used to design SAW filters is clearly quite unlike that used for LC filters. SAW filters are normally of a type described as transversal filters, which is a fancy way to describe the process of

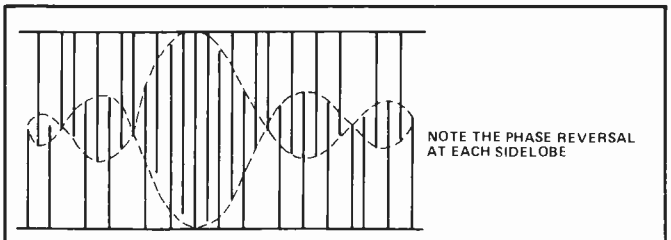

Fig. 2 Simplified view of a transducer arranged to give a sin(x)/X characteristic.

producing a desired output by adding many signals tapped from a delay line. CCD filters also work on this principle, and another technology which lends itself to this method is digital filtering.

It is interesting to compare digital and SAW devices when used for signal processing rather than filtering. In digital terms, the accuracy of a SAW device would be perhaps five bits, but the processing speed is two orders of magnitude faster than that of any digital IC currently in use or under development. There are applications which use digital and SAW technologies together to give the best of both worlds, but such applications are a specialised topic on their own.

Real Devices

So far, all that I have said about SAW devices sounds almost too good to be true, but there are some drawbacks. A look at some device configurations will help us understand the problems and their effects on the functioning of SAW devices.

One annoying phenomenon is signal coupling via bulk waves. While the method of excitation is designed to produce surface waves, bulk waves can be launched at frequencies outside the passband. If a bulk wave is launched at a particular angle to the surface of the crystal, the wavelength at which the

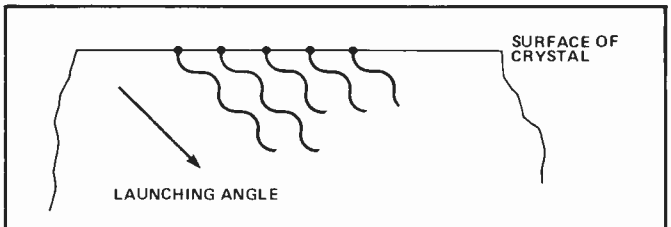

Fig. 3 Although the method of excitation is desired to produce surface waves, bulk waves are also generated and if launched at certain angles to the surface of the crystal they may reinforce and give rise to a response out of the normal passband of the filter.

signals from the transducer fingers are in phase and will produce a strong wave is different from that for surface waves. If this wave reaches the receiving transducer, a response out of the normal passband will be generated. The angle between the direction of propagation of this wave and the plane of the transducers affects things in much the same way as coloured light is split by a diffraction grating. This effect is illustrated in Fig. 3.

To cause problems, the bulk wave launched by the transmitting transducer must be reflected back from the bottom face of the crystal to the receiving transducer. This effect can be minimised by roughening the bottom face of the crystal, making it as

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thin as possible, and coating the bottom with a sound absorbent glue.

A far more effective measure is to offset the transducers and couple energy between them by means of a multistrip coupler, as shown in the photograph. This idea came from the RSRE (Royal Signals Research Establishment) and is now widely used the world over. In simple terms, the coupler acts both as a receiving transducer at one end and as a transmitting transducer at the other.

Another important advantage of this coupling technique is that both transmitting and receiving transducers may be weighted to give a particular response — a process known as apodising — without an unmanageable design problem. If two apodised transducers are not offset but used directly in line, to work out the response one has to consider the effect of the wave launched by each pair of fingers in the transmitting transducer on the receiving transducer as a whole, and the effect of the overall wave pattern launched by the transmitting transducer on each pair of receiving transducer fingers. This is equivalent to the mathematical process of convolution, which is rather complicated. Offsetting the transducers simplifies things considerably.

Driving Techniques

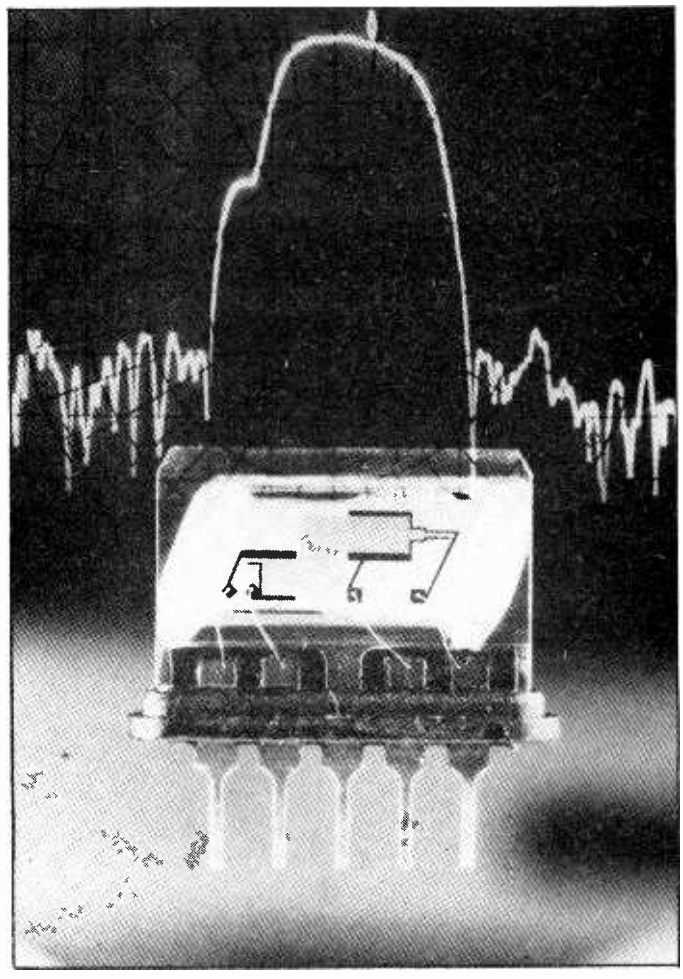
To use SAW filters it is necessary to couple signals to and from them, which is not made easier by the complex impedances of the transducers. To take a practical example, the Signal Technology BP1102 70MHz bandpass filter (2MHz bandwidth) is quoted as having input and output impedances of 6R in series with 10p. At 70 MHz, 10p has an impedance of 227R, which makes a series inductor to tune out the capacitance very desirable.

This is only the start of the problems. The BP1102 is quoted as having a 24dB insertion loss with a matching inductor. Without one it has a midband attenuation of 44dB.Unfortunately, even at 2MHz bandwidth, the use of a matching inductor can cause response ripple due to an effect called triple transit, in which the acoustic wave bounces from the receiving transducer back to the transmitting transducer and then back to the receiving transducer again.

Acoustic absorbers are used to minimise reflections from the end of the crystal, but the reflections in question here are from the actual transducers. They occur whenever there is a significant electrical load coupled to the transducers because power is drawn from any incident wave and dissipated. This inevitably disturbs the wave and causes reflections.

The transducer is in fact a three port network with a matched load on one of the ports. If an extra load is added on the electrical port, the mechanical impedance of the acoustic wave no longer matches.

One solution to this dilemma is to match the input source to the transmitting transducer, and use a high impedance input amplifier on the receiving transducer (the output of the SAW device). This means that there is little reflection from the receiving end and the effects of triple transit are small. Another solution is to drive the input of the device from a high impedance and with a high voltage signal, either by means of a step up transformer or a cascode amplifier with a high voltage power supply. This delivers plenty of power to the input while presenting an electrical mismatch.



A Siemens OFW 361 SAW filter shown without its case. Note the offset of the transducers and the use of a multistrip coupler between them. The graph in the background illustrates the performance of the filter: the centre frequency is 36.5 MHz and the scale divisions represent 10dB on the vertical axis and 2 MHz on the horizontal axis.

Material Characteristics

The BP1102 is made on a quartz substrate, ST cut (which is similar to the more familiar AT cut used for oscillator crystals), and has the advantage of almost zero temperature coefficient. In general, a given material can only offer a bandwidth which is a certain percentage of the operating frequency before the insertion loss becomes too high: for quartz this bandwidth is only a few percent.

One of the wider bandwidth filters from the same family has a 9MHz bandwidth at 72MHz, and is made on lithium niobate. It boats an insertion loss of 24dB without any electrical matching at all, but it has a temperature coefficient of –90 PPM/degree centigrade which is a characteristic of the material. The percentage bandwidth available with lithium niobate and lithium tantalate is about 40%, which might suggest that they are suitable for use as an input "roofing filter" in, for example, television receivers. Such a filter could provide a flat response over the entire television broadcast band, and about 60dB rejection outside it.

The drawback is that the loss is much too great, and the resultant noise figure would render reception

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in any but the strongest signal areas impossible. Development work aimed at low loss devices is being carried out and there are several angles from which the problem can be attacked. One of the obvious ones is to develop a transmitting transducer which launches all its energy in one direction, and a receiving one which picks up almost all the energy flowing past it.

The normal types of transducer launches the same power in each direction, so one half of the signal actually transferred to the substrate is wasted in the acoustic absorber. By the same token (because of reciprocity) the receiving transducer can pick up only one half of the incident signal power. This immediately gives a 12dB loss, even if every other aspect of the device is free of losses.

A unidirectional characteristic can be achieved by clever phasing which cancels the wave in one direction. It is difficult to prevent unwanted reflections or other response ripples when designing this type of transducer, which is why it is only used where low loss is important.

Other SAW Applications

So far we have concentrated mainly on transversal filters, but this is not the only application of SAW devices. It is also possible to produce resonators which are similar in principle to microwave resonator

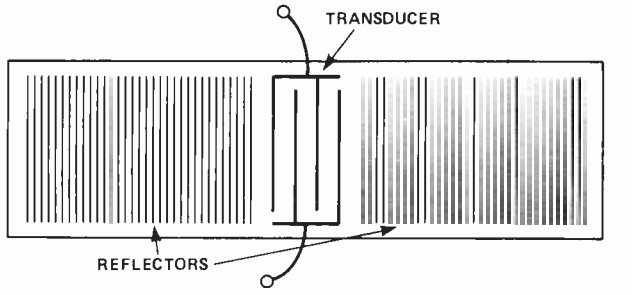

Fig. 4 A SAW device designed to act as a resonator. The reflectors on either side of the transducer consist of metallisation which are phased to suit the frequency of operation.

cavities, and if two of these are coupled a narrow bandpass filter with low insertion loss may be made. The structure of a single resonator is illustrated in Fig. 4.

The diagram shows a transducer between two reflectors. The reflectors consist of many strips, suitably phased for the frequency of operation, rather than one thick strip. If too heavy a strip is placed in the path of the wave, the mechanical impedance mismatch causes bulk waves to be launched. As it stands, this type of resonator may be used as the frequency determining element in an oscillator.

It may also be coupled electrically to another similar resonator, in which case a bandpass response can be generated similar to the response given by coupling two ordinary tuned circuits. Alternatively, two resonators may be fabricated on the same substrate and the reflector between them may be made shorter to allow coupling. The response is similar to that obtained with electrical coupling but only one substrate is used, making it preferable for large volume applications. The device layout and energy distribution is illustrated in Fig. 5. Little of the energy coupled into the input resonator is wasted, so

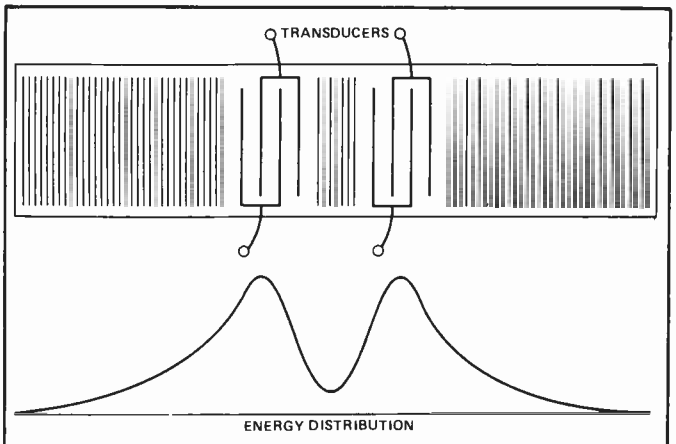

Fig. 5 Two SAW resonators fabricated on one substrate to produce a bandpass response.

a narrow bandwidth low insertion loss device may be made.

Another interesting SAW application not so far mentioned is the convolver, a device which carries out the mathematical process of convolution in real time on two input waveforms. Effectively it multiplies the two waveforms and integrates the result. In order for the multiplication to take place, the signal level must be high enough for non-lineary to occur. To achieve this, wide transducers are used to launch the waves, and they are then focussed to a narrow beam by a metalisation structure which looks like a lens. This is logical when you consider that a glass lens bends light because the light is slowed down by the glass, and that metalisation on the SAW substrate has the same effect.

To maintain a focussed beam, a metalised track is deposited. This works in a way closely analogous to that of an optical fibre in guiding the wave. The piezoelectric effect generates a voltage in this strip, which is integrated by its capacitance.

The Future

It is likely that developments in low insertion loss devices will continue, and will result in their extensive use in receiver input stags. We may eventually achieve a low enough loss to permit the use of SAW devices in input roofing filters for television reception, covering the range 40 to 800 MHz. The technology is already at the stage where an input filter having 2MHz bandwidth at a centre frequency of 900MHz and an insertion loss of 2dB is becoming practical. This would be ideal, for example, for cordless telephone applications.

If satellite TV ever turns out to be as major a development as it is cracked up to be, there will be a strong incentive for developments such as the use of a SAW resonator to make a quadature detector working at 1GHz. Along with a specially developed IC for the job, it is easy to imagine that a TV receiver head about the size of a matchbox could be developed, giving out digital signals for processing in the digital television sets now becoming available.

It is quite likely that some of the signal processing applications of SAW devices, for example in chirp radar, will gradually be taken over by higher and higher speed digital processors, but there is likely to be more than enough expansion in other applications to offset this for the forseeable future. **ETI**

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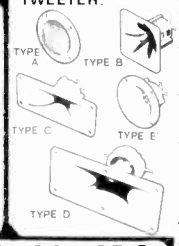

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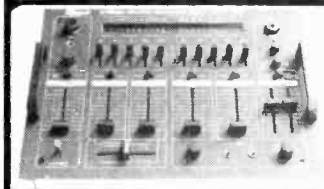

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AUTOMATIC TEST EQUIPMENT

Things will never be the same again, now that simulation testing is here. W.P. Bond elucidATEs.

The traditional approach to functional testing of digital circuits has been to use simulation techniques. The principle is simply to compare the real board or module (the unit under test or UUT) to a computer model. Input test patterns — in the form of logic highs and lows — are applied to the model and to the UUT. The computer monitors the response of the UUT and verifies it against results obtained from the model.

There are several simulator packages available. The one described here is used by Hewlett-Packard on their DTS (Digital Test Station) and is based on the Eichelberger simulator. It is table-driven, which simply means that the circuit description is held in tables. Other features of this simulator are that it is capable of handling three states (high, low and x, or unknown, states); it is fault-inserting (that is, it can simulate faults itself); and it assumes zero propagation delay. This latter may be desirable because physical circuits display different propagation delays across the board and from board to board. Zero delay is a simplying assumption. To ensure adequate testing with the zero delay assumption, the H-P simulator introduces a variable delay before the ATE comparators strobe the UUT outputs after a test pattern has been applied. The default value of this 'safeguard' delay is 4 microseconds.

This Year's Model

All chips are simulated by reference to a set of primitive model functions: AND, NAND (or NOR), XOR, AMP, INV, ROM, RAM and DELAY. For convenience, a disc-based library is kept of most standard TTL and CMOS devices, which can be called upon for use by the model and can also be updated. To construct a model circuit, a source 'Topology' file is developed. This is a description of the board to be tested, including all devices on the board, signals (or vectors) and input and output connections. The circuit in Fig. 15 was used to illustrate test points last month (Fig. 3, p.43, ETI October 1985). The following listing shows how a model is made up for this circuit:

★ **Headers** — board name, code, etc.
★ **Libraries** — TTL1, TTL2 (which call up the required tables).
★ **Networks** — used to build models of specialised chips not already included in the standard library.
★ **Main board** (5) $
★ **Inputs** PL1(1,2,3,)$
★ **Outputs** PL1(4,5,) $
★ **Packages** G1(7408) $ G2(7404) $ — types of gate used, for library reference.
★ **Gates**
G1 INP1.1 INP3.5 G2–2.(2,4) G1–3.3 G1–6.6 $
G2 1NP2.1 G2-2.2 $
PL1 INP1.1 INP2.2 INP3.3 G1–3.4 G1–6.5 $
★ **Signals** INP1 PL1-1 G1-1 $
INP2 PL1-2 G2-1 $
INP3 PL1-3 G1-5 $
G2-2 G2-2 G1-(2,4) $
G1-3 G1-3 PL1-4 $
G1-6 G1-6 PL1-5 $
★ **END**

The sections of this outline program labelled ★Headers, ★Libraries and ★Networks are self-explanatory. ★Main board indicates the total number of input/output pins used — in this case, five. The dollar sign, $, is simply a delimiter used to indicate the end of a data-block.

★Inputs, ★Outputs and ★Packages give further details of the hardware — input pins, output pins and device types.

The section labelled ★Gates gives a signal name for each pin used in each gate — INP2, for example. Where a conventional name has not been used, the name is derived from the gate and its output pins — G1-3, for example. Notice that the connector, PL1, is included as a gate, and can be given the label 'CONN', which is a primitive.

The section labelled ★Signals is optional and can be used to cross-check the ★Gates section for extra reliability. In the ★Gates section, the top line shows that pins 1, 5, 2 and 4 together, 3 and 6 of gate G1 are connected to signals INP1, INP3, G2-2, G1-3 and G1-6, respectively. In the ★Signals section, the top line

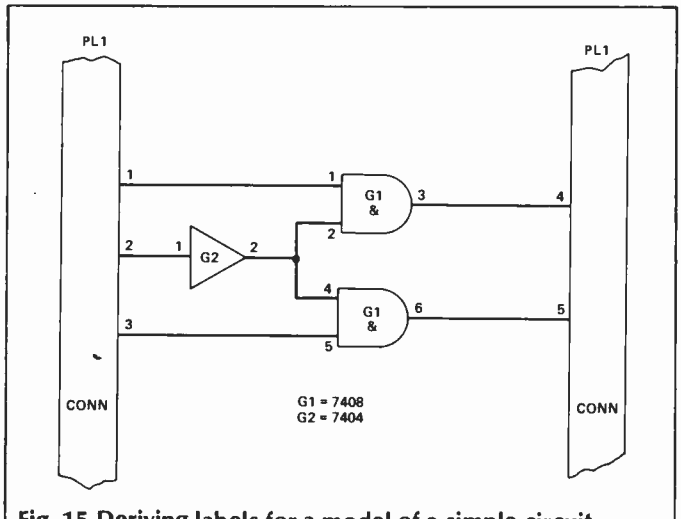

Fig. 15 Deriving labels for a model of a simple circuit.

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shows that signal INP1 runs between pin 1 of PL1 and pin 1 of G1. Note that the ★Signals section includes information on the outputs from PL1 (PL1-4 and PL1-5).

★END indicates the end of the model-program.

Under certain conditions, complex devices can behave curiously. Usually, such conditions are rare, but models should take account of all possible operating conditions. Those that don't are described as 'optimistic', while models which take even the most unusual and unexpected conditions into account are known as 'pessimistic'.

The Program Guide

When the model is finished and the source file created, several utility programs are run on it.

The first — called SGLST — checks syntax and cross-checks the ★Signal and ★Gates section, where both are used. It also translates the user Topology file into an actual software model.

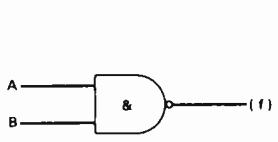
A second program — SMSET — expands the software model generated by SGLST by breaking it down into primitive elements and interconnections. It also generates a listing of numbers assigned to the I/O signals.

At this stage, the board's response to applied patterns can begin to be simulated. The patterns can be applied either manually or by means of 'Automatic Pattern Generation' (APG). (APG is sometimes expanded as 'Automatic Program Generation', when it refers to the whole process described here, up to and including pattern generation).

With 'manual patterns', the desired inputs are set up by the user and the board's behaviour is simulated by the model. Another program then monitors the response of the model. This enables the user to look at any particular device or signal on the model and assess its condition.

APG is a fairly straightforward technique to understand, and the results are comprehensive. But applying it to find or investigate faults can be very tricky.

Take the simple NAND gate in Fig. 16 as an example. The tri-state logic truth table (showing combinations of 0,1 and x-states) demonstrates that only in some cases does an x-state on an input produce an x-state at the output. Whenever an x-state propagates through a gate, the gate is said to be 'sensitive'. The two input NAND gate is sensitive when one input is at a 1. Similarly, a two-input NOR gate is sensitive when one input is at a 0.



A	B	(f)
0	0	1
0	1	1
1	0	1
1	1	0
1	X	X
0	X	1
X	1	X
X	0	1
X	X	X

Fig. 16 Truth table showing how sensitive a NAND gate is.

Using a combination of algorithmic and heuristic methods, APG sets up a sequence of test patterns in order to sensitize signal paths in the UUT. In the example shown in Fig. 17, there are three possible signal paths. Since an AND gate is sensitive whenever one input is non-zero, to sensitize each of these paths in turn it is only necessary to set-up the following sequence of test patterns on PL1, PL2 and PL3: x11, 1x1 and 11x. That is, to sensitize one path it is only necessary to hold the two inputs not included in the path at 1. If, for example, PL1.1 is stuck at 0 (SA0), setting PL1.2 and PL1.3 to 1 will reveal the the fault, since the output of the circuit will be 0 whatever the state of the sensitized path from PL1.1. This part of the test procedure is known as a 'Forward Trace Phase'.

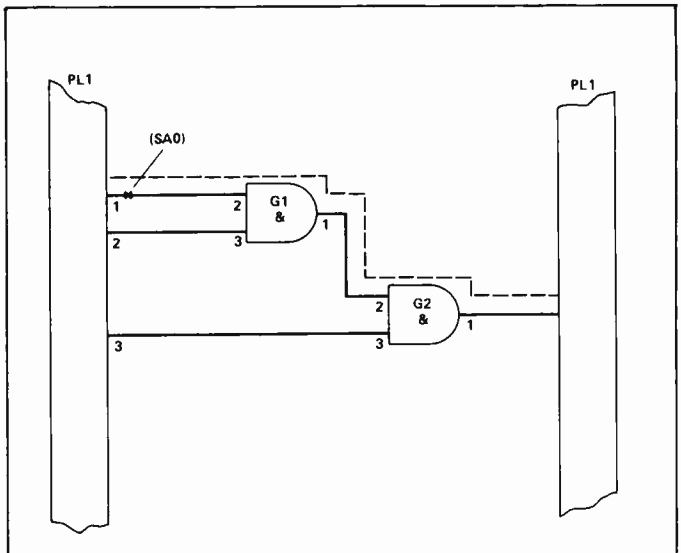


Fig. 17 Path sensitization detects a fault.

Deriving a suitable sequence of test patterns for APG is partly a matter of developing a simple algorithm to cover all possibilities and partly a matter of selecting courses of action when certain conditions apply in order to maximize the test procedure. The selection is done on a rule-of-thumb (or heuristic) basis — which is to say, by following courses of action which 'seem to be working best'. APG can be costly in terms of the number of patterns used to track down all possible faults especially if the wrong heuristics are applied. APG is an effective and useful technique if it is only required to test for the presence or absence of faults. If you want to track down particular faults then the use of manual patterns (relying, as they do, on the tester's experience and intuition) will probably be more fruitful.

A Catastrophic Failure

In a digital circuit, a fault is considered to be any physical defect which causes the circuit to respond abnormally. The sort of simulation-based ATE dealt with so far responds to any such faults, but the tests are static only and the faults they can uncover are generally described as catastrophic.

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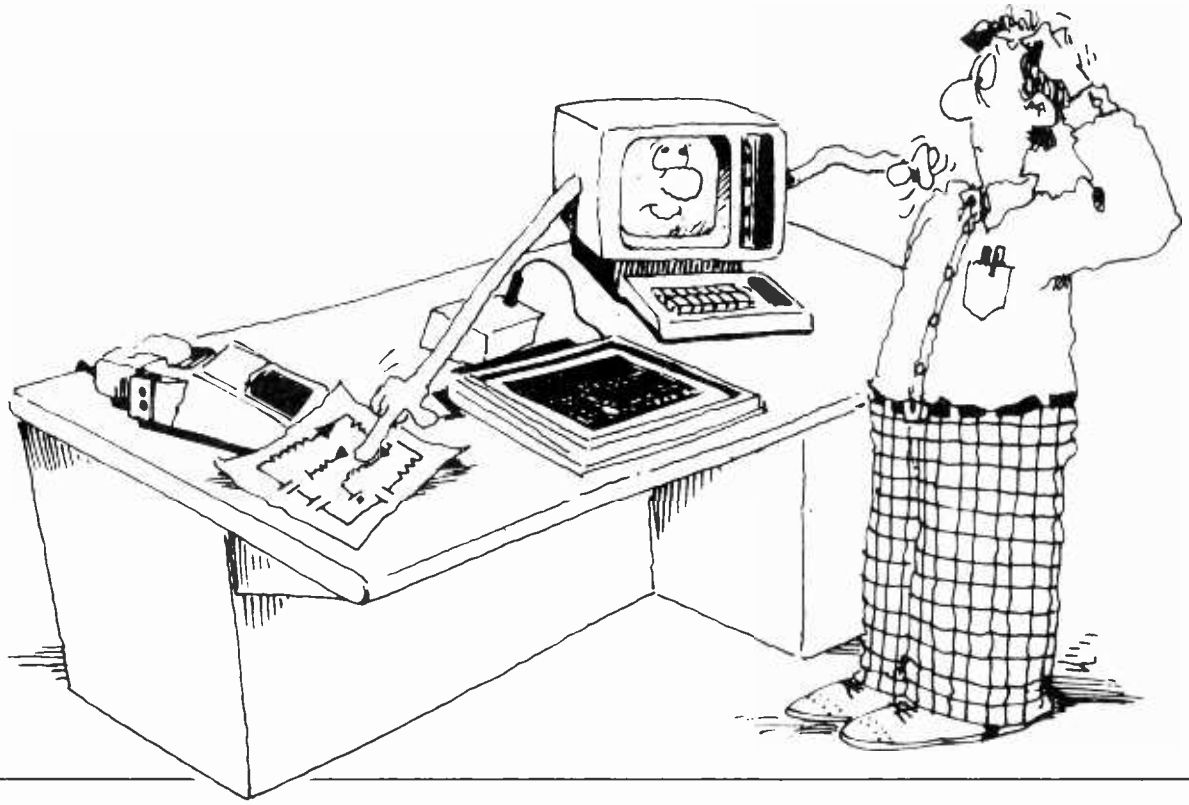
To say that the testing procedures are static is actually to say that the rate at which patterns are applied to UUT is much less than the propagation times of the devices connected in the UUT. Between the application of any two patterns the UUT is allowed to settle in to a stable condition. Dynamic and time related faults are not uncovered by static signal tests and, in general, the fault coverage is restricted to failures due to missing parts, incorrect installation of parts and the partial or complete death of parts. Such catastrophic faults are the commonest kind, especially in production runs of fully de-bugged circuits, but they are by no means the only or the most frustrating kind.

In essence, dynamic testing follows the same course as static testing with automatic pattern generation, but at far greater speeds, usually at data rates greater than 1MHz up to the full system speed of the UUT (at which point component dynamic testing becomes dynamic real-time testing). Dynamic faults vary with the level of integration of the UUT. For gates, the faults are usually associated with propagation delays. Latches display dynamic faults connected with set-up and hold time. Memories are associated with data addressing faults and microprocessors with cycle-time stability faults. We'll be dealing with such dynamic faults at greater length in a future article, but for the moment it's worth noting that dynamic faults can be tested by simulation-based equipment by means of some fairly elaborate modelling techniques.

A typical simulator has been developed by Brunel University for Smiths Industries and goes by the name 'HILO'. The 'LO' of 'HILO' refers to the low-level modelling already described, while the 'HI' indicates that the simulator includes a high-level language so that programmable propagation delays can be set up for individual devices and allowing functional modelling of complex VLSI devices which do not, therefore, need to be broken down into primitive gates.



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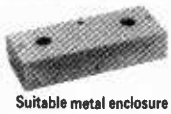

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DESIGNING TRANSISTOR STAGES

Les Sage gives a general introduction to transistor amplification stages and some rules of thumb for those who want to design their own.

One of the main problems facing an engineer in designing an amplifier is the choice of circuit to suit the particular application. Many engieners, unaware of the advantages and disadvantages of different circuits, play safe and go straight for an IC op-amp, widely accepted as a near perfect black box amplifier with high input impedance, low output impedance and an infinite open loop gain which, if biased correctly, is sure to work better than a hastily designed transistor stage.

The op-amp has many uses, some of which are beyond the scope of simple discrete transistor circuitry. But there are many applications for which a discrete one or two transistor amplifier will do the job better and cheaper. An IC is only a box of transistors which a designer has put together as a circuit block, usually with a view to as many applications as possible. Many areas of design are often compromised in the process of IC design.

IC op-amps are often deficient in one or more of these areas:

1) Very low noise amplification (even today the lowest noise amplifiers are still built with discretes);
2) High frequency amplification (op-amps are so stuffed full of transistors their transition frequencies are best measured in weeks rather than nanoseconds!);
3) Distortion (the majority of op-amps have class B output stages and hence generate crossover distortion which is undesirable, especially in low level pre-amplifiers);
4) High power output (amplifiers above 20W are generally discrete circuits).

The aim of this series is to demonstrate some useful amplifier circuit building blocks using transistors. Performance is discussed — and ways of improving it — and various two transistor circuits are shown for situations where one transistor is just not good enough.

The Common Common Emitter

In order to design a single stage amplifier (for example, Fig. 1), its purpose must first be established. Let's assume that we're designing a circuit to boost the ouptut level of a tape-recorder phono socket to drive a power amplifier.

The tape-recorder gives an output level of 100mV RMS from a 1k0 source impedance. The power amplifier, however, requires 1V RMS and has an input impedance of 50k ohms.

Having opted for the familiar common emitter configuration of Fig. 1, the first choice to be made is R3 — the collector load with which the transistor will develop the required signal output. The calculated value will affect all other calculations and values, so it must be carefully worked out from the first. A number of things must be considered.

If the circuit is to be battery powered, a high value for R3 will be preferred to save battery power. If it is to be mains powered, lower values will mean improved performance.

In theory, maximum power transfer requires our circuit source and load impedances to match the preceding tape-recorder load and succeeding power amp source impedances. This means the circuit should have a 1k0 input impedance and a 50k output impedance.

Perhaps the dominant argument against the theory, particularly in this case, is that distortion enters the practical picture. Transistors are essentially nonlinear current-operated devices. To maintain minimum distortion the maximum amount of voltage negative feedback must be applied. Since we require an overall voltage gain of 10, we must ensure there are no significant signal voltage losses at input or output,

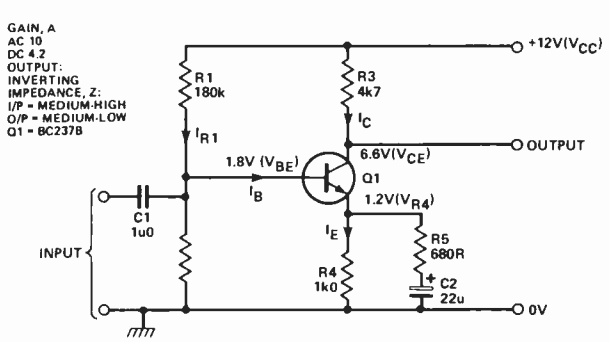

Fig. 1 Common emitter amplifier circuit discussed in text.

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or the amplifier would need extra gain to compensate.

The two practical starting criteria are that, as a rule of thumb, the input impedance of the amplifier should be around 10 times *greater* than the signal output impedance (in this case, greater than 10k) and that the amplifier output impedance should be around 10 times *lower* than the load impedance (or less than 5k). Thus signal losses are kept low.

Now back to the original problem — the choice of R3. To be 10 times less than the power amplifier's input impedance, it should have a value of 4K7.

The next practical assumption to make is that the potential at the transistor's emitter should be about 10% of the supply voltage — in this case, about 1.2V. This is to ensure DC stability over a wide range of operating conditions.

Many engineers, unaware of the advantages and disadvantages of different circuits, play safe and go straight for an IC Op-amp . . .

For the amplifier to provide maximum output voltage swing, the collector potential should lie halfway between the supply rail and the emitter potential. For a 12V supply it must be:

$$V_{CE}=(V_{R4}+V_{CC})/2=6.6V$$

From this we can calculate the nominal collector current (which, together with Vcc, helps us determine a suitable transistor):

$$I_C=(V_{CC}-V_{CE})/Re=1.14mA$$

The emitter potential has already been set at 1.2V, so R4 can be found from

$$R4=1.2/(1.14\times10^{-3})=1k0\ (approx).$$

R1 and R2 are there to ensure that the transistor base is always supplied with enough current to maintain the required collector potential, and the third rule of thumb is that there should always be more than 10 times the required base current, I_B, flowing down the bias chain R1–R2.

To determine the base current we have to look in the manufacturer's data sheet for probably the most important of the h-parameters — h_{FE} or the transistor's common emitter DC current gain. For a BC237B, h_{FE} is between 250 to 500. The variation is due to manufacturing tolerances and we should take the worst case figure of 250 to ensure that our circuit will function correctly with any BC273B transistor. The rules of thumb used earlier make sure that a higher-than-minimum gain transistor will not significantly alter the bias condition we are about to set up.

Since base current equals collector current divided by current gain

$$I_B=/h_{FE}=(1.14\times10^{-3})/250=4.5\ \mu A\ (approx).$$

The current flowing down the bias chain, R1–R2, should be around 10 times I_B, say, 50 μA.

Since the transistor is passing collector current, the base potential must be about 0.6V above the emitter potential, 1.2 + 0.6 = 1.8V. It is clear that the potential across R1 equals V_{CC} –1.8V, or 10.2V. Resistor R1 should pass around 50 μA and should therefore be about $10.2/(50\times10^{-6})$ ohms. This comes to about 204k and, bearing in mind that it is better to round down than up, since more current is better than not enough, we set R1 at the preferred value, 180k.

To avoid a build up of errors due to rounding, it is best to recalculate I_{R1} the current through R1. I_{R1} equals $10.2/(180\times10^3)$, or about 56.6 μA.

Since the current through R2 equals the current through R1 minus the transistor's base current, we can calculate R2 simply:

$$R2=1.8/((56.6–4.5)\times10^{-6})=34.5\times10^3\ \Omega$$

The nearest preferred value is 33k.

The DC conditions are set up so that the transistor is operating in its linear region and can provide amplification. The amount of amplification, or voltage gain, is determined by the total collector impedance divided by the total emitter impedance.

Collector impedance equals R3 plus the load plus the transistor's own output impedance all in parallel. In most cases, the transistor's output impedance can be ignored as it is high compared with the collector load resistor. This makes collector impedance equal to 4k7//50k, or around 4k3. The transistor's emitter impedance is derived using complex mathematics from the diode equation and can be approximated to $25R/I_E$ (mA).

Note that we've assumed that collector current and emitter current are equal. This is acceptable for modern day transistors with h_{FE} figures of 200 or more. Some transistors have an h_{FE} of well over 1000, these days, and in these cases the transistor's base-emitter current is so small, compared with collector-emitter current, that it can be safely ignored.

The emitter resistance can now be calculated by dividing 25 by the emitter current in mA, bearing in mind that emitter current equals collector current:

$$Re=25/1.14=22R\ (approx.).$$

This internal resistance is in series with the emitter load resistor R, so the total emitter impedance is 1022R. The voltage gain is simply

$$A=4300/1022=4.2\ (approx.).$$

This is not the value of 10 we were aiming for. To get that, the total emitter resistance should equal the collector resistance divided by the required gain, or around 430R.

Current Complications

To alter R4 now would upset our carefully calculated bias conditions. So we introduce R5 and C2 to lower the effective emitter resistance to *AC signals* and therefore to increase AC gain. The DC bias conditions are left unaffected, thanks to C2, but to AC signals, R4 and R5 are in parallel.

R5 should be chosen so that R_e+ (R4//R5) equals 430R. Thus:

$$(1/1000)+(1/R5)=1/(430-22)$$

and

$$R5=(408\times10^3)=680\ (approx.).$$

R5 determines the overall AC gain and can, of course, be altered for different requirements or even replaced with a small preset potetiometer. C2 should be large enough to pass the lowest audio frequency expected without too much attentuation. Very roughly, the AC gain will drop by 3dB when the

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reactance of C2 plus R5 equals R4, assuming Re is low. If the roll-off frequency is to be 20Hz, then,

$C2 = 1/(2\pi \times 320 \times 20) = 24.8\mu F$
($22\mu F$ is the nearest preferred value).

A quick look at the input impedance will complete the calculations around this single stage amplifier. Then we will be able to look at its limitations and some ways to overcome them.

The transistor's input impedance can be calculated from h_{FE} and the total emitter resistance:

$R_{IN} = 250 \times 430 = 107k5$,

But the input signal also has to flow through the DC bias resistor, R2, which can be considered to be in parallel with the input, reducing input impedance.

Total input impedance is approximately 107k//33k or about 22k. Happily, this still falls within the original specification that input impedance should be greater than 10k.

Maximum Gain

An interesting problem faced by many enthusiasts is to estimate the stage gain when the emitter resistor, R4, is totally decoupled — that is, when R5 is a short circuit. Some people guess quite high figures. Others like to impress and bring out a string of complex formulae straight from a text book. The formulae are enough to put most people of electronics for life, while the guesses are usually wrong.

There is a very simple rule of thumb which works very well. The gain of a common emitter stage without emitter degeneration is simply 20 times the supply voltage.

The formulae are enough to put most people of electronics for life, while the guesses are usually wrong . . .

Since this often surprises people, here are the sums:

Assuming high frequency operation, so that C2 is very low, and making all the other simplifying assumptions we've used so far,

gain, $A = R3/((R5//R4)+Re)$.
Since R5=0, this reduces to
$A = R3/Re$.

Now, $Re=25\times10^{-3}/I_E$ and $I_E=I_C$.
In turn, $Ic=(V_{CC}-V_{CE})/R3$, so:

$Re = (25\times10^{-3}\times R3)/(V_{CC}-V_{CE})X40$.

$A = (V_{CC}-V_{CE})/(25\times10^{-3})$ so

$A = (V_{CC}-V_{CE})\times1000/25$ or $(V_{CE}-V_{CE}ce)\times40$.

If we now assume that component values are chosen so that V_{CE} lies more or less midway between V_{CC} and 0V, then $V_{CC}-V_{CE}$ will be $0.5V_{CC}$. Thus the gain equation reduces to $A = 20V_{CC}$.

The last assumption we made follows from setting the transistor's operating point. The '$20V_{CC}$' rule of thumb then gives the maximum gain under ideal conditions and without taking input and output loading into account. In practice, maximum gain is usually between ½ and ¾ of this figure.

In order to design a single stage amplifier, its purpose must first be established . . .

Next month, we'll discuss refinements to the common emitter circuit and other configurations. There will be considerably less mathematics, since the principles we've dealt with above should be enough to stand you in good stead should you want to make your own practical calculations.

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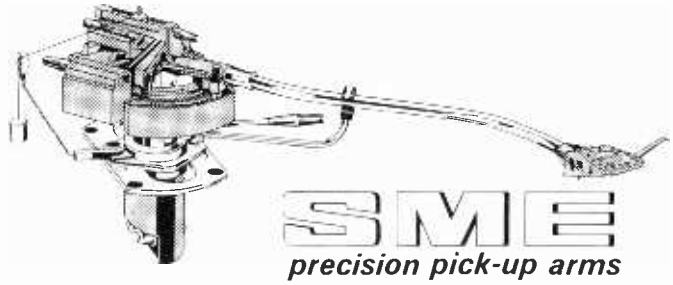

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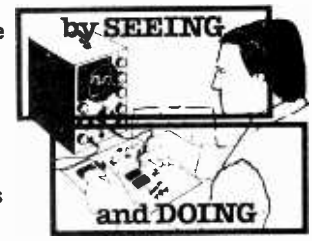

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WOMEN AND IT

Information technology is the industry of the future. But where are the women in the electronics and computer industries, asks Anna Paczuska?

Discussion of the chronic skills shortage which threatens the British IT industry centre on whether the government or industry should finance the training programmes needed to make good the shortfall. Both parties, however, effectively ignore one area of recruitment — women.

Girls and women represent a sizeable resource of untapped skill at technician and technologist levels as well as at professional level. This is particularly important in view of the population trends which predict a significant downturn in the overall number of school leavers over the next ten years.

Token statements about the need to encourage women appear in all the reports. The Department of Trade and Industry (DTI) for instance, states in one report about skills shortages at technician level:

> 'Everyone involved with the provision or application of IT skills should encourage initiatives at school level and onwards to increase the number of people studying relevant disciplines and in particular to interest girls in IT-related subjects.'

But 'everyone' clearly does not include the DTI. There is no further mention of women in that report beyond the predictable generality that 'initiatives are under way to attract more women into the industry.'

Invisible Signs

But where? The DTI certainly isn't doing it. It is constrained by the government's lack of funding for training schemes and consequently lays stress on the need for training initiatives at industrial level, pointing to such solutions as in-house and in-company training schemes, private provision as offered by the electricians' union (EEPTU) and courses only *part* funded by the government, such as the Microelectronics Applications Programme (MAP). The DTI is also keen on training courses provided for third parties by, for example, BT at Stone, Cable and Wireless at Portcurno and systems houses such as STC/IAL at Bath.

In its latest report the DTI argues optimistically that:

> 'there are signs that a more positive message is being transmitted by IT companies both to girls at school and to women already in employment.'

A gross inflation of the facts.

Not only are there pitifully few training schemes at all, but girls hardly get a sniff at those. Engineering Industry Training Board (EITB) figures for 1984 show that only 5.3% of scientists and technologists in the electronics industry were female, and only 9.9% of the trainees. Similarly, 4.4% of the technicians, including draughtsmen, (*sic*) were women, and they were only 8% of the trainees.

The problem is that not only do employers do very little to encourage and recruit girls, but circumstances in the schools positively discourage them.

Far fewer girls than boys present themselves for training. Figures show that Computer Studies is, at present, a minority subject in all schools and that everywhere it is studied very largely by boys. The attitudes are formed early on and harden as the pupils get older. A study by the Equal Opportunities Commission (EOC) in Croydon of pupils taking CSE,

Women only earn 83% of the average male rate for the same work . . .

O and A level exams in computer-related subjects suggested that the proportion of girls taking a course declined as the course became more advanced. At GCE A-level, almost four times as many boys as girls took Computer Science while at O-level the ratio was less than 2½ to 1.

Girls' learned helplessness with machinery and technology is initiated at an early level and reinforced from all sides. According to a representative of Acorn Computers we spoke to, a recent 'Audit of Great Britain' showed that in all households owning micro-

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computers, boys are 13 times more likely than girls to be using them. Only 4% of home micros are used by mothers. The idea that microcomputing is a boys' game has prompted Angela Bowie, professor of Business Administration at the University of Strathclyde to describe home computers as 'the Meccano sets of the 80s'.

Bowie says that by putting up with this state of affairs, women are seriously handicapping their daughters. She argues that more women should buy and use home computers.

Girls And Boys Together?

Lack of access to home computers is not the only barrier between girls and new technology. Research shows that even in school, where computers *are* available, girls get a raw deal. A recent study funded by the EOC and conducted by Lorraine Culley in Midlands secondary schools revealed that whenever boys and girls worked together in mixed groups, the boys hogged the machines and the girls rarely got a turn. Small groups of boys in a mixed class argued so much about turns and were so noisy that they effectively demanded all the teacher's time. The girls in their groups tended to work more co-operatively but got less teacher time (because of the boys) and so were often stuck for long periods and achieved less. Small wonder girls opt out of computer studies.

Against this pessimistic picture, the Acorn survey found that girls in 'girls-only' schools did much better at computer studies than girls in mixed schools. It seems that girls are better off without the boys around. The EOC has suggested that computer clubs for girls only may help to encourage them. It has also made a long list of recommendations about the extended use of computers across the curriculum, the training of teachers, and the preparation of non-sexist teaching materials in order to give all pupils equal chances to acquire computer skills.

Women form a majority only at one level of the electronics industry: they make up 78% of all clerks, typists and secretaries . . .

Where such measures have been implemented, says the EOC, girls do much better. But they cost money and with the present government policy of education cuts it is doubtful whether such schemes will be widely implemented.

All Work And No Pay

Sadly, girls are still worse off than boys even if, against all the odds, they eventually make it into a skilled job in the IT Industry. A Computer Staff Salary Survey recently produced by Computer Economics revealed that not only do women lose out in terms of access to the most skilled jobs (only 1.6% of data processing managers are women) but they earn only 83% of the average male rate for the same work.

Recent studies in the US have shown similar results. A group of researchers at Stanford University who monitored women working in high technology companies over a ten-year period found that even women with qualifications as good as men earned only 72% of the average male rate.

In Britain, the disparity between male and female salaries may partly be explained by the fact that highly skilled women tend to find top jobs in smaller companies, which pay less. But it also indicates that companies think female skills are somehow worth less than men's. As the Computer Skills report says:

> 'Generally, the largest proportion of women was to be found at the bottom of each category of job, and in the less prestigious of the jobs.'

That is borne out by the EITB figures which show that women form a majority only at one level in the electronics industry; they make up 78% of all clerks, typists and secretaries. They also provide a third of all manual workers.

A Woman's Place

Despite the massive growth of the computer industry, women's work remains limited to traditional areas. If girls receive any training at all at school, it is for jobs as typists and secretaries. Ironically keyboard skills are essential for work with computers, but as all sectors of industry become increasingly computerised the demand for workers with keyboard skills alone gets smaller and smaller. At the same time the women workers who make up the bulk of assemblers and semi-skilled operators in the electronics industry lose their jobs.

It's a problem that has forced even the frequently complacent EEPTU into action on the issue of retraining their women members. Last year, EEPTU members at Thorn-Ericsson in Darlington made a demand for retraining as part of their annual pay claim. After a long battle, the management agreed to sponsor retraining for women workers. They go in pairs for week long courses to the union college at Cudham, in Kent, where they get an introduction to analogue electronics. The scheme has only just started but research officer, Liz Allen, says there is a lot of enthusiasm for it among the women.

> 'Times have changed. Women want to hang onto their jobs. Though many of our

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> women members have long service in companies, what they know isn't valued.'

Liz also points out why training is such a difficult demand to negotiate'

> 'Many managements still don't believe that semi-skilled workers can be skilled.'

Management prejudice toward training girls and women as technicians is, unfortunatley, all too common. The Women's Technology Centre in Leeds, which provides 60 women a year with training in electronics and computing, found work placement difficult in its first year.

'Some firms wanted to know why *girls* wanted to become trainees at all,' says Christine Donaldson, one of the Centre's organisers. Now, after three years many firms have become more enlightened, probably because the courses have been so successful.

The Centre takes on 30 under-25s and 30 over-25s every year, recruiting with a positive discrimination policy which gives priority to women from ethnic minorities, the disabled and women with few or no formal qualifications. The Centre also has a child-care co-ordinator who helps place children in day-nurseries or with registered childminders.

The results are excellent. Of the second year intake, 63% got jobs in related areas and a further 18% went on to higher training, including three to degree level courses. Much of the credit is undoubtedly due to the staff who have to re-apply for funding from the European Social Fund and Leeds Council each year, but stick with the course despite the insecurity.

Money, Money, Money

Which is remarkable. Money is the main problem and money is what many schemes, even the good ones, don't get. Funds have just been withdrawn from the Girl Technician Training Scheme funded by the Manpower Services Commission and run by the EITB. The scheme grew out of the Scholarship Scheme for Young Women set up in 1975. This was designed to publicize the idea that the electronics industry can and should recruit women. In 1979 it was replaced by the Girl Technician Training Scheme in which employers receive a £5000 grant (now £6000) for every girl technician they recruit above normal requirements.

Over 150 employers, mainly the large concerns who employ the most technicans, took on girl trainees during the Scheme's life. Training used to be 'off-the-job' in workshops or FE colleges during the first year, and 'on-the-job' in subsequent years. Of the 346 girls recruited in 1979-80, 61% completed their training. The drop-out rate among girls was higher than for boys in the first year because, as EITB researcher Sue Peacock says, 'Some girls found they just couldn't cope with being the only girl.' But as Sue points out, the scheme *has* been successful and has been responsible for the slight rise in the number of girl technicians in electronics over the past few years, from around 1% when the scheme started to over 4% of the total.

Despite the scheme's success, the MSC has withdrawn its funds because money for training 16-to-19 year olds must now go to YTS, not to higher level schemes.

'It's a pity our scheme can't continue just because of a silly rule,' says Sue Peacock. 'The girls on our courses have been highly motivated because they're pioneers. Five percent of them went onto employer sponsored degree schemes, compared with 3% of the boys.'

Even at the highest skill levels in the computing industry, women still suffer from prejudice and discrimination. Traditional and inflexible attitudes have been responsible for driving some women out of the centre of the industry into home-based initiatives. Indeed the DTI seems to think this is a good idea. In its latest report it says:

> 'The very flexibility of IT, and the fact that IT systems make it possible to work from home as well as the office or factory, means that it is particularly well suited as a career for women at all levels.'

Doubtless the DTI have taken a cue from firms which have set up on just such a basis.

The systems house, F International, is a case in point. Set up as far back as 1962 it started as a small group of freelance programmers working from home. They now handle consultancy, design, training and systems analysis, employing over 850 people in the UK alone. Some 96% of their workers are female, but that's not because they are biased against men. As their representative told us, it's because 'men think they have to go *out* to work.'

Staff at F International work on a project contract basis, and work literally pours in — from multinationals and large British concerns alike. Barclays, Babcock Construction, British Steel, Lloyds, Shell, the Department of the Environment and British Aerospace are just some of their customers. Like everyone else, they're currently advertising for staff. They take only people with a minimum of 4 years experience in data processing and believe that they make available a pool of skills which traditionally organised firms cannot do.

'Why should career people with skills be lost to the computer industry just because they have family commitments?' their representative asked me. Why indeed? But do women have to go back into their homes and turn information technology into a glorified cottage industry before manufacturers will recognise, and pay for, their skills? **ETI**

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OSCILLOSCOPE MEMORY DISPLAY

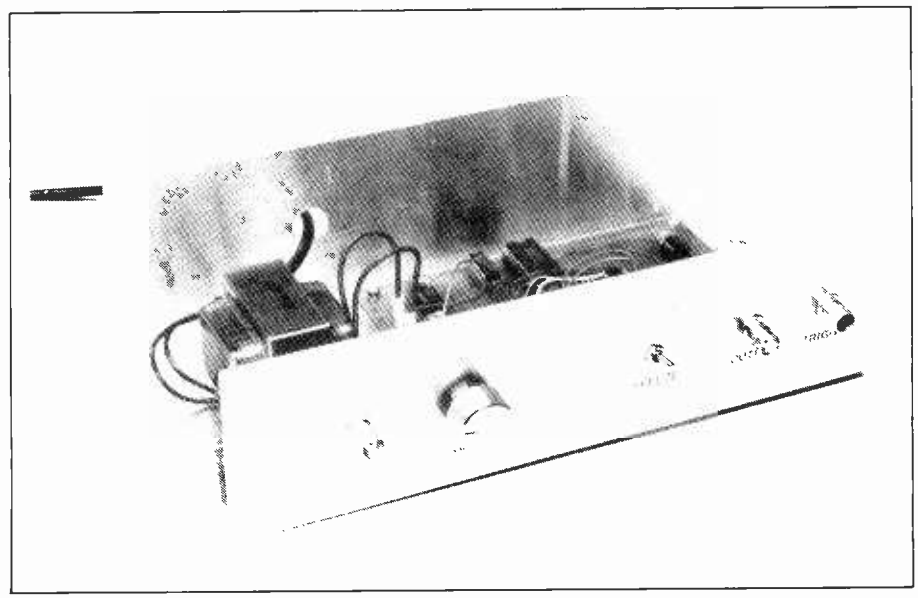
Does your oscilloscope persistently refuse to display slowly-changing waveforms? Ian Marshall explains how a little updating can help.

Anyone who uses an oscilloscope will know how frustrating it is trying to view slowly-varying signals on a standard short-persistence screen. Waveforms such as capacitor charge/discharge curves, modulation envelopes in electronic music generators, transducer outputs and physiological signals just cannot be satisfactorily displayed and studied on a general-purpose oscilloscope.

This add-on memory display allows flicker-free viewing of such signals by storing ten seconds of signal and constantly refreshing the screen fast enough to eliminate visual flicker. The displayed waveform scrolls across the screen in real-time or can be frozen for closer examination.

As a spin-off from the explosive growth of microprocessor electronics, a wide range of complex support chips are now available at virtually throw-away prices. This opens up all sorts of possibilities for projects which would have been inconceivable even ten years ago.

A microprocessor need not be used to take advantage of Random Access Memory (RAM) and analogue/digital interface IC's. The memory display uses simple gates, flip-flops and counters to perform a function which does not warrant the complexity of microprocessor control. Apart from an inexpensive 2K RAM, an ADC and a DAC, only a few popular CMOS logic IC's are required to build the display and all components should be readily available from a number of mail-order suppliers. The total cost should not exceed £35.



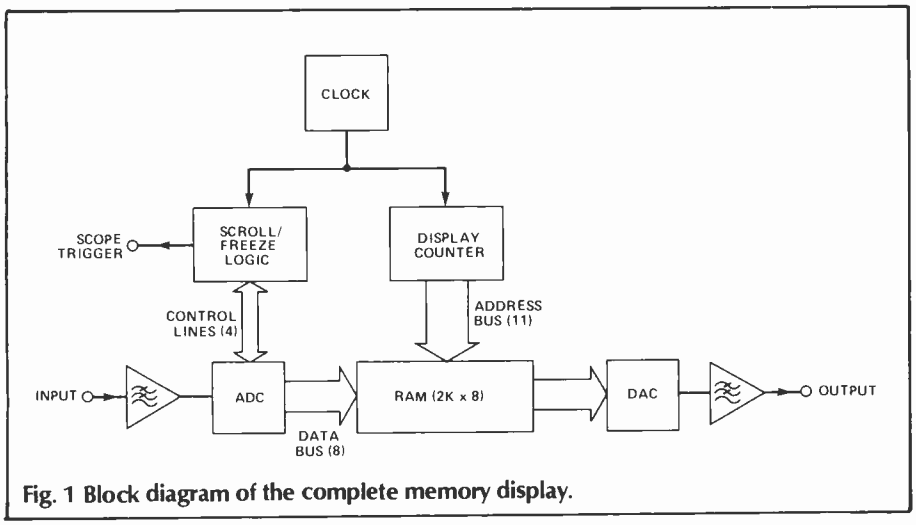


Fig. 1 Block diagram of the complete memory display.

The Circuit

The input signal is first filtered and then sampled 200 times per second by the ADC. The resulting 8-bit data is stored in the 2K of RAM. In between the storing of samples, the entire memory contents are read out to the DAC and are displayed on the 'scope screen, with the timebase triggering from the scroll/freeze logic. The refresh rate of 200 per second (5ms per frame) is high enough to create the illusion of a continuous, flicker-free display.

In the normal scroll mode the control logic ensures that successive

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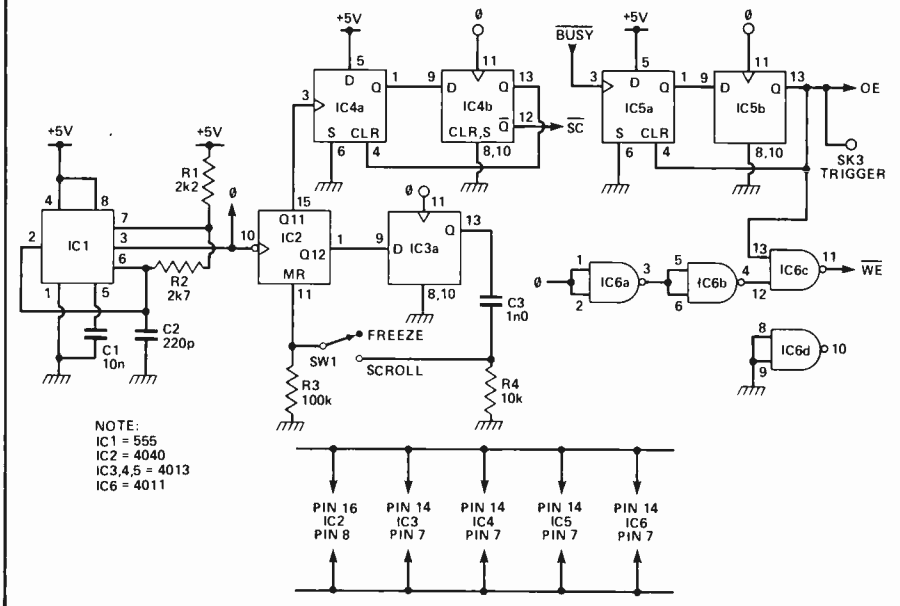

Fig. 2 Circuit diagram of the control logic.

samples are stored in consecutive memory locations, so the memory contents are gradually updated at the rate of one location per display sweep of 5ms. The displayed waveform thus appears to scroll across the screen, taking ten seconds for all 2048 addresses to be updated.

In the freeze mode, successive samples are stored repeatedly at the same memory address at the extreme left-hand side of the display. The stored data corresponding to the other 2047 addresses remains unchanged from sweep to sweep, so the display appears stationary.

The circuitry conveniently breaks down into the control logic (Fig. 2), the memory channel (Fig. 3) and the power supply (Fig. 4). The elements of the block diagram are readily identified in the complete circuitry.

The input signal is passed through anti-aliasing filter IC9 before being sampled by the ADC converter IC10. Samples are stored in the 2K x 8 memory IC8 at the address present on the outputs of display counter IC7. Except when a sample is actually being stored, the RAM is in read mode and as the addresses are sequentially counted through, data is read out to the DAC, IC11. The resulting analogue signal is low-pass filtered by IC12 before being displayed on the oscilloscope.

The scroll/freeze logic (IC2 and IC3a) dictates the relationship between sampling interval and display memory address and, with ICs 4, 5 and 6, produces the pulses necessary to take a sample, store it at the correct address, and trigger the oscilloscope sweep. In the scroll mode, IC3a introduces a one-cycle delay so that 2049 clock cycles elapse in between samples. During this time the memory address counter IC7 has progressed through all its states and advanced one further count. Samples are thus stored progressively one memory location later each time, creating the scrolling action. In the freeze mode, the sampling pulses are synchronised with the memory address so that only the one location is updated repeatedly while the rest of the data remains frozen.

Construction

With the exception of the mains transformer, all the circuitry is contained on a single printed circuit board of standard Eurocard dimensions (160 x 100mm). For ease of etching and essembly, the board is single-sided and requires several wire links to be inserted as shown on the overlay diagram. The short links can be of bare tinned copper wire, but the longer runs carrying the ADC control signals should be of insulated wire.

Once the links are in place, proceed with the IC sockets, resistors, capacitors and terminal pins. The copper tracks are quite fine and closely spaced around counter IC7

HOW IT WORKS — CONTROL LOGIC

The ubiquitous 555 timer, IC1, is used in the astable mode to produce a clock 0 of approximately 400kHz. The clock signal drives both the scroll/freeze counter IC2 and the memory address counter IC7.

In the normal scroll mode of operation, the Q12 output of counter IC2 is taken back to its reset input via flip-flop IC3a which introduces a delay of one clock cycle before the count sequence restarts. Thus 2049 clock cycles elapse before the count sequence repeats itself. The rising edge of output Q11 drives flip-flops IC4a and IC4b to generate a Start Convert (SC) pulse for the ADC. This pulse is synchronised with the clock, and is one clock cycle in duration.

Once the ADC conversion is initiated, its Busy line goes low until conversion is complete (in nine clock cycles) when it returns to the high state. The rising edge of Busy sets flip-flop IC5a, and flip-flop IC5b generates an Output Enable (OE) pulse to request data from the ADC. OE is gated with 0 to produce a Write Enable (WE) pulse for the RAM; the gating is necessary to ensure that WE is not still low when the RAM address lines are changed as counter IC7 advances on the next clock edge. Gates IC6a and IC6b are used to provide a delay from 0 to the WE gating, matching the propagation delay through flip-flop IC5b. By means of the OE and WE pulses, the new sample of data is stored at the address specified by IC7. Samples are taken every 2049 clock periods, giving a sampling rate of approximately 200 per second. Because 2049 clock cycles elapse in between successive sample/store operations, the address counter IC7 will have advanced 2049 states - one complete count sequence of 2^{11} plus one extra state. Thus each sample is stored progressively one memory location later, overwriting the old data. With the oscilloscope sweep triggered from OE the display appears to scroll, the input signal appearing at the right-hand side, moving to the left across the screen, and disappearing. At the sampling rate of 200, all 2K addresses are updated in just over 10 seconds which is therefore the amount of signal displayed.

In the freeze mode, the reset line of IC2 is held low by R3 and the counter is allowed to cycle freely in natural binary fashion. Output Q11 has positive trausitions every 2048 clock cycles and the resulting SC pulses, ADC conversion and sample storage are thus synchronised with the memory address counter. Successive samples are stored at the same one location in memory whilst the contents of the other 2047 RAM addresses remain unchanged. The display therefore appears stationary with the latest 10 seconds of signal frozen.

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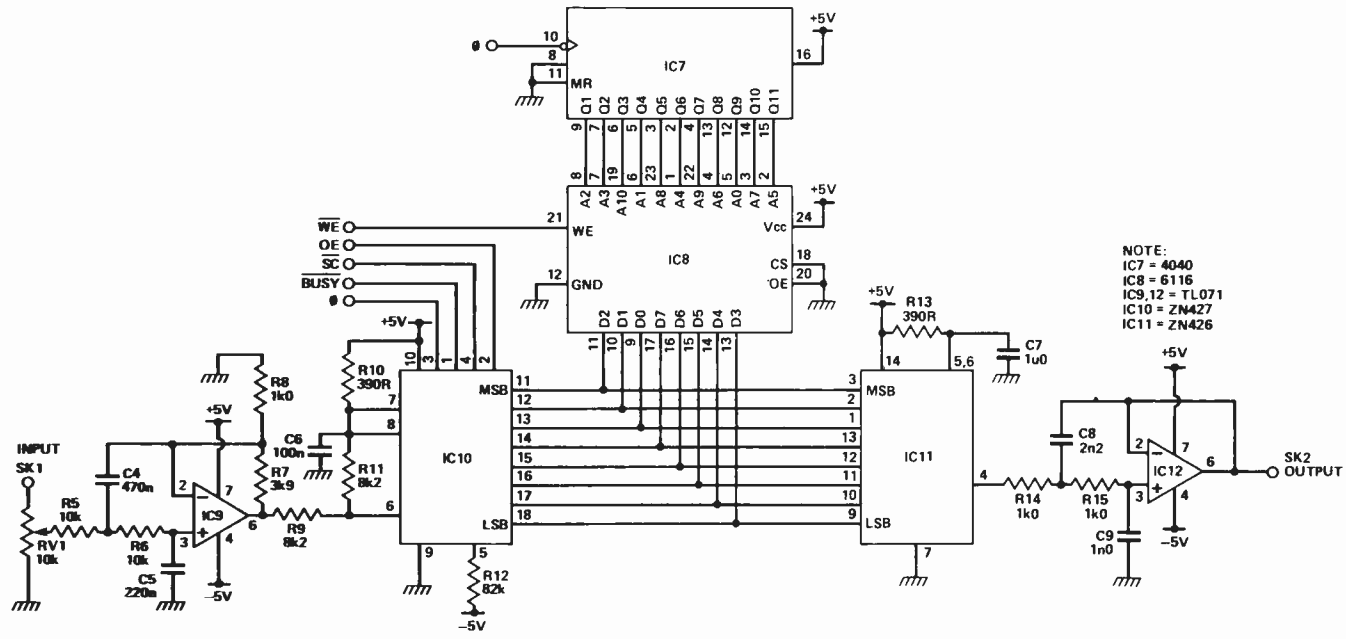

Fig. 3 Circuit diagram of the memory channel.

HOW IT WORKS — MEMORY CHANNEL

In the memory channel, the signal to be displayed is applied to potentiometer RV1 and a portion of it is taken from the wiper to the second-order low-pass filter (LPF) formed by IC9. With a frequency cut-off of approximately 50Hz, this filter prevents aliasing of the signal by removing frequency components above half the sampling rate. The filter has a passband gain of 5, (set by resistors R7 and R8), so that in conjunction with the gain control RV1, a wide range of signal levels can be accommodated.

The ZN427 analogue-to-digital converter (ADC) IC10 is an 8-bit successive approximation type, taking nine clock cycles to complete a conversion. It has an on-chip reference voltage of 2.56V which is available at pin 8, and in this design it is used as the reference input by connecting it to pin 7. A conversion is initiated by an $\overline{SC}$ pulse, whereupon the $\overline{Busy}$ line goes low. At the end of the conversion period, $\overline{Busy}$ returns high, signalling the control logic that a sample has been taken and is ready to be stored in memory. The subsequent $\overline{OE}$ pulse from IC5 enables the ADC outputs (which are normally in the high impedance state) placing the new data on the data bus. Simultaneously, $\overline{WE}$ is taken low so that the new data is written into the 2Kx8 RAM IC8, the address being dictated by address counter IC7. This sampling and storage operation occurs in between successive display sweeps.

During a display sweep, the RAM is in read mode and counter IC7 clocks round the address lines. The data from the RAM is read out in sequence to the digital-to-analogue converter (DAC) IC11, and the reconstructed analogue signal is available at pin 4. The output from the DAC is passed through low-pass filter IC12, which cleans up the discrete step-like nature of the waveform for subsequent display. The output signal lies in the range zero to +2.55V, so a zero input voltage will emerge from the memory channel with an offset of 1.27V. This is of little consequence as the output signal is displayed on an oscilloscope which will have a Y-shift control.

HOW IT WORKS — PSU

Mains transformer T1 together with bridge rectifier BR1 and reservoir capacitor C10 provide an unregulated supply of approximately 8V DC. This is regulated to 5V by IC13 to supply the logic circuitry and the positive rail of op-amps IC9 and 12. Capacitors C11 and C12 are situated close to the regulator to improve its stability and noise performance.

The op-amps and the ADC also require a negative supply, at a total current of typically 3mA. Rather than use a centre-tapped transformer and another reservoir capacitor/regulator combination, this low current is provided by voltage converter IC14. This is configured to generate a mirror-image of its supply votage, -5V from +5V. The total current drain of the memory display at 5V is approximately 90mA.

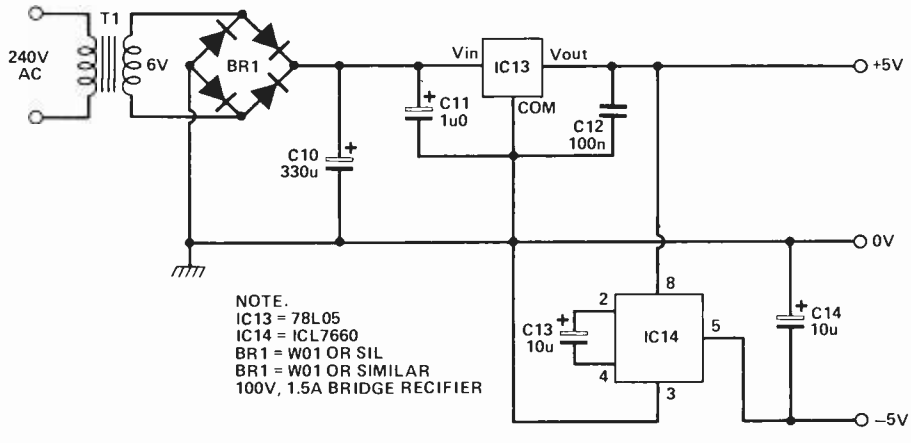

Fig. 4 Circuit diagram of the power supply.

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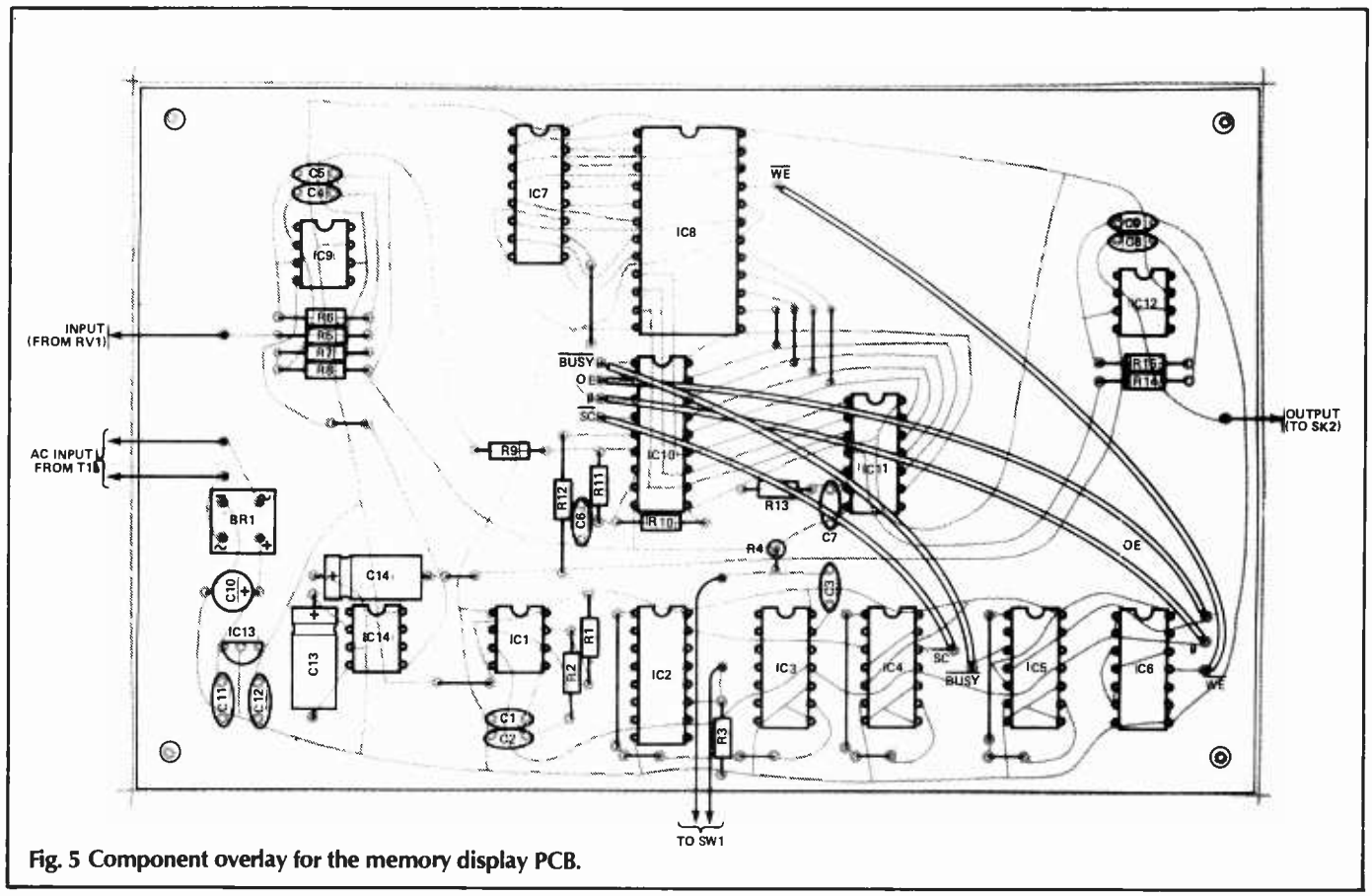

Fig. 5 Component overlay for the memory display PCB.

PARTS LIST

RESISTORS	**(all ¼W,5%)**	**C5**	**220n**	**BR1**	**W01 or similar bridge rectifier**
R1	2k2	C6,12	100n		
R2	2k7	C7,11	1u0 10V electrolytic		
R3	100k	C8	2n2		
R4-6	10k	C10	330u 25V electrolytic	**MISCELLANEOUS**	
R7	3k9			SK1-3	BNC chassis-mounting sockets
R8,14,15	1k0	C13,14	10u 25V electrolytic		
R9,11	8k2			SW1	Single pole toggle, slide or pushbutton switch with NC contacts
R10,13	390R	**SEMICONDUCTOR**			
R12	82k	IC1	NE555	T1	Mains transformer 6V, 200mA (1.2VA) secondary
RV1	10k linear potentiometer	IC2,7	4040		
		IC3-5	4013		
		IC6	4011		
CAPACITORS		IC8	6116 RAM		
C1	10n	IC9,12	TL071		
C2	220p	IC10	ZN427		
C3,9	1n0	IC11	ZN426		
C4	470n	IC13	78L05 or LM340L-5		
		IC14	ICL7660		

PCB; mounting pillars; case strain relief grommet for mains lead; knob; IC sockets, 4 off 8-pin, 5 off 14-pin, 2 off 16-pin, 1 off 18-pin and 1 off 24-pin DIL; nuts, bolts, etc.

and the RAM IC8, so care is necessary to avoid forming solder bridges between adjacent tracks and pads around this part of the layout. Solder in the regulator IC13, but do not insert any of the other IC's at this stage.

The case can be of plastic or metal (or even French-polished walnut for that matter!), the only restrictions being that it should be large enough to house the PCB and mains transformer and that it should have a front panel, preferably of metal, on which to mount the various sockets and controls. The mains cable enters from the rear, being securely anchored in the back panel by a strain relief grommet. The PCB is fastened to the base of the case by means of short spacers. The transformer frame and all accesible metal parts of the case must be earthed, which may mean taking earth wires to the individual panels. Assembly screws do not necessarily provide an adequate low-resistance contact.

The choice of transformer is not critical, and practically any mains type capable of providing between 6 and 9V RMS at 200mA will suffice. The raw DC voltage at the input of IC13 should not fall below 6.5V or the regulating action will be lost. If this happens, the output will track the input voltage but at about 1.5V lower. On the other hand, the mean input-output differential at the load current of 90mA should not be

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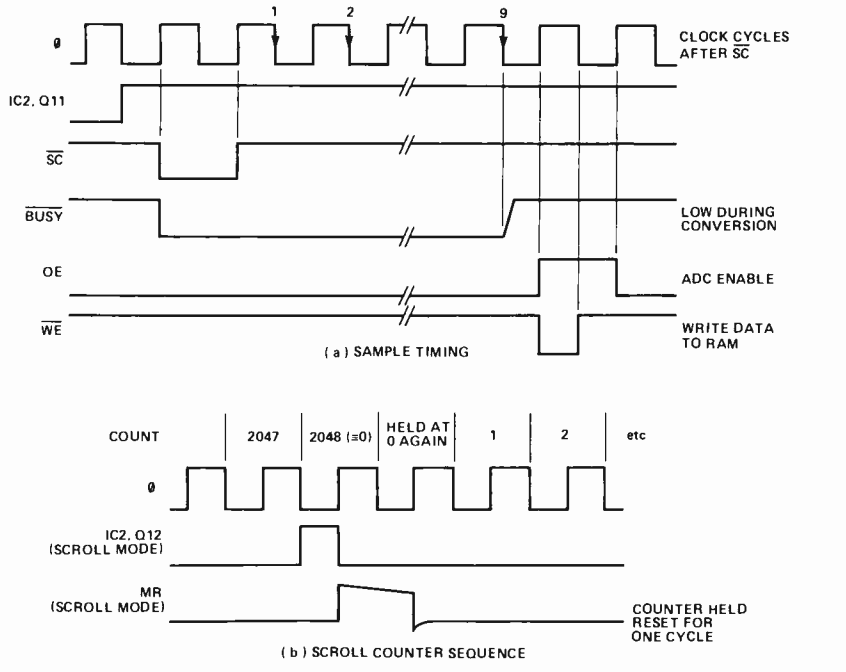

Fig. 6 Timing diagram for the control logic.

greater than 6V or the dissipation in the regulator will exceed the safe limit (0.6W for the TO-92 package). If you already have, say, a 12V transformer in the junk box, the excessive power can be burned off by using a TO-220 packaged 7805 regulator for IC13. This device has a maximum dissipation of 2W in free air, rising to about 8W with a 10°C/W heatsink fitted.

Mount the BNC sockets, the switch and the potentiometer on the front panel. A toggle switch is specified for the Freeze control, but if momentary action is preferred a biased toggle switch or a pushbutton could be used instead. The contacts should be normally closed. The wiring to the controls is very straightforward and should present no problems provided the diagrams and the photograph are followed carefully. Construction is completed by wiring the mains lead to the transformer primary and connecting the secondary winding to the PCB.

Testing

Apply power to the Memory Display and check the DC voltages present at the input and output of the regulator, IC13. The output should be within 0.3V of 5V. If all is well, insert the negative rail generator IC14 and check that -5V is present on its output, pin 5.

Having established that the power supply is working correctly, testing of the logic circuitry can begin. It is assumed that the constructor has access to an oscilloscope, and waveform diagrams are given in Fig. 6. Proceeding systematically, using these waveforms and the circuit description given in How It Works, it is possible to insert the IC's in easy stages and check circuit operation. In this way any problems due to solder bridges, bent IC pins and so on will be quickly brought to light.

Begin with the master clock (Ø) generator IC1. A square wave at a frequency of approximately 400kHz should be seen at its output, pin 3, and should appear on the appropriate pins of other IC sockets across the board. Next insert IC2 and IC3 and monitor the Q11 output (pin 15) of IC2, which should be a squarewave of period 5ms. Now insert IC4 and check that each rising edge of Q11 produces a Start Convert (SC) pulse. At this stage the ADC (IC10) can be inserted, ensuring that SC and the clock Ø reach it, and that its Busy line goes low for nine clock cycles after the SC pulse. With ICs 5 and 6 in place, the rising edge of Busy should be seen to produce the OE and WE pulses.

With the control logic tested and working properly, proceed to the memory channel. Insert the address counter IC7 and check that its outputs are clocked round by Ø. If all is well, the RAM IC8 can be carefully put in its socket, and the DAC IC11 and the two op-amps IC9 and IC12 inserted. It should now be possible to apply a signal or a voltage level to the input socket and see the scroll/freeze action at the output socket, with the 'scope display sweep triggered by the OE pulse which is brought out to SK3, the Trigger output.

BUYLINES

The resistors, capacitors, semiconductors and other general components are all widely available from various advertisers and the usual mail-order suppliers. No case has been specified but, as pointed out in the text, its dimensions and construction are not critical.

The PCB will be available from our PCB Service.

In Use

The waveform to be displayed is applied to the input socket and the oscilloscope trigger input is connected to the trigger socket. The scrolling display is taken from the output socket to the scope Y-input. Set the scope timebase to produce a sweep of approximately 5ms so that the memory contents are read out once per sweep. Adjust the gain control until the displayed waveform is as large as possible without exceeding the range of the ADC. This will be apparent as clipping of the display in much the same way that analogue circuits clip if over-driven.

The frequency response is from DC up to a theoretical maximum of 50Hz (set by the low pass filter, IC9), but if sine waves are being viewed the practical upper limit is set by the number of cycles that can be resolved across the screen. This is a function of the trace width, screen size and viewing distance.

Potentiometer RV1 sets the input impedance at 10k, so some form of buffer amplifier will be required if you wish to look at high-impedance sources such as capacitor charge/discharge curves.

Refinements

Experimentally-minded readers have plenty of scope (sorry!) for modifying the memory display from the form presented here. The most obvious possibilities include expanding the memory and/or having more than one memory channel. The primary design constraint is that however much waveform is stored, it must all be read out to the scope screen at least 50 times per second to avoid annoying visible flicker. Happy viewing!

ETI

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THE RHYTHM CHIP

Geoff Phillips calls it the RHYTH.ROM because it uses EPROM data to generate and measure beats-per-minute. Hit me, hit me!

The simple method of designing a beats per minute meter is to use the standard analogue frequency-to-voltage approach.
Each beat is made to trigger a monostable of set pulse width and the pulses are then averaged in an integrator. The output voltage of the integrator is proportional to the beat rate and an analogue meter can be scaled accordingly.

A design employing this technique would have a slow response time and always has an annoying ripple voltage present which causes the meter needle to quiver at the beat rate being measured. As always, a digital method is best. A binary counter can be used to count up pulses from an oscillator during the time period between two beats of the music. The number of pulses in the counter is a measure of the beat rate.

The problem is converting this count into a binary coded decimal number equivalent to the beats per minute. Real time calculation of the beat rate digitally would involve the use of microprocessors. If all the answers are calculated by hand, however, they may be loaded into an EPROM which would then act as a look-up table giving a correlation between the binary number in the counter and the appropriate BCD numbers for an LED display.

Beat The Clock

As most EPROMs have 8-bit outputs, the beats-per-minute information will best be stored as two-digit BCD numbers. This will look just the same as two-digit hex numbers to the EPROM but the display will be limited to a maximum beat rate of 99. It was decided to incorporate a 2x switch facility to cater for beat rates up to 198. The clock input of the binary counter is switchable between the clock oscillator and a divide-by-2 flip-flop. If the EPROM is programmed for the divided clock then switching to the normal clock will enable beat rates of 99 to 198 to be measured. The display resolution is obviously 1 beat per minute. Ninety-nine beats-per-minute is 0.606 seconds-per-beat and 98 beats-per-minute is 0.612 seconds-per-beat, so a measuring resolution of about 6ms would be adequate. A 100Hz clock was chosen to make the maths easier. The lowest beat rate that needs to be catered for is in the region of 25 which means that only the first 256 addresses of the EPROM need be programmed.

Ninety-nine beats-per-minute is equivalent to 0.606 seconds-per-beat. During this time, 0.606/.01 (=60) clock pulses would be counted in the binary counter. The first 60 (decimal) addresses of the EPROM should therefore be loaded with hex A1 which will give an overrange indication on the LED display of blank-1. The data for the remaining EPROM addresses may be calculated as follows:

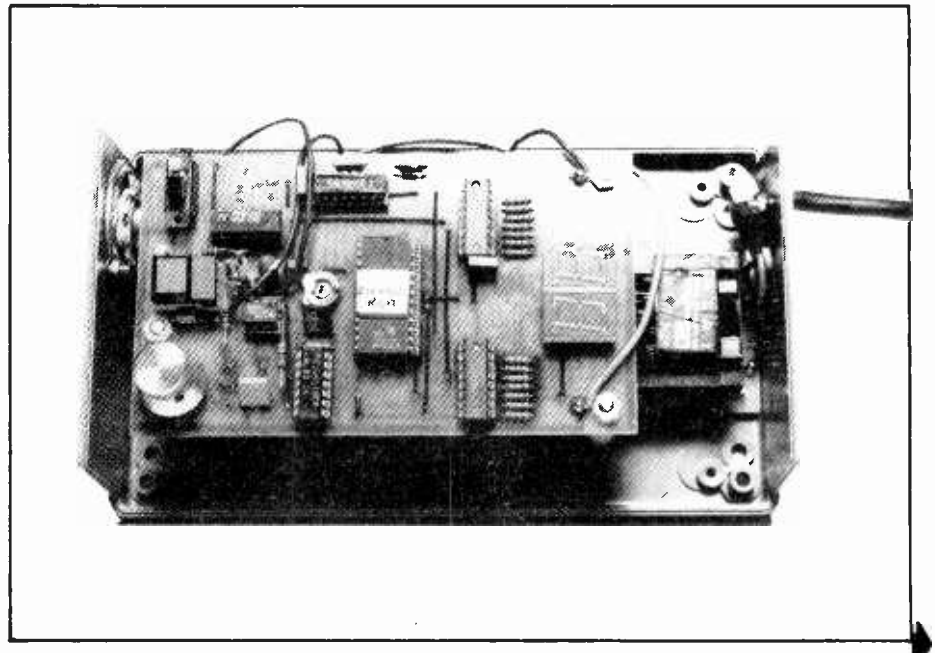
$$\text{EPROM data} = \frac{60}{\text{EPROM address} \times 0.001}$$

rounded to the nearest whole number. The calculation is performed in decimal but the data entered in 2-digit hex format.

For those who can't be bothered to work them all out, Table 1 shows all the answers. For those of you who are even lazier, a preprogrammed EPROM is available (see Buylines).

Making ROM

A 555 timer is used as the metronome. It is connected in the astable mode and can drive a 50 ohm speaker direct. It gives a series of clicks not unlike a conventional metronome. The speed is adjusted with a potentiometer.



Inside the prototype Rhyth-ROM — wire integral PSU.

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Fit the resistors and capacitors first. This is always a good idea when CMOS ICs are being used. When fitting the push button ensure that the two notches are in line with the length of the PCB. The 'x1–x2' switch is soldered straight onto the PCB. The leads of the tempo pot must be bent 90° towards its shaft and the pot is then fed from the rear of the PCB through the large hole and then secured with the pot nut on the top of the PCB. The switch section of the tempo pot is hard wired to the PCB with flying leads. Ensure that the LED displays are fitted with the decimal points towards the centre of the PCB. When the PCB is complete connect it to a 5V power supply and the Rhyth-ROM is now ready for calibration. (The prototype included a 5V supply in the case, but this is not necessary).

If you have access to a frequency counter, monitor the speaker output of the Rhyth-ROM. Set the 'x1–x2' switch to x1 and turn the tempo pot slowly until 1 beat-per-second is obtained and the frequency counter reads a period of 1.000 seconds. Adjust RV1 until the LED display of the Rhyth-ROM reads 60 beats-per-minute, If you don't have a frequency counter, use a watch or clock to adjust the tempo rate.

Operation

The Rhyth-ROM is in the metronome mode of operation when the tempo pot is switched from its fully anti-clockwise position. Clockwise rotation of the pot increases the tempo. The LED display shows beats-per-minute directly when x1 is selected. If overrange is shown on the LED display then select x2 and multiply the display by 2. If the musician coincides the first beat of the bar of the music with the clicks of the Rhyth-ROM then the LED display will obviously show bars-per-minute. The speed of the music in ballroom dancing is very important. A modern waltz should be 32 bars-per-minute, a quickstep 48–50.

The tempometer mode is selectable by turning the tempo pot fully anticlockwise so that its switch is operated. The Rhyth-ROM's speaker will then click when the rhythm button is pressed. Tap along with each beat of the music with the rhythm button and the LED display will show the tempo being played.

In the resistor manufacturing industry, resistor blanks are cut to length by a machine. Metal cups are then fitted by another machine and then a helix is cut by a laser spiral machine. All these machines are of a cyclic nature and production managers are very anxious to know their production rates in pieces-per-minute. The Rhyth-ROM is simply tapped in time with the machine and after a minimum of two taps the production rate is shown.

After a workout in the gym, feel your pulse and tap the Rhyth-ROM to measure your heart rate. The speed at which your heart recovers is an indication of how fit you are. It will probably indicate that you should be spending less time constructing electronic circuits and more time jogging.

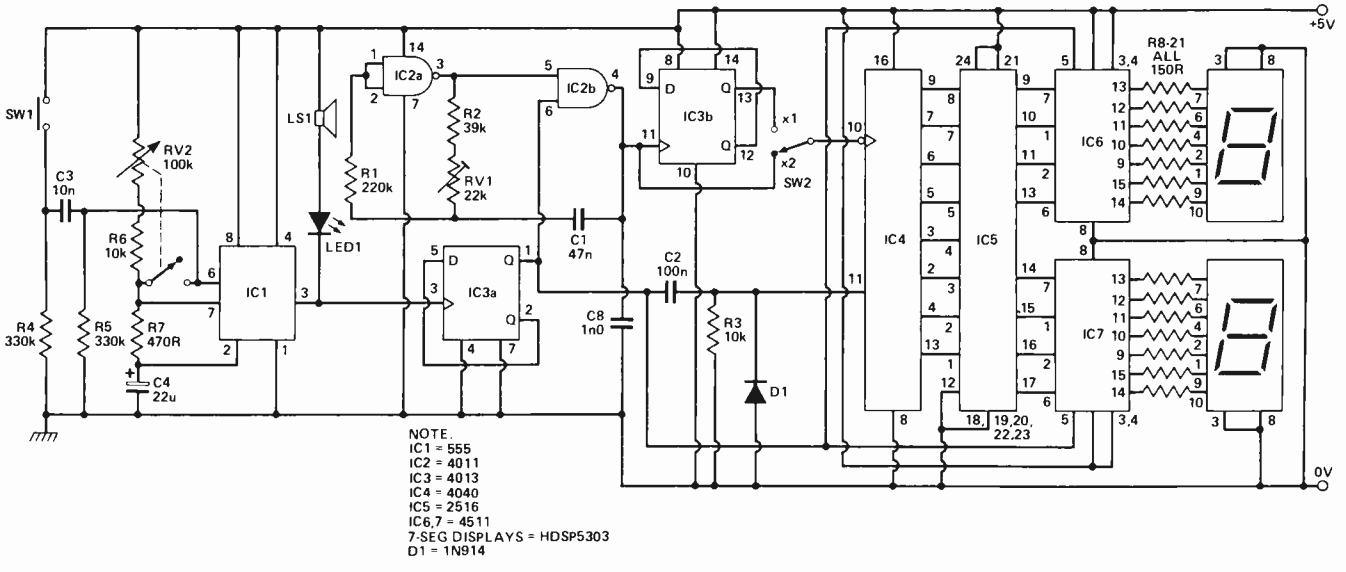

Fig. 1 The circuit diagram of the Rhyth-ROM.

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EPROM Address HEX	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0000	A1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0010	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0020	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0030	.	.	.	.	.	.	.	.	.	.	.	A1	99	98	97	95
0040	94	92	91	90	88	87	86	85	83	82	81	80	79	78	77	76
0050	75	74	73	72	71	71	60	69	68	67	67	66	65	65	65	63
0060	63	62	61	61	60	59	59	58	58	57	57	56	56	55	55	54
0070	54	53	53	52	52	51	51	50	50	50	49	49	48	48	48	47
0080	47	47	46	46	45	45	45	44	44	44	43	43	43	43	42	42
0090	42	41	41	41	41	40	40	40	39	39	39	39	38	38	38	38
00A0	38	37	37	37	37	36	36	36	36	36	35	35	35	35	34	34
00B0	34	34	34	34	33	33	33	33	33	32	32	32	32	32	32	31
00C0	31	31	31	31	31	30	30	30	30	30	30	30	29	29	29	29
00D0	29	29	29	28	28	28	28	28	28	28	28	27	27	27	27	27
00E0	27	27	27	26	26	26	26	26	26	26	26	26	25	25	25	25
00F0	25	25	25	25	25	24	24	24	24	24	24	24	24	24	24	24
0100	23	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 1. EPROM contents, only first 256 bytes are used.

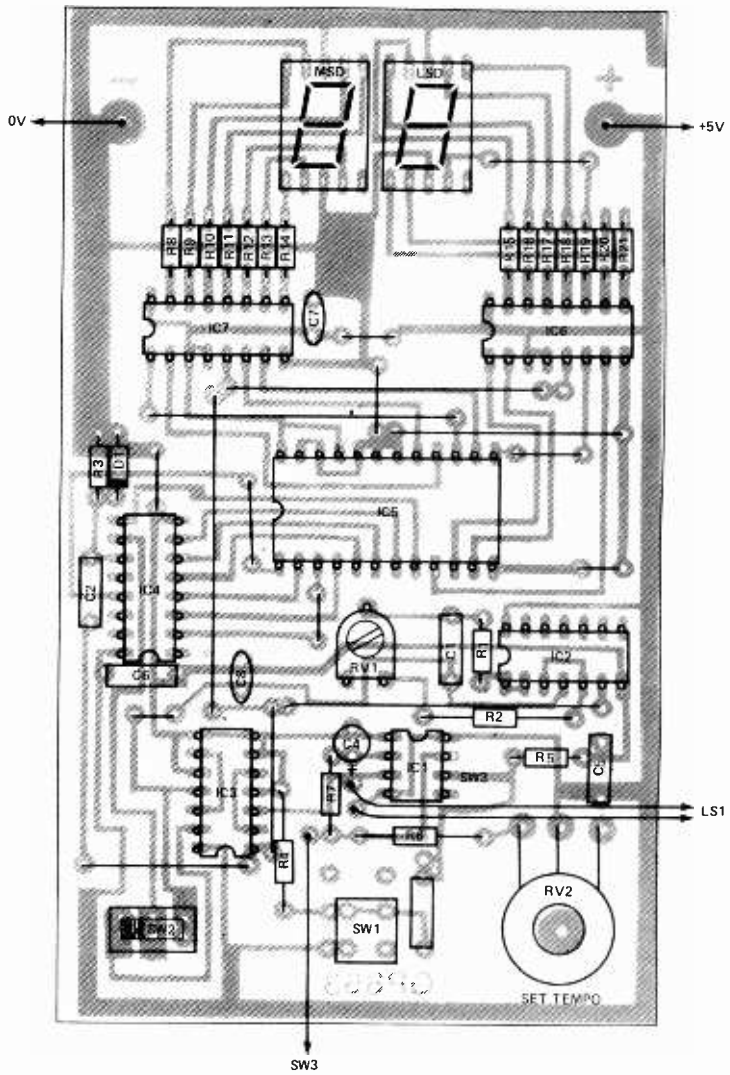

Fig. 2 Component overlay.

HOW IT WORKS

IC1 is a 555 timer connected in the astable mode. When the charge on C4 has increased so that the voltage at pin 6 increases to 2/3 of V_{CC}, then pin 3 goes low producing a click in the loudspeakers. Pin 7 goes low also which quickly discharges C4 via R7. When the tempo pot is switched to manual or tempometer mode, it is the rhythm button, SW1, which triggers IC1.

The pulses from IC1 are formed into a 1:1 mark space ratio by flip flop IC3a. At the positive going edge from IC3a, the binary counter IC4 is quickly reset to zero via C2, R3 and the contents of the EPROM, IC5, are latched into IC6 and IC7. The clock oscillator formed by IC2a and b is then enabled via pin 6 and depending upon the position of the x1–x2 switch, pulses from pin 4 of IC2b or IC3b are fed to the binary counter IC4. When pin 1 of IC3a goes to a 0, counting ceases and the stored count in IC4 selects the appropriate address of IC5. The data from IC5 is allowed into IC6 and IC7 by virtue of pins 5 being at 0. ICs 6 and 7 decode the data and drive the appropriate segments of the LED displays. When pin 1 of IC3a goes to a 1 again the whole process is repeated.

PARTS LIST

RESISTORS (all 1/4W 5%)

R1	220k
R3,6	10k
R4,5	330k
R7	470R
R821	150R
RV1	22k horizontal miniature pre-set
RV2	100k lin pot with switch

CAPACITORS

C1	47n
C2	100n
C4	22μ 16V electrolytic
C5,6,7	100n
C8	1000p

SEMICONDUCTORS

IC1	555
IC2	4011
IC3	4013
IC4	4040
IC5	2516 (or 2716) single rail EPROM
IC6,7	4511
D1	1N4148

LED Displays (two off) HDSP5303 or equivalent
Red LED

MISCELLANEOUS
Printed circuit board
50 ohm loudspeaker
PCB mounted switch, PCB mounted button, case, knob.

BUYLINES

The loudspeaker, button, switch, and LED displays are available from Maplin. The tempo pot with switch is available from Electrovalue. The pre-programmed EPROM and PCB are available from G P Electronic Services, 87 Willowtree Ave., Durham DH1 1DZ, at £5.20 for the PCB and £5.99 for the EPROM.

ETI

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MODULAR TEST EQUIPMENT

Mike Meakin describes the second of his low-cost, slot-together test gear modules — a 1Hz to 100kHz sine, square and triangular wave generator.

This article describes the construction of a waveform generator which assembles onto a single printed circuit board complete with all the necessary controls and connectors. It is one of a series of test equipment modules which we plan to present over the next few months which together form a versatile integrated test system. Each module is entirely self-contained on one PCB, removing the need for cases and all the other hardware usually required and allowing a high performance test system to be assembled at minimum cost.

The heart of the system is a power supply module which was described in last month's ETI. As well as providing variable voltages to power equipment under test, it also provides the correct voltages to drive each of the other modules and so avoids the costs associated with providing separate PSUs. Ideally the power supply module should be built first, but there is no reason why the waveform generator should not be fed from any other suitable supply if constructors don't require all the facilities of the main PSU or want to assemble the modules in some other order.

The waveform generator produces sine, triangle and square wave outputs variable in frequency from 1Hz to 100kHz and with an output level of up to 5V RMS. The board continues the basic design philosophy of the system by having switches and potentiometers which mount directly onto the board. The switches are designed for preset programming but should still have a life of about 20,000 operations. They can be operated by a small screwdriver. The potentiometers are of a type normally used as presets and are small, PCB mounting and have an integral knob.

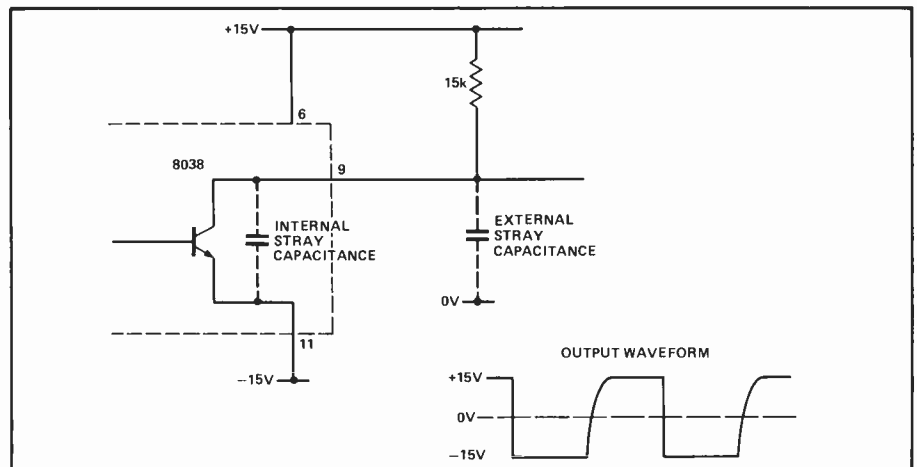

Fig. 1 Internal and external capacitances are charged through the 15k pull-up resistor and prevent the output voltage rising quickly on the leading edge of squarewaves.

While superior performance can be obtained from waveform generators using op-amps and discrete components, it was decided for reasons of simplicity and cost to use an IC. The 8038 was chosen because it is readily available and offers reasonable performance for its cost. However it is not without minor problems.

These arise when using the square wave output, which consists of an open collector NPN transistor with its emitter connected to the negative supply

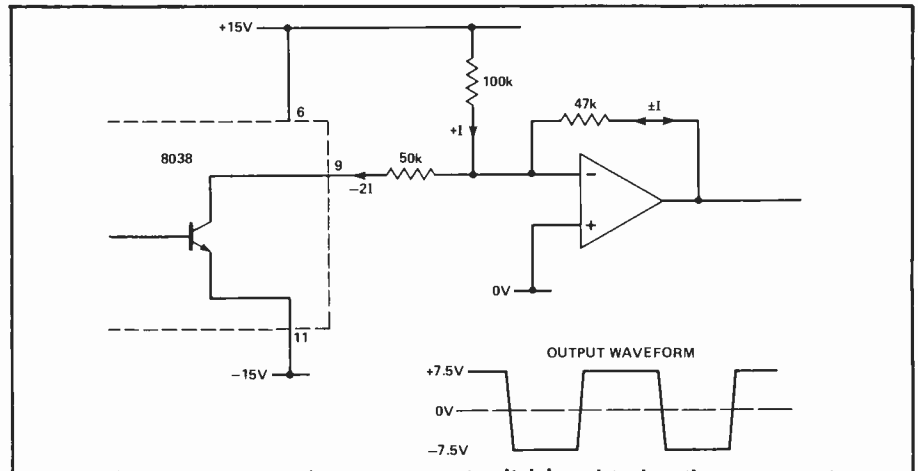

Fig. 2 Using the output transistor as a current switch in a virtual earth arrangement minimises the effect of the stray capacitances and gives a greatly improved rise-time.

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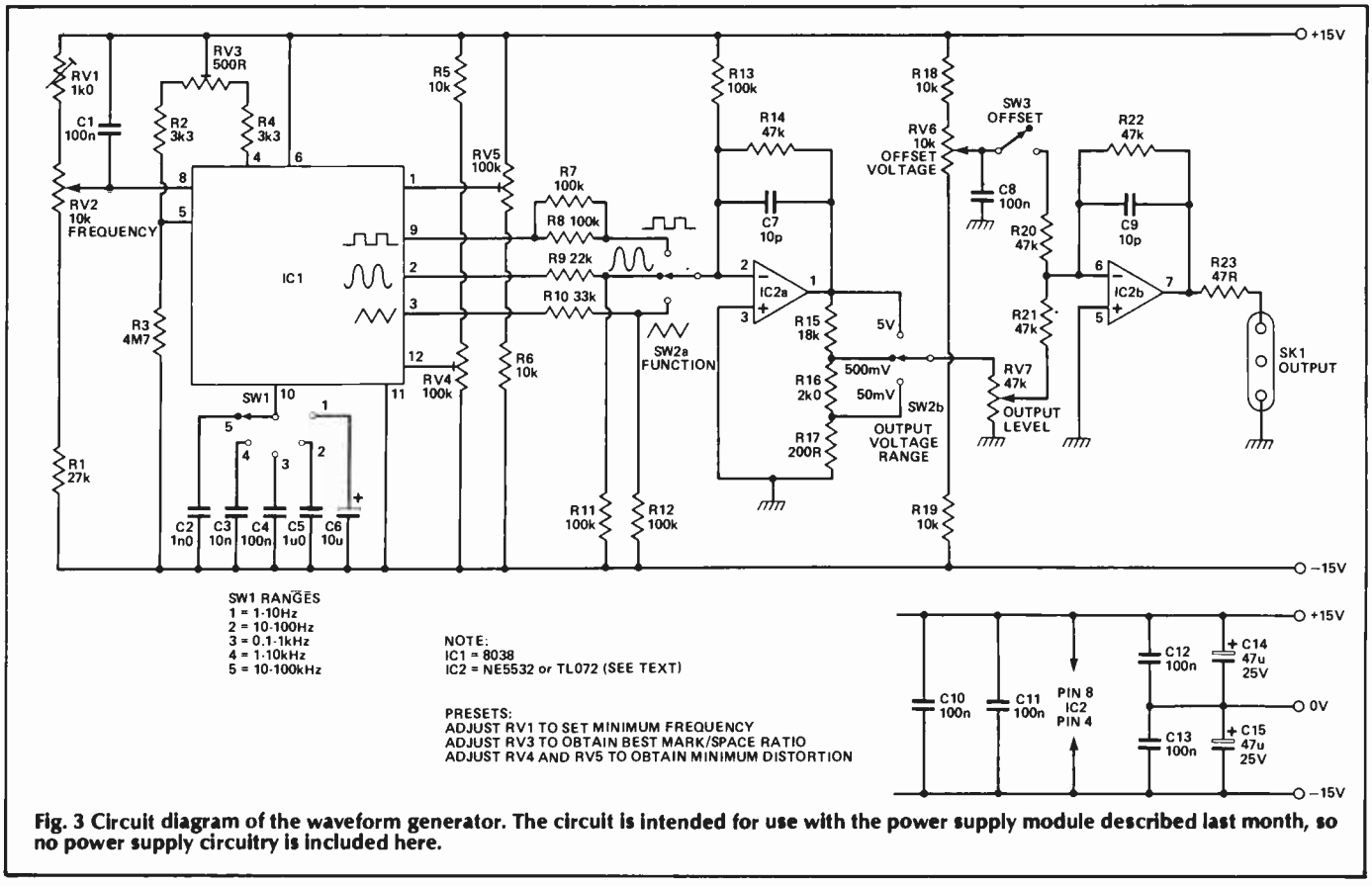

Fig. 3 Circuit diagram of the waveform generator. The circuit is intended for use with the power supply module described last month, so no power supply circuitry is included here.

HOW IT WORKS

The 8038 is configured in the manufacturers application circuit and interested readers should refer to the Intersil data sheet. RV2 controls the frequency with RV1 setting the minimum frequency. The component values chosen allow a 1:10 frequency range to be covered in 5 switched overlapping ranges.

The output waveforms are buffered and scaled by IC2a to give an output of 5V RMS±7V p-p for the sine wave output and similar peak to peak outputs for the square and triangle waveforms. A passive attenuator, R16-R17, and the output level control RV7 give three switched decade ranges and continuous level control.

The output amplifier consists of a unity gain inverting amplifier which sums the output from RV7 with a switched variable DC offset of ± 5V controlled by RV6 and SW3. A47R resistor in series with the output provides additional protection for the output amplifier under short circuit conditions

The power supplies are decoupled both by 47u electrolytic capacitors and polyester capacitors. The module consumes about 30MA from each 15V supply rail.

BUYLINES

Verospeed and Cricklewood are among those who can supply the enclosed horizontal presets and RS Components stock the carbon track presets with integral knob. RS will only accept orders from trade and professional customers but Crewe-Allen & Co of 51 Scurtton Street, London EC2 will obtain parts from them on payment of a small handling charge. The stock numbers are 184-350 for the 10k presets and 184-372 for the 47k preset.

The DIL switches used on the prototype were on ERG DS16D 1-6 or SW1 and an ERG DS16D 1-3 + 1-3 for SW2. ERG will not handle small orders but electronics clubs and other groups prepared to order reasonable quantities could try contacting them directly at Luton Road, Dunstable, Bedfordshire LU5 4LJ, tel 0582-62241. The PCB has extra holes to allow eight position switches to be used instead (the extra positions can be ignored) and RS stock number 337-532 could thus be used as SW1. A standard eight-way DIL switch could be used as SW2 but you would have to make sure that only one switch in each group of four is ever on at one time. Another alternative is to use standard rotary or slide switches and glue or bolt them to the board.

The PCB will be available from our PCB Service.

pin. The manufacturers recommend pulling the output up to the plus 15V supply via a 15k resistor. Both internal and external stray capacitances are charged via this pull up resistor, so the square wave output has slowly rising edges which are particularly noticeable at high frequencies (Fig. 1).

A more serious problem is that when the square wave output is used, spikes appear on the peaks of the sine wave output. These may possibly be due to internal earthing arrangements within the IC itself and the only sure cure is to disconnect the pull up resistor.

Both of these problems can be minimized by using the circuit shown in Fig. 2. The output transistor is now used as a current switch in a virtual earth op-amp circuit. When the transistor is off the output of the op-amp goes to approximately −7.5V due to the 100k resistor connected to the +15V supply. When the transistor conducts a current is drawn from the virtual earth and the output of the op-amp rises to +7.5V to supply this current. Rise and fall times of the square wave output are much improved and this configuration allows the use of a single pole switch, with

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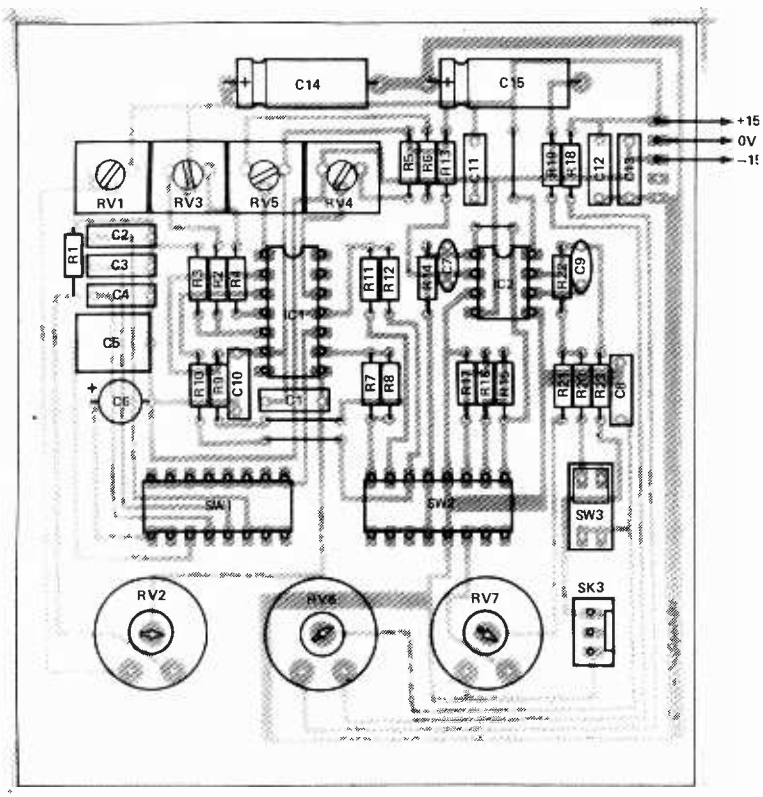

Fig. 4 Component overlay for the waveform generator PCB.

disconnection of the pull up resistor when not selected.

There is a choice of output amplifier. A TL072CP biFET op-amp can be used for low cost or alternatively an NE5532 dual low-noise op-amp can be used for superior output performance. This IC can deliver over 10V RMS into a 600R load and was designed specifically for audio applications.

Construction

Because the waveform generator is designed for use without a case or front panel, the range markings on SW1 and the other legends will all have to printed on the PCB itself. This is best done by screen printing the boards, but the cost is considerable and we have decided to supply the boards without screen printing in order to keep the price down. This allows constructors to choose their own method of labelling.

The cheapest method would be to mark the boards with a chinagraph pen or something similar. It might also be possible to use embossed tape (eg, Dymo) but the character size would probably be too large to allow much information to be fitted in the available space. Labelling by either of these methods is best done when the board has been assembled.

A better but more expensive method is to use rub-down lettering. This would have to be done before installing any of the components. Begin by cleaning the upper surface of the board thoroughly with a suitable solvent and then spray on a light coat of clear varnish — the type sold in motoring shops for lacquering chromework is quite good. Wait until the varnish is thoroughly dry then loosely install the components which require labels and note how much space you have around them.

It is best to use white letting rather than black since it shows up well against the board. Most art shops stock sheets of rub down lettering in a variety of typefaces and typesizes, but white is less frequently used than black and you may have to order some and wait. The most widely available lettering has a series of parallel broken guide lines on the sheet, and these can be lined up against the edge of the PCB as each letter is rubbed down to ensure that the row of lettering is straight. Check frequently as you work that none of the lettering will be obscured by the components when they are inserted, and when all is finished apply several coats of varnish at suitable intervals and leave to dry.

Installing the components should present no problems provided a reasonable degree of care is taken and the overlay diagram is followed closely. Begin by soldering into place the wire links, the socket, the switches and, if you are using them, the IC sockets, then move on to the resistors, the potentiometers and the capacitors. The hole positions may need to be adjusted with a small file if you are using potentiometers which are physically different from those used on the prototype. Finally, install the two ICs, making sure that they are the right way around.

If you are using the waveform generator with the power supply

PARTS LIST

RESISTORS	
R1	27k
R2, 4	3k3
R3	4M7
R5, 6, 18, 19	10k
R7, 8, 11, 12, 13	100k
R9	22k
R10	33k
R14, 20, 21, 22	47k
R15	18k
R16	2k0
R17	200R
R23	47R
RV1	1k0 enclosed horizontal preset
RV2, 6	10k carbon track preset with integral knob
RV3	500R enclosed horizontal preset
RV4, 5	100k enclosed horizontal preset
RV7	47k carbon track preset with integral knob
CAPACITORS	
C1, 4, 8, 10–13	100n polyester
C2	1n0 polyester
C3	10n polyester
C5	1u0 polyester
C6	10u 35V tantalum
C7, 9	10p ceramic
C14, 15	47u 25V axial electrolytic
SEMICONDUCTORS	
IC1	8038CC (Intersil)
IC2	NE5532 or TL072 (see text)
MISCELLANEOUS	
SK1	3-way Molex plug
SW1	1-pole 6-way DIL slide switch
SW2	2-pole 3-way DIL slide switch
SW3	single-pole DIL switch

PCB; IC sockets if desired, 1 off 14 pin and 1 off 8 pin DIL.

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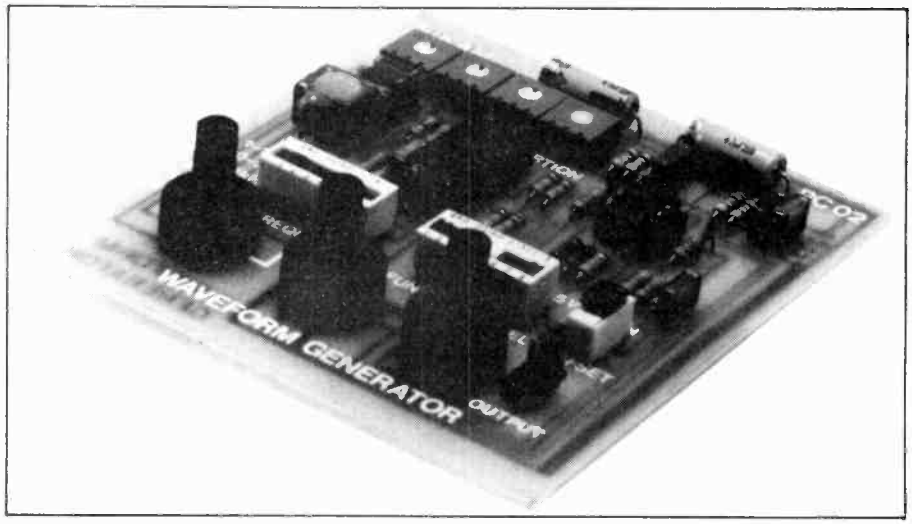
module described last month, solder leads from the appropriate pads on the generator to the thick copper tracks on the supply board. Note that only the ±15V rails are needed and that the +5V output from the supply is not used. If you have not built the power supply module, you will need a regulated ±15V supply in order to operate the waveform generator. The current drawn will be about 30mA from each rail.

Testing And Setting Up

Set the potentiometers and presets to their mid positions, the function switch to sine, the range switch to 100Hz – 1kHz, the level switch to 5V and the offset switch to off. Apply power and monitor the output, either with a 'scope or by connecting it to an audio amplifier. For those without access to any other test gear, there is little more that can be done at this stage apart from checking ranges and operation of the offset control. However, in a future article the construction of a universal counter timer/frequency meter will be described which will allow the complete setting up to be carried out.



Those who have a 'scope and frequency meter should select a square wave output at a frequency of about 100Hz and adjust the mark space ratio for 50% duty cycle using the preset RV3. The frequency span should be adjusted for a 1:10 range using RV1 and the frequency potentiometer, RV2. There is considerable overlap of the ranges.

Switch to sine wave output and trim the distortion presets until you get the best wave shape. These interact with each other and can best be adjusted by looking at the waveform on a scope. A distortion meter could be used if you have access to one. Finally, check the output levels.

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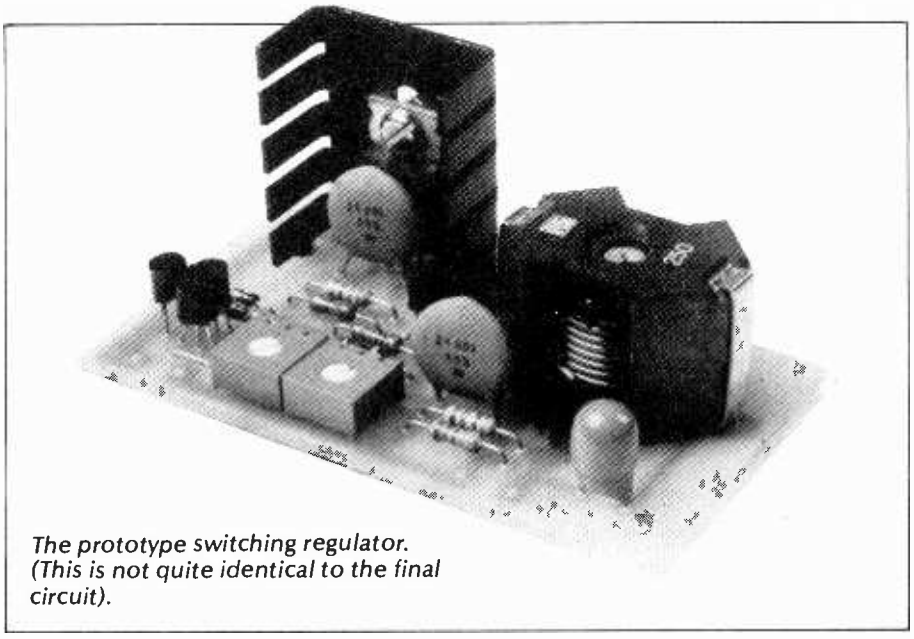
SWITCHING REGULATOR

To kick-off a new, occasional series on circuits using discrete components only, Paul Chappell brings you a switching regulator that will provide a steady 5V at up to 1A.

I wonder if you can guess how many projects featured in ETI this year have *not* included at least one IC? Apart from a Tech Tip, which was almost apologetic about the fact, I can't find any at all. Now, I'm not advocating a return to the electronic stone age of cat's whisker and Leyden jars. Contrary to popular belief it really is possible to design circuits with discrete components that work well and don't use an excessive number of parts. The chances are you'll have most of the components in your spares box anyway, so the project won't cost much to build, and if anything burns it will be a 10p transistor and not a £10 IC. The best thing of all about using discrete components is that you can experiment with every part of the circuit, since it's not set solid in a block of silicon. Convinced? Then read on.



The prototype switching regulator. (This is not quite identical to the final circuit).

Switching Regulators

This month's circuit is a switching regulator. The basic circuit delivers 5V at 1A and has an efficiency of around 80%. With an input of 20V and a small heatsink on the switching FET, the circuit runs under full load at what washing powder packets call 'hand hot'. You can comfortably touch the heatsink without asbestos gloves, which is more than can be said for linear regulators under the same conditions. The output current capability can easily be increased with a suitable choice of FET and some attention to the choke.

No doubt you're all aware of the ideas behind switching regulators so I'll be as brief as possible. The main problem with linear regulators is that they waste a lot of power. If we have an input of 20V and need an output of 5V at 1A, the regulator has to drop 15V and pass a current of 1A plus whatever its internal circuitry needs, and my calculator says that this comes to more than 15W. As the output to the load is only 5W the efficiency of the best linear regulator in the world under these conditions is going to be less than 25%.

A switching regulator, on the other hand, can have an efficiency of 100% in theory. When a switch is on it passes current but has no voltage across it. When it is off, it has a voltage across it but no current flows. In either of these conditions V x I = 0, so no power is lost. Naturally the 100% efficiency can never be achieved, partly because the regulator's internal circuitry requires some current, but mainly because of imperfections in the switch. The most serious imperfection is the time taken to switch from one state to the other, during which period it will be wasting power. Sensible efficiencies to aim for are between 70 and 85%.

One way a switch can be used to drop an input voltage is shown

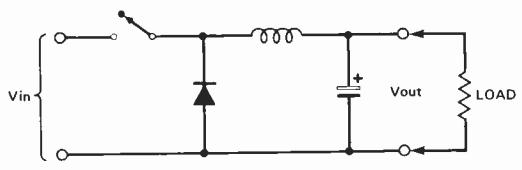


Fig. 1 Basic switching regulator configuration.

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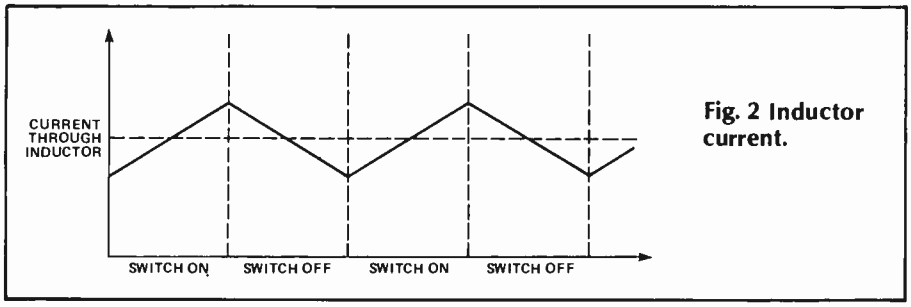

Fig. 2 Inductor current.

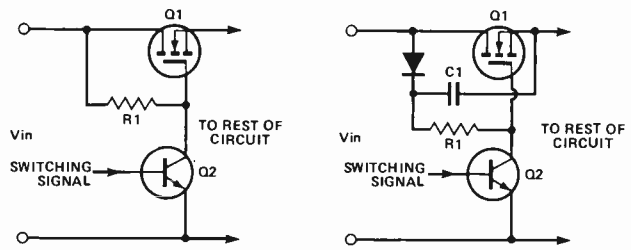

Fig. 3 (left) Basic drive circuit and

Fig. 4 (right) improved bootstrap drive circuit.

in Fig. 1. When the switch is closed, current begins to flow in the inductor and Vout starts to rise. When the switch is open, the inductor will produce a voltage in the direction needed to maintain the flow of current, so the right hand side will become positive with respect to the left hand side. As the voltage at the right hand side can't change instantly, because of the capacitor, the left hand side will go negative until it is 'caught' by the diode at 0V or thereabouts. Current will continue to flow into the load, the circuit now being completed by the diode, but will reduce as the energy stored in the inductor leaks away. If the switch is continuously opened and closed, the current through the inductor will vary about a mean level, and as long as the switch is operated frequently enough it will never stop flowing altogether. The inductor effectively smoothes out the pulses from the switch.

For a given load, the output voltage will depend on the mean current and therefore on the ratio of 'on' to 'off' times of the switch. With the addition of some circuitry to sense the output and keep it at a constant level by operating the switch, we have a switching regulator.

The Switch

I chose an n-channel MOSFET as the switching element more for reasons of economy than anything else. P-channel devices tend to cost around twice the price of their n-channel counterparts, so it makes sense to avoid them where possible.

The circuit of Fig. 3 would work as a means of driving the FET, given a high enough input voltage to allow Q1 to be driven hard into conduction and a small enough value of R1 to charge the gate capacitance within a reasonable time. (The faster Q1 turns on, the lower will be the power it will dissipate, so the higher the efficiency of the regulator.)

The circuit of Fig. 4 gives an improvement in turn-on time. The idea is that when the drive transistor Q2 is conducting, the FET will be turned off, its source

HOW IT WORKS

Q5, D3, L1 and C5, 6 and 7 correspond to the parts shown in Fig. 1 with Q5 taking the place of the switch. Q3 acts as a constant current source giving 1mA into the emitters of Q1 and Q2. The portion of the current that each transistor will take depends on the relative voltages of their bases. If Q1 base is at a much lower voltage than Q2 base, Q1 will take the current. If Q2 base is lower than Q1 base, Q2 gets the current. There is a small linear region when the base voltages are almost equal and the transistors share the current, but othewise one transistor or the other gets the lot. A portion of the output voltage is tapped off by RV1 and applied to the base of Q1 while Q2 base is held at a constant voltage by D1. (I used a band-gap reference diode there, by the way, but in this application a zener would be just as good.) RV1 is set so that when the output is at exactly 5V, the voltage at the slider equals the voltage of the reference diode. If the voltage at the output rises, so will the voltage of Q1 base, so current will be steered into Q2, turning on Q4 which in turn takes the gate of Q5 low. This turns off Q5, the current in the inductor begins to decay, and when the inductor current becomes lower than the load current the output voltage will begin to drop. When the output voltage drops below 5V, Q1 base goes low with repect to Q2 base so current is steered into Q1 and away from Q2. Q4 then turns off, allowing the bootstrap action of C4 and R5 to take the gate of Q5 high. Q5 turns on, the current in L1 builds up, the output voltage eventually rises slightly and the whole cycle takes place again. The entire circuit will therefore be in a state of continuous oscillation — around 100kHz in the prototype.

The action of the bootstrap components is described elsewhere. C2 and R3 serve to pull Q1 and Q2 quickly through their linear region to improve the comparator action.

This type of circuit is known as a ripple regulator because the switching is controlled entirely by the ripple on the output. It has the advantage of simplicity but the disadvantage is that the switching frequency will vary considerably with changes in the load, so it is not possible to tune the circuit for optimum performance at one particular frequency. Output filtering to give a perfectly smooth voltage is also more difficult.

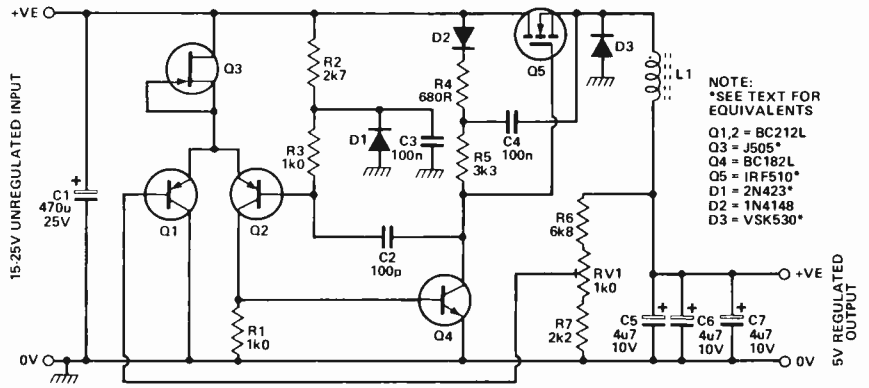

Fig. 5 Circuit of the switching regulator.

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PARTS LIST

RESISTORS (all ¼W, 5%)

R1, 3	1k0
R2	2k7
R4	680R
R5	3k3
R6	6k8
R7	2k2
RV1	1k0 horizontal cermet

CAPACITORS

C1	740μ25V electrolytic
C2	100p ceramic
C3, 4	100n ceramic
C4	100n ceramic
C5,6,7	47μ 10V tantalum

SEMICONDUCTORS

Q1, 2	BC212L
Q3	J505 (or equivalent see text)
Q4	BC182L
Q5	IRF510 (or equivalent see text)
D1	ZN423 (or equivalent see text)
D2	1N4148
D3	VSK530 (or equivalent see text)

MISCELLANEOUS

L1 18 turns 19 SWG on RM10 pot core; PCB.

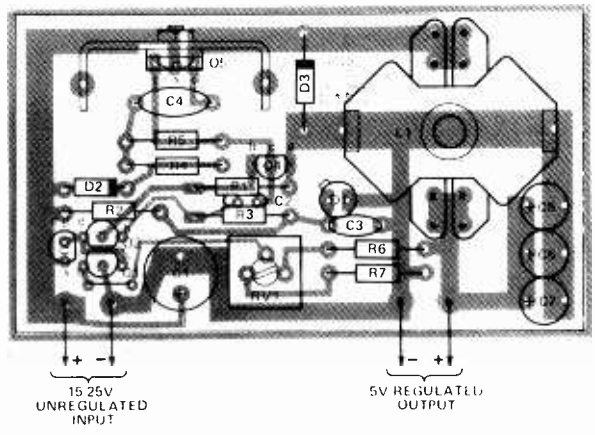

Fig. 6 Component overlay for the switching regulator.

voltage will be at 0V or thereabouts, and C1 will charge up to the full input voltage. When Q2 turns off, Q1 conducts and its source voltage rises to the input voltage. The voltage across C1 remains, and as the voltage at Q1 source rises, so does the voltage at the other end of C1. This reverse-biases the diode and lifts the voltage at the top of R1 to almost twice the input voltage. This gives a considerable improvement in turn-on time and allows the circuit to be used with smaller input voltages than would otherwise be possible.

Components For The Regulator

Most components in the circuit are working under conditions that are not too demanding, and following Auntie Static's advice (ETI September, 1985) I have stuck to general purpose devices. There are a few exceptions.

D3 must have a low forward voltage drop and short recovery time. I chose a Schottky barrier rectifier but a silicon fast recovery device would also do the trick, although the much higher conduction voltage drop of these would mean lower efficiency for the regulator. Components you can't use are signal diodes (when Q5 is off, D3 takes the entire load current) or ordinary rectifier diodes like 1N4001 (the reverse recovery is painfully slow.)

D2 must also have a fast recovery, but as all the requirements are met by a general purpose 1N914 or 1N4148 there is no need for anything exotic here.

The choke L1 is working under difficult conditions. It must pass the entire DC component of the output current as well as dealing with any fluctuations, so care must be taken to avoid saturation of the core. Two other points to watch if you want to make any changes to L1 are that it is one of the components which determines the oscillation frequency of the circuit, and secondly that it can radiate a good deal of EM interference. Remember that the circuit is producing powerful oscillations at low radio frequencies, so interference with other equipment can easily become a nuisance.

Finally, you may wish to choose a different FET. Some desirable characteristics are a low drain-source resistance (r ds(on)) short rise time (tr) and fall time (tf), high foward transconductance (gfs) and low input capacitance (Ciss).

Experiments, Modifications, Etc

If you have never built a switching regulator before, don't just take my word for it that the components should be such-and-such. Replace D3 with a 1N4002 and see what happens!

The circuit could be improved by better output filtering. You should bear in mind that there's no point in increasing the size of the capacitors on the output. About 20mV of ripple is needed to switch the circuit and increasing the capacitor value will just slow down the frequency of oscillation. Any additional filtering will have to be 'tacked on the end' of the circuit.

There are two fairly important things that the circuit lacks: a soft start and overload protection, The idea of a soft start is that the input voltage should be established before the regulator begins to deliver current to the load, to ensure that the regulator will function correctly. The easiest way to achieve this is to introduce a time delay, as shown in Fig. 7. This method is not ideal because the regulator would switch on even if the input only rose to 4V and stopped, but it will cope with normal powering up and most fault conditions. As Vin rises, the transistor in parallel with Q4 holds Q5 off. When Vin reaches its final

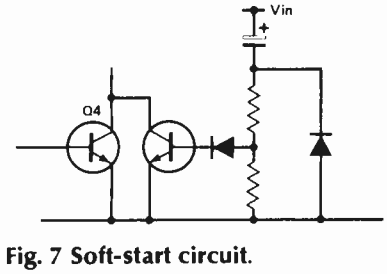

Fig. 7 Soft-start circuit.

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value, the capacitor will continue to charge through the resistors until the negative plate drops below the voltage needed to hold the transistor on. The regulator can now start working. The diode to ground discharges the capacitor quickly when Vin falls. The diode

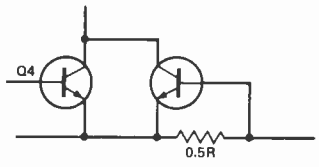


Fig. 8 Simple current limit.

in series with the transistor base is to increase the amount of ripple that can be present on Vin without switching the transistor on and off.

The circuit of Fig. 8 is a simple form of over-current protection. At a little over 1A the extra transistor will begin to turn on, limiting the voltage applied to the gate of Q5. This circuit is not ideal as the resistor will waste power at all times. More important, the action of the circuit is to reduce the switching efficiency of Q5 which will get rather hot under overload conditions.

A circuit with possibilities is shown in Fig. 9. The extra transistor allows Q1 to work as normal when Vout is high. If Vout drops, conduction in the transistor is reduced and R begins to take the collectors high. A point will quickly be reached where Q1 can no longer pass any current; Q2 gets it all and holds off Q5 by the normal action of the circuit. Q1 collector will end up at a voltage higher than its emitter. As transistors work 'back to front' to some extent, the effective circuit will be as shown in Fig. 10 with Q1 supplying extra current to hold Q2 hard on. The regulator will be locked off and will not supply any current at all.

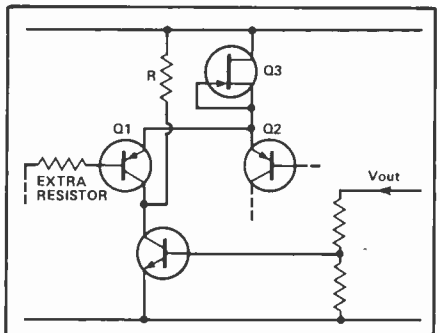


Fig. 9 A possible protection circuit.

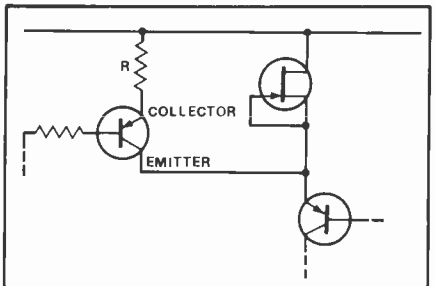
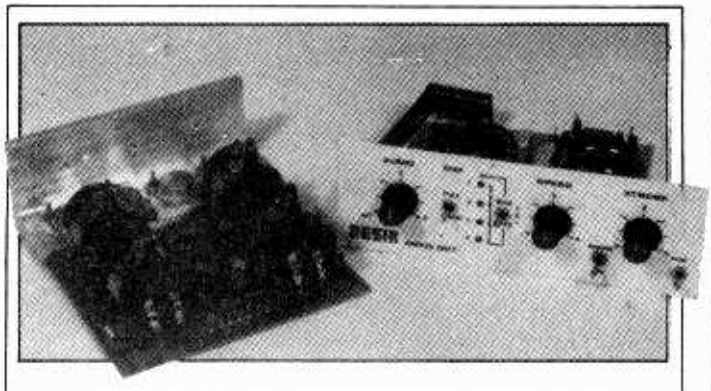


Fig. 10 No, the labels aren't wrong...

Naturally, arrangements will have to be made to ensure that the extra transistor turns on when power is first applied. The regulator will then be reset after overload by turning the supply off and on again. With a little ingenuity the transistor could be switched by a sudden drop in the output voltage rather than at a certain voltage level. As all good text books say, I leave these as an exercise for the reader. . . . .

ETI



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ETI MILLI-FARADOMETER

This one is definitely wacky, but it's also an ingenious and reliable way of measuring large-value capacitors. Thank God it's Faraday, we say, and thanks to designer Ray Bold.

This instrument is capable of measuring capacitors in the range 1μF to 100,000μF, and was inspired by the purchase by the author of a 'goody bag' containing a huge number of unmarked electrolytics, and the prospect of a long tedious exercise using a bridge to measure them. A handy electromechanical counter and some development work led to the construction of a prototype instrument from which this design derives.

Construction is straightfoward. The meter uses a bench supply rated at 12V DC and the full load current is in the region of 200mA.

Theory

If a capacitor, which is initially discharged, is charged from a constant current source, the voltage across it will change linearly with time. The time taken to charge to a given voltage will be dependent on the size of the capacitor and the magnitude of the charging current. Expressed mathematically,

$$CV = It$$

or

$$t = CV/I.$$

If we fix V and I, then t will be a function of C, and if we then arrange to measure t, we will also be measuring C.

In this design, a constant current of either 9μA, 90μA, 900μA or 9mA is supplied to the capacitor under test (CUT). The voltage across the capacitor is monitored by a window comparator and, while the voltage is within the limits of the window comparator, a counter operates at approximately 10Hz to give an

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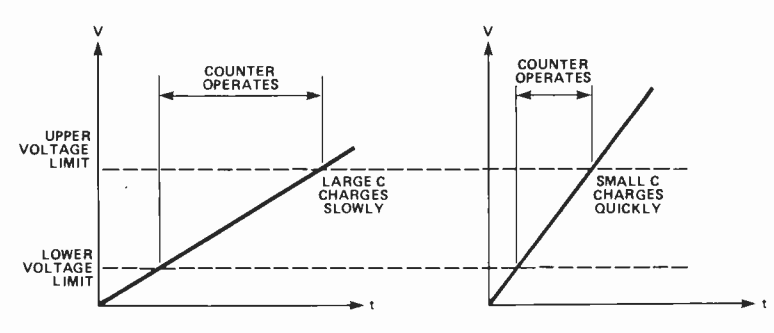

Fig. 1 Charging time between voltage limits is proportional to capacitance under constant current conditions.

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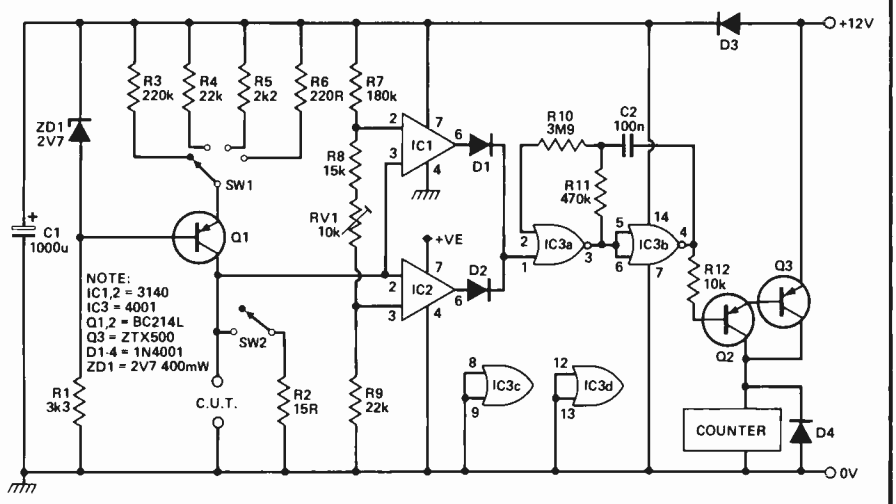

Fig. 2 Circuit diagram of the ETI Millifaradometer.

indication of the capacitor's size. Figures. 1 and 2 help to illustrate the theory.

Circuit Description

The circuitry around Q1 (Fig. 3) forms a constant current source with the current being selected by SW1. The capacitor under test is connected to the terminals marked CUT. SW2 and R2 remove any initial charge on the capacitor. When SW2 is opened the capacitor charges at a constant current and its voltage increases linearly with time. Since the relationship is CV = It, for a given current, the voltage will rise between two limits over a time determined by the value of the capacitor.

IC1, IC2 and associated components form a window comparator whose output goes low when the voltage across CUT lies within certain limits. The limits can be adjusted by RV1, so providing a means of calibration. The window comparator gates the astable built around IC3 which counts at the rate of approximately 10Hz, driving the counter via Q2 and Q3 as long as it is gated on.

D3 and C1 decouple the supply to the sensitive parts of the circuit and protect them from the interference generated by the counter. D4 suppresses the spikes generated by the counter. Figure 3 shows the voltages at various parts of the circuit during a measurement cycle.

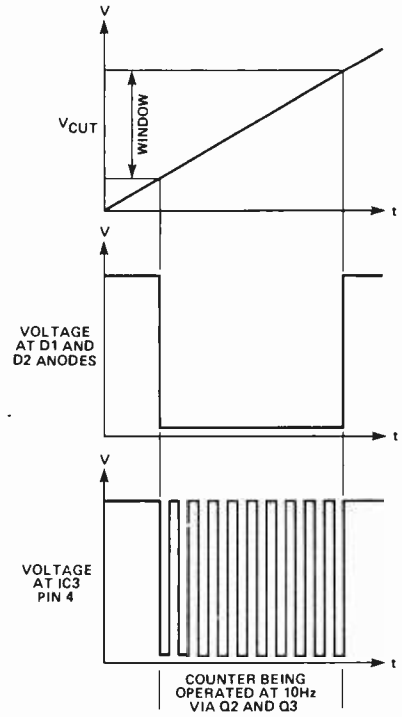

Fig. 3 Voltages at key points in the circuit.

BUYLINES

The counter used in the prototype was supplied by MS Components, Zephyr House, West Norwood, London SE27 9HL, (01-670 4466), catalogue no. 9036, price £5.75. Its dimensions are: 45.7 x45.7 x 50.5mm (depth to end of terminals), cut-out size 37x23mm. The case was also supplied by MS Components, catalogue no. 4108, price £2.71. Its dimensions are 170 x 143 x 56mm. No other components should pose any problems and the PCB will be available from our PCB Service.

HOW IT WORKS

The Millifaradometer consists of four basic sections.

a) A constant current generator based on Q1 and associated components.

b) A window comparator built around IC1 and IC2.

c) A gated astable multivibrator around IC3a and IC3b.

d) A counter and driver transistors Q2 and Q3.

With SW2 closed, the capacitor to be measured is connected across the terminals marked CUT. The switch and 15R resistor ensure that the capacitor is discharged at the outset. When SW2 is opened the capacitor charges up via Q1, and the voltage increases linearly at a rate dependent on the current and size of capcitor.

When the bottom of the 'window' (set by the divider chain R7, R8, R9, RV1) is reached, the output of the window comparator goes low gating on the astable multivibrator IC3a and b. This runs at approximately 10Hz and drives the counter via Q2 and Q3. After a time, determined by the value of the charging current, the size of capacitor and the width of the window (set by RV1), the output from the comparator goes high and the counter stops.

The charging currents and window width are so arranged that on range 1 the voltage across a capacitor of 10μF will change by 1V/s and during this time the counter will count to 10. A capacitor of 20μF will take twice as long and count to 20 in 2 seconds on range 1. On the X 1000 range a capacitor of 47,000μF will take 4.7 seconds to change its charge by 1V and the counter will register 47.

Construction

The printed circuit overlay is shown in Fig. 4 and is mounted using two of the mounting posts in the case, drilled 3mm. The board is drilled 3.5mm and 3mm set screws are used. Another 3mm set screw, with nut and spacer is inserted just above IC1.

Take care to mount polarised components and semiconductors correctly, and solder in the semiconductors last. Component values are not critical but if R3 to R6 are close tolerance so much the better. Electrolytics have large tolerances which vary with age and temperature, so extreme accuracy is unnecessary.

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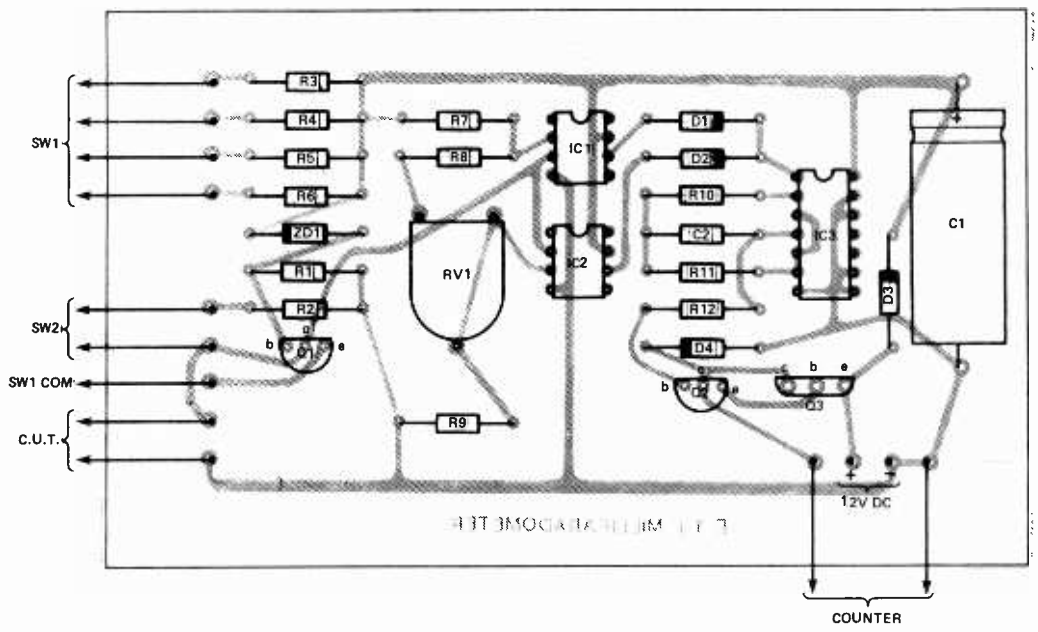
Fig. 4 Component overlay of the ETI Millifaradometer.



PARTS LIST

RESISTORS (All ¼w 5% carbon film)

R1	3k3
R2	15R
R3	220k
R4, 9	22k
R5	2k2
R6	220R
R7	180k
R8	15k
R10	3M9
R11	470k
R12	10k
RV1	10k horizontal skeleton preset

CAPACITORS

C1	1000μ 16V electrolytic
C2	100n polyester

SEMICONDUCTORS

IC1, 2	3140
IC3	4001
Q1, Q2	BC214L
Q3	ZTX500
D1 to 4	1N4001
ZD1	2V7 400mW zener diode

MISCELLANEOUS

SW1	Single-pole 4 way rotary switch
SW2	SPST toggle switch

Counter, 12V, 10 impulses per second with reset; case (console type); PCB; terminals; pointer knob; red and black 4mm plugs; connecting wire; set screws; nuts, washers, transfers.

Flying leads are used to connect the instrument to the bench power supply or 12V battery.

The panel layout is shown in Fig. 5. If the case is supplied with a protective film on the panel, leave this on until all marking out (with a ballpoint pen) and drilling is completed. Peel off the film just prior to lettering and assembly. This will reduce the risk of damage to the finish. Take care not to mount the counter any lower than indicated as clearance below is minimal. Even so, the terminals may need carefully bending a little, supporting them with pointed nose pliers near the body. After applying the lettering, the finish can be protected with two thin coats of clear laquer.

Setting Up

Find a capacitor of between 10 and 20 μF. If possible, measure it accurately on a piece of commercial equipment. Reset the counter to zero and connect the capacitor. With SW1 on the X1 range switch SW2 to test. The

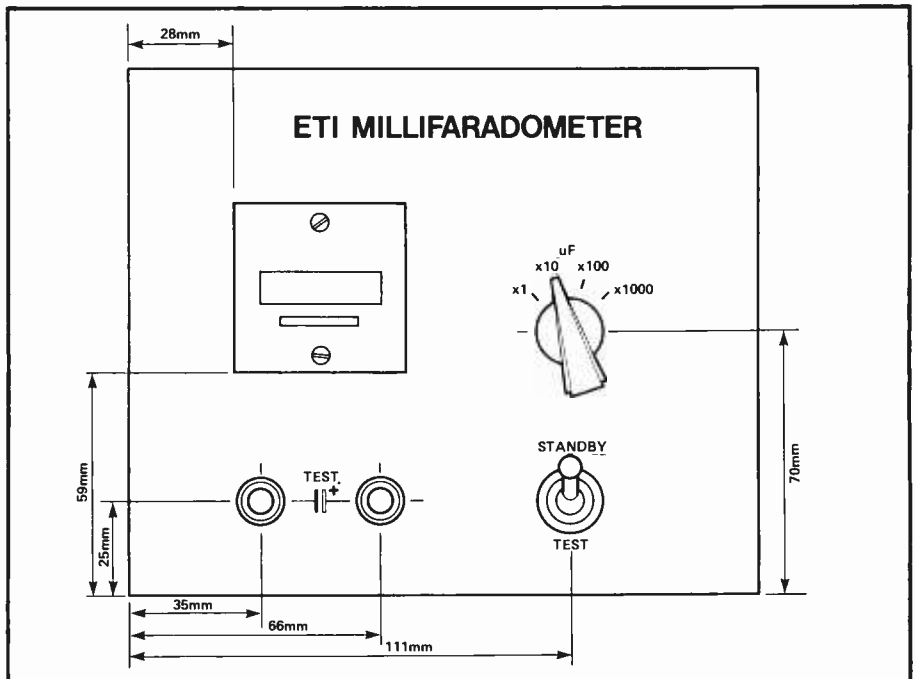


Fig. 5 Front panel layout of the ETI Millifaradometer.

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counter should operate. Note the reading and repeat the procedure adjusting RV1 to give consistently accurate results. With large value capacitors there is a delay before counting begins while the bottom of the window is reached.

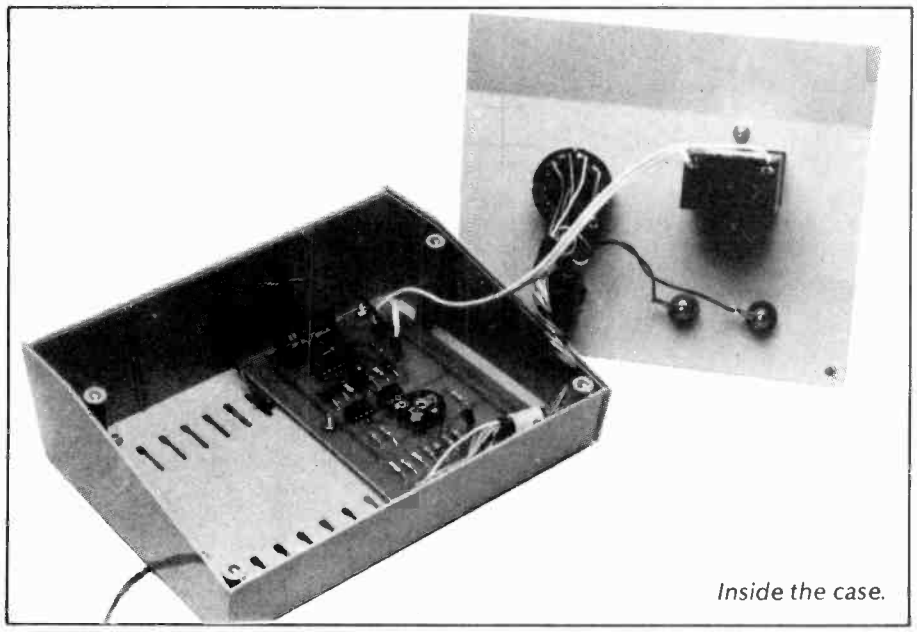
In Use

If in doubt about the value of a capacitor, set the range switch to a high range. The counter may count a couple of times or fail to count at all, which will indicate that a lower range is required. Starting on a low range may mean watching the counter for an excessive time until it stops. When counting finishes, simply add the number of zeros indicated by the range switch and that is the value of the capacitor.

To test another capacitor, switch the test switch up, replace the tested capacitor with the one to be tested, zero the counter and select a likely range. Then switch the test switch to test and watch.

After finding the value of a capacitor (bearing the +50%/–20% tolerance in mind) it is frequently possible to find the voltage rating by referring to catalogues, as these often give data including the physical size of capacitors.

The Millifaradometer can also be used to check electrolytics in faulty equipment. It should be remembered that a capacitor which is very leaky will charge slowly and seem to have a large value because of the current shunted through its own internal resistance. Capacitors which behave in this way should have their leakage checked with a multimeter set on resistance.



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CHORUS UNIT

Designed to complement the Noise Gate described in our July issue, Ian Coughlan's Chorus unit offers the maximum of versatility in the minimum of space.

Two of the most popular effects available to musicians are double-tracking and auto double-tracking, better known simply as echo and chorus respectively. The design to be described offers both of these effects in a simple, compact, battery-operated unit.

Double-tracking can be produced by placing a large, heavy, metal plate close to the vocalist or musician, to reflect sound back to the microphone. The result is a much richer, fuller sound. Strictly speaking, this ought not to be called echo since the time-delays involved are too short for the ear to interpret them as such. The subtle phase-differences produced will be interpreted quite correctly as a 'a large, heavy ojbect close to the sound-source'! Plates are still popular in the studio and many electronic delay units seek to reproduce their sound or perhaps offer several types of 'plate sound'.

Chorus is an attempt to emulate the sound of another instrument or voice playing or singing along in perfect harmony with the first. To understand what is involved in producing this effect, consider for a moment what an extra instrument or voice would sound like — exactly the same as the original. Either heard singly would be indistinguishable from the other, but heard together they will interact, producing subtle phase shifts which our ears then interpret as a second instrument or voice.

The chorus effect can be produced by delaying a portion of the audio signal, slowly varying this

HOW IT WORKS

IC2a is connected as a high-impedance input buffer, and R7 and C5 provide high frequency pre-emphasis, or boost, to the input signal. Part of this signal goes to Mix control RV1, and part goes through IC2b which has a gain of about 0.3 and then through a low-pass filter built around IC3a. This filter prevents high-frequency components from reaching the BBD line, IC4. IC4 requires two DC bias voltages, and these are provided by the divider chain R12, R13 and R14. The delay-line also requires two anti-phase clock signals, and these are supplied by IC5 which is a phase-locked loop IC, but is used in this design as a simple voltage controlled oscillator. IC4, a TDA1097, is specified for a supply voltage of no less than 12 volts. Because this is a compact battery-operated unit and the supply must be regulated, 5V is all it gets. It will work, but the performance suffers. In particular the attenuation from input to output, typically 0dB at 12V, is very much higher at the reduced supply voltage.

IC3b is configured as another low-pass filter, and gets rid of most of the clock-frequency from the output of the delay-line. Q1, a field-effect transistor, functions as a simple switch to gate the signal through to the next stage depending on whether or not the Effect is selected. The next stage is an amplifier with sufficient gain to compensate for the attenuation of the delay-line. The output from this stage goes to the Mix control. It can be seen that at one end of the Mix potentiometer is the un-delayed signal and at the other is the delayed signal. The position of the Mix control determines the proportion of each that appears at the output.

The 1n0 capacitor (C21) across the feedback resistor of IC2c will reduce the high-frequency response of this stage but remember that high-frequencies were boosted at the input stage, so the overall response is fairly flat.

IC6 is the sweep-generator. IC6a is an integrator, and IC6b is connected as a Schmitt. If the voltage on IC6 pin 7 is of a sufficiently high level, pin 1 will also be high. This will cause pin 7 to ramp downwards at a rate determined by R32, C23, C24 and the Rate control. When the voltage is low enough, it will cause IC6b to switch, sending its output low. This will cause IC6 pin 7 to ramp upwards, and the cycle repeats itself.

Unfortunately, the linear ramp which IC6 produces is of little use in a chorus. The sweep-generator is used to vary the clock-frequency of the BBD line, and hence the delay-time. There's no problem when the delay-time changes from, say, 7 to 10 milliseconds, but if the delay-time changes from 17 to 20ms in the same time, the ear hears a not-very-musical "whoop". What is needed is some way of slowing down the rate-of-change of the delay-time as it approaches the 20ms end of the range.

The solution relies on the fact that bipolar transistors have a very non-linear switch-on characteristic at low levels of base current. This characteristic is used to turn the linear output of the ramp generator into something approaching that shown in Fig. 3. At the 7ms end of the delay-time range, the rate-of-change is high but inaudible; at the other end, the rate-of-change is much slower. RV3 and RV4 are used to adjust the shape of the waveform.

When the width control is fully clockwise, it can be seen that the signal present at IC3d will appear at the input of the VCO, and therefore the delay-time will sweep over the entire range. As the width control is turned counterclockwise, the input to the VCO is derived more and more from IC2d, whose output is set by the Manual control, RV5. Thus the Width control provides the option of a fully swept delay-time, a fully manual delay-time, or anything in between.

All of the op-amps are supplied with +9V except IC6, which is supplied with +5V. The delay-line and its clock generator are also supplied with +5V. A 78L05 provides the +5V supply. Some parts of the circuit require half the battery voltage and others require +2.5V. These voltages are provided by potential dividers.

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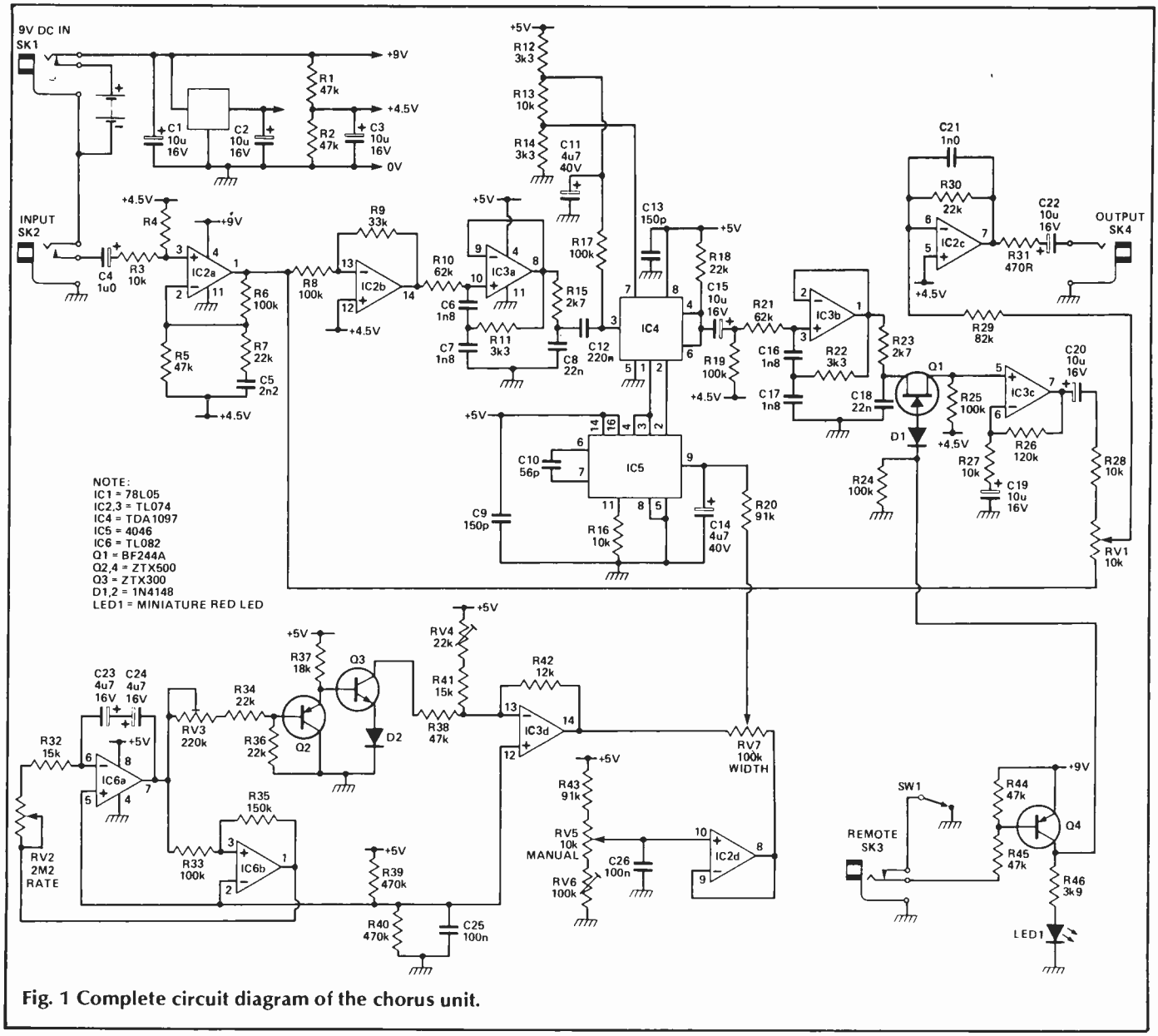

Fig. 1 Complete circuit diagram of the chorus unit.

delay, and mixing the delayed signal with the undelayed signal.

The two signals are identical, but mixed together they will interact, sometimes adding together and sometimes cancelling out. Our ears are fooled into thinking that what they are hearing is a second instrument or voice.

The Circuit

The heart of the Chorus is a Bucket Brigade device (BBD), in this case a TDA1097 which has 1536 stages or 'buckets'. To get an idea of how a BBD device works, imagine a line of people trying to put out a fire by handing buckets of water along the line, then imagine that they don't pass the buckets but each pour the water from their bucket into the next person's bucket. If we ignore spillage, then it's clear that the contents of the first bucket will eventually find their way into the last bucket, delayed by the time taken to pass along the line.

In an electronic 'bucket-brigade' the buckets are capacitors, the men are transistors and the water is a voltage level. The voltage level on the input to the BBD line will eventually appear at the output, delayed by the time taken to pass through all the 'buckets'. The delay time is dependant on the clock frequency applied to the BBD line.

The TDA1097 requires a two-phase clock and this is supplied by the voltage controlled oscillator section of a 4046 phase-locked loop chip. Two clock cycles are required to shift the input signal through each stage, so the delay time can be expressed as:

$$t\,(d) = \frac{N}{2f}$$

where N is the number of stages and f is the clock frequency. For chorus, a delay range of seven to 20 milliseconds is about right, and this gives a minimum clock frequency of 38.4kHz and a maximum of 109.7kHz. The TDA1097 is only specified to 100kHz, but no problems were encountered with the prototype.

A BBD line is essentially a sampling device, and as such introduces the problem of the clock-signal interfering with the audio-signal. The clock signal will

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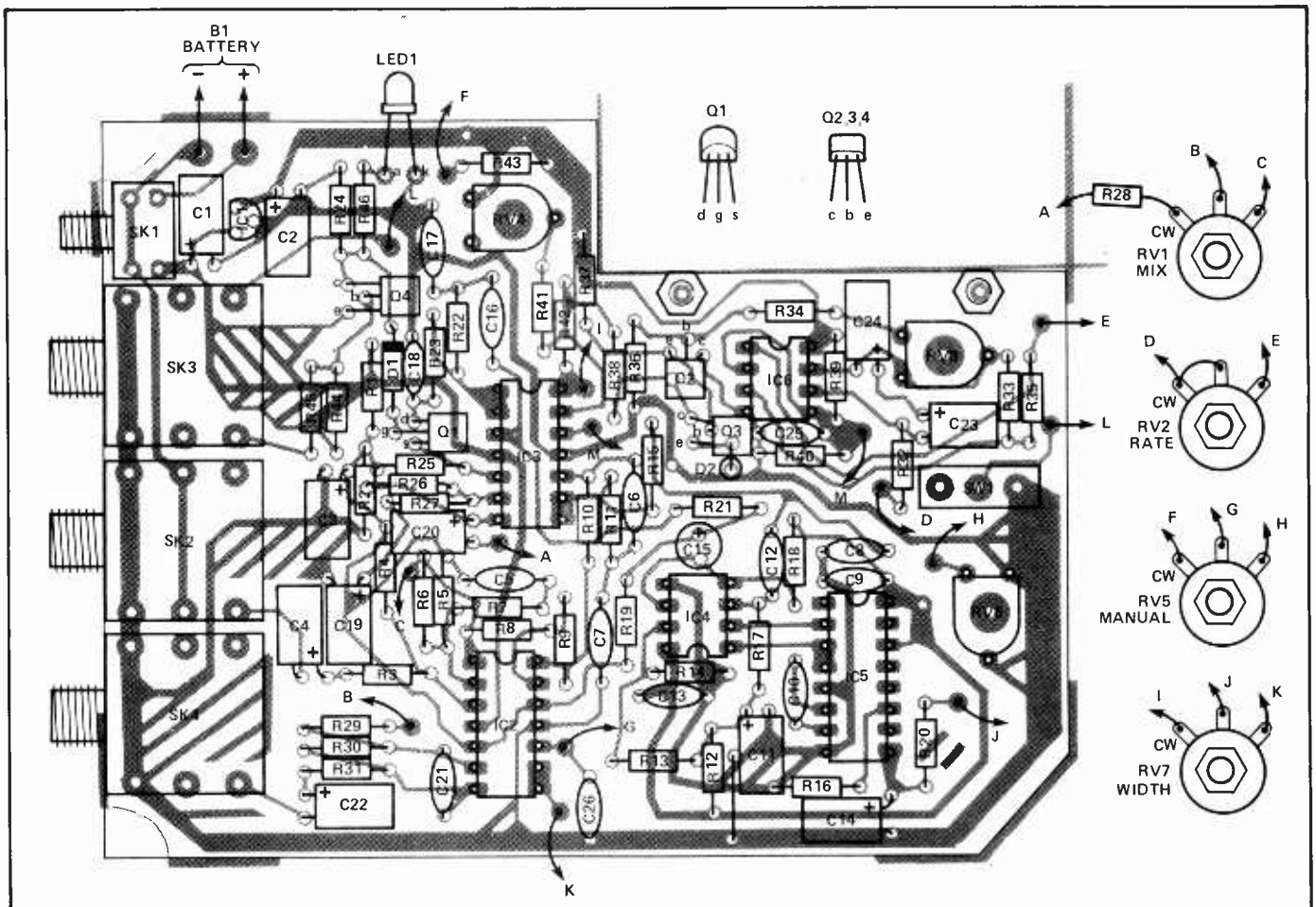

Fig. 2 Component overlay for the chorus unit PCB.

inevitably find its way to the output, albeit at a much lower amplitude than the audio signal. The clock frequency never falls below 38.4kHz so it will not be audible. The problem is that as the harmonic or noise frequency components of the input signal approach half the clock frequency, the lower sideband of the clock frequency will become audible. For example, if noise components in the range 10kHz to 40kHz are present at the input to the BBD line, they will mix with the clock signal to produce sum and difference signals. The difference signals will be in the range 1.6kHz to 28.4kHz. Trying to filter out these difference signals is obviously impractical, since doing so would also get rid of most of the audio signal.

The solution is to put a low-pass filter immediately before the input to the BBD line, with a cut-off frequency of around 6kHz. In this way, difference signals can only be produced above 32kHz, and a similar low-pass filter on the output of the BBD line effectively gets rid of those.

A cut-off frequency of 6kHz may seem a bit brutal, but the chorus effect ceases to be audible above this, and in any event, only the delayed portion is so affected: the undelayed signal is not filtered. The filters in this design have an actual cut-off of 6.2kHz and a slope of –20db/octave. In addition, pre-emphasis on the input and de-emphasis on the output endow this unit with a good noise performance.

In order to achieve adequate chorus effects, the delay time must vary steadily rather than being constant. This is made

BUYLINES

The ¼" jack sockets used in the prototype are made by Cliff and are designed for PCB mounting. They are not readily available in small quantities but their pin spacing is the same as that of Cliff's panel mounting ¼" jack sockets which are available from Electrovalue. The panel mounting type have solder tags with eyelets rather than pins, but it is a simple matter to cut away one side of the eyelet so as to leave a pin narrow enough to suit the holes in the PCB. Other makes of jacket socket available from other suppliers may also be suitable if so modified but we have not tried this.

The potentiometers used are also supplied by Electrovalue and are from their P20 range. RS Components stock a suitable switch (catalogue number 339-241) and a 15mm button for it (catalogue number 339-279 for a pack of three) but they do not stock a shroud as used on the prototype. A switch with a shroud is available from Electromatch for £4.15 including post and packing. The part numbers are MPA106D for the switch, C23 for the button and G13 for the shroud and you can contact them on 0403 - 814111 to obtain up-to-date ordering information. The box is made by STC and is type number 73399B. It costs £1.97 plus VAT but inclusive of post and packing from STC Electronic Services Ltd, Edinburgh Way, Harlow, Essex CM20 2DF. All of the other components are available from our regular advertisers except the TDA1097 which you can obtain from Cricklewood (It's listed in their catalogue even if it isn't in their advertisement). The PCB will be available from our PCB Service.

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PARTS LIST

RESISTORS

R1, 2, 5, 38, 44, 45	47k
R3, 13, 16, 27, 28	10k
R4, 39, 40	470k
R6, 8, 17, 19, 24, 25, 33	100k
R7, 18, 30, 34, 36	22k
R9	33k
R10, 21	62k
R11, 12, 14, 22	3k3
R15, 23	2k7
R20, 43	91k
R26	120k
R29	82k
R31	470R
R32, 41	15k
R35	150k
R37	18k
R42	12k
R46	3k9
RV1, 5	10k linear potentiometer
RV2	2M2 linear potentiometer
RV3	220k horizontal skeleton preset
RV4	22k horizontal skeleton preset
RV6	100k horizontal skeleton preset
RV7	100k linear pontentiometer

CAPACITORS

C1, 2, 3, 15, 19, 20, 22	10u 16V radial electrolytic
C4	1u0 63V radial electrolytic
C5	2n2 polyester
C6, 7, 16, 17	1n8 polyester
C8, 18	22n polyester
C9, 13	150p polystyrene
C10	56p polystyrene
C11, 14	4u7 40V radial electrolytic
C12	220n polyester
C21	1n0 polystyrene
C23, 24	4u7 16v tantalum
C25, 26	100n polyester

SEMICONDUCTORS

IC1	78LO5
IC2, 3	TLO74
IC4	TDA1097
IC5	4046
IC6	TLO82
W1	BF244A
Q2, 4	ZTZ500
Q3	ZTX300
D1, 2	1N4148
LED1	miniature red LED with mounting bezel

MISCELLANEOUS

SK1	3.5mm miniature jack socket, PC mounting, with switch
SK2	¼" stereo jacket socket, PC mounting
SK3	¼" mono jack socket, PC mounting, with switch
SK4	¼" mono jack socket, PC mounting
SW1	SPDT alternate action push switch, panel mounting

PCB; case; knobs, 4 off; battery connector; ¾" (20mm) high pillars, 2 off and screws or bolts to fit; IC sockets if desired, 2 off 8 pin and one off 16 pin DIL; thin foam rubber; 9V battery, PP3 or similar.

possible by a sweep facility which repeatedly swings the delay period from its maximum to its minimum and back again. The sweep rate can be varied from once every ten seconds to ten times a second, and the width of the sweep is continuously variable from full sweeps between the limits of 7ms and 20ms delay and no sweep at all (ie, a constant delay period). In the latter condition, the delay period can be manually set to permit the 'plate' effects described earlier. Further versatility is provided by a Mix control which allows the delayed and undelayed signals to be mixed in any proportions. This makes it possible, for example, to use the full amount of sweep but still achieve a very subtle effect.

Power to the unit is provided by a PP3 size battery (preferably alkaline), and a socket allows connection to an external supply. The unit is switched on by inserting a mono jack plug into the input socket, and Effect or Bypass mode is selected by the built-in footswitch or by a remote switch connected to the REM socket. An LED indicates when the unit is in Effect mode.

Construction

Commence assembly by installing the wire link, the four jack sockets, and if desired, sockets for ICs 4, 5 and 6. Sockets cannot be used for ICs 2 and 3 or they will interfere with the potentiometers when the unit is assembled. The jack sockets must be of the recommended type if they are to fit correctly into the prepared holes in the PCB.

Continue assembly by soldering into place the resistors, capacitors, and presets, taking care that the capacitors near the connector end of the board are mounted flat so as to clear the potentiometers. Next fit the diodes, transistors, and ICs 1, 2 and 3. Cut to length three pieces of ordinary insulated connecting wire, and solder them between the points shown on the PCB overlay, then fit the two battery-guide pillars and the battery connector. Connect the four potentiometers, R28 and the LED to the PCB using insulated wire. Lastly, fit ICs 4, 5 and 6. The board can now be tested.

An oscilloscope is essential if the chorus unit is to be accurately set up, so if you don't own one you will have to borrow or otherwise acquire one before proceeding further.

Connect the oscilloscope input to IC5 pin 2 and check that a square wave signal is present with an amplitude of about 5V peak-to-peak. Turn the Width and Manual controls fully anti-clockwise and adjust RV6 until the frequency of the square wave is about 38.4 kHz. Turn the Manual control fully clockwise and check that the frequency rises to about 109 kHz. If either of these frequencies are outside the range of adjustment of RV6, try altering the value of R43.

Connect the oscilloscope input to IC6 pin 7 and check that a triangular waveform is present with an amplitude of about 2V peak-to-peak. Rotate the Rate control (RV2) and check that the frequency varies from about 0.1Hz when it is fully anti-clockwise to 10Hz when it is fully clockwise. Move the oscilloscope probes to IC3 pin 14 and check that the waveform present is similar to that shown in Fig. 3. Make any

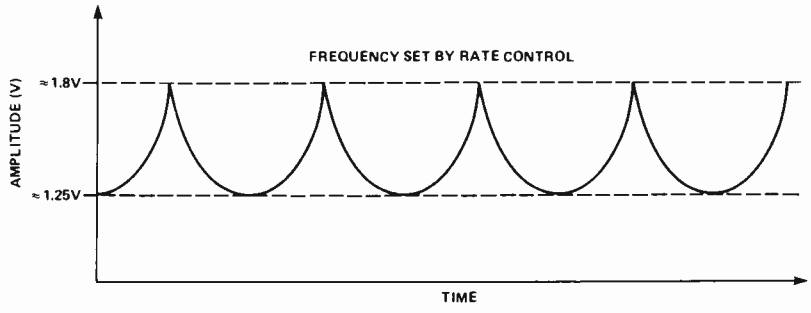

Fig. 3 The sweep generator ouput waveform, as measured at IC3 pin 14.

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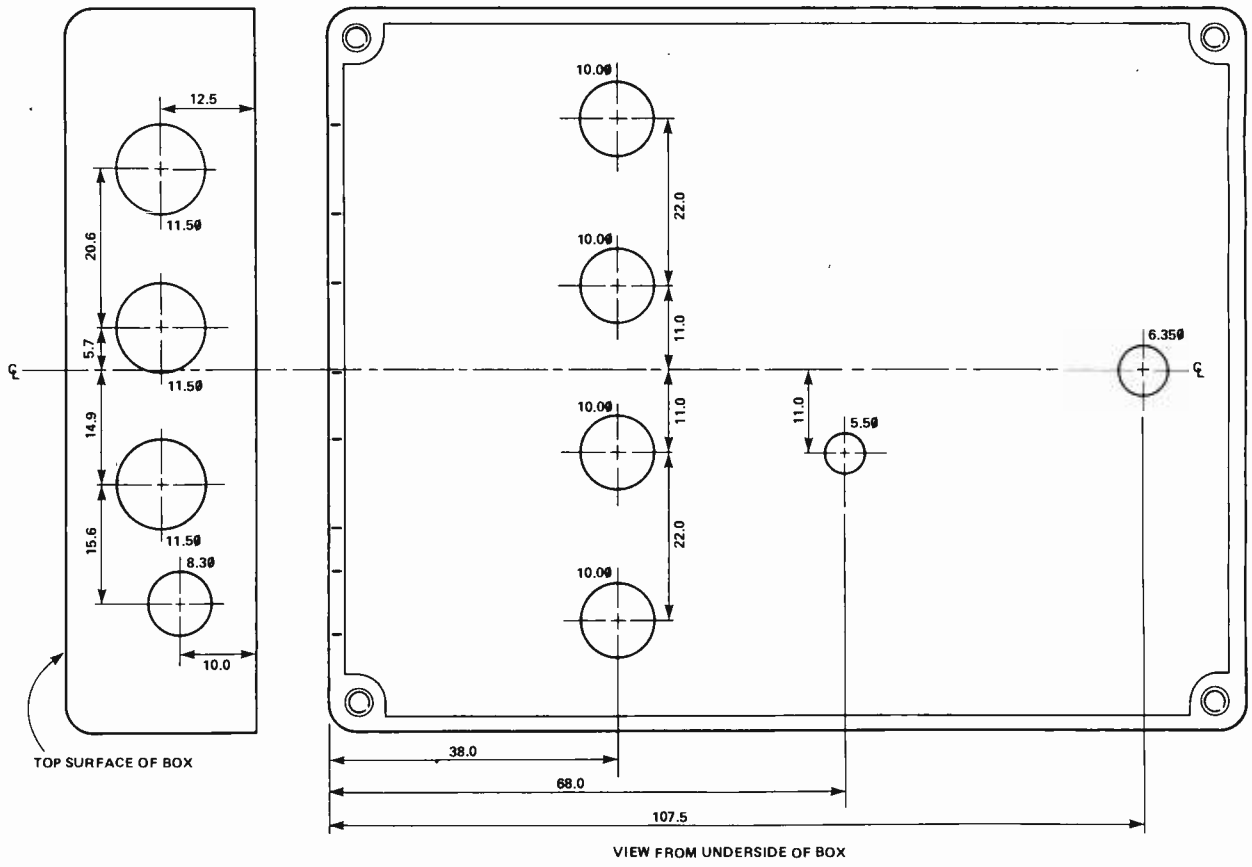

Fig. 4 Drilling details for the case, shown here at its actual size.

necessary adjustments, using RV3 to set the amplitude and RV4 to alter the offset.

Return the oscilloscope connections to IC5 pin 2 and set the Width control fully clockwise and the Rate control fully anti-clockwise. The frequency of the signal should be slowly changing between the previously-set limits of 38.4 kHz and 109 kHz. Carry out any fine tuning required using RV3 and RV4 and the setting up is complete.

If you want a particularly compact unit it is best to use the recommended box, but if you are unable to find the correct type or for any other reason wish to use a different box, choose one that is slightly larger than our prototype so as to avoid cramping the components.

Refer to Fig. 4 and drill the necessary holes as accurately as possible. Take particular care with the holes for the switch and the sockets since these must line up with the components on the PCB. If you have any doubts about your skills in this direction, try drilling the holes a little smaller than is required in the first instance, then offer up the PCB to check that they coincide and make any necessary adjustments with a small file before enlarging the holes to their final diameter.

When drilling is complete, rub down the outside of the box with glass paper to deburr the holes and prepare the surface. Clean the box thoroughly and then prime and paint it allowing suitable drying times. Loosely assemble the potentiometers and knobs as a guide and use rub-down lettering to apply the legends. Remove the fittings, lightly buff the surface to remove any fingerprints, etc, then apply a coat of clear varnish and leave to dry.

Glue a piece of foam rubber inside the box to prevent the battery rattling around. Mount the switch in position through the appropriate hole in the case but do not tighten the fixing nut. Mount the potentiometers through the top panel of the case. Place fibre washers onto each of the sockets on the PCB, then offer the board up to the case, socket end first. Loosely assemble the socket securing nuts from the outside to stop the board slipping back through. Jiggle the switch and the PCB until the switch pins appear through the holes in the board, then solder them to the pads and tighten the switch into position. Complete the construction by adding the switch cap, the knobs and the base plate and tightening the securing nuts on the sockets. Don't forget to install a battery!

Apply an input signal of about 1kHz at a few hundred millivolts to SK2. Inserting the jack plug should turn the unit on. Connect up an oscilloscope so that you can alternatively observe the input signal and the output signal from SK4. Better still, if you have a dual-beam oscilloscope use it to monitor both at once. Press the footswitch if necessary until the Effect LED is off and check that the output waveform closely resembles the input waveform. Press the switch again and the output waveform should start to subtly alter in shape. Operating the various controls should influence the nature and extent of the alteration.

Having got the pretend stuff out of the way, you can now plug in a real instrument, hook the unit up to an amplifier and get chorused away!

ETI

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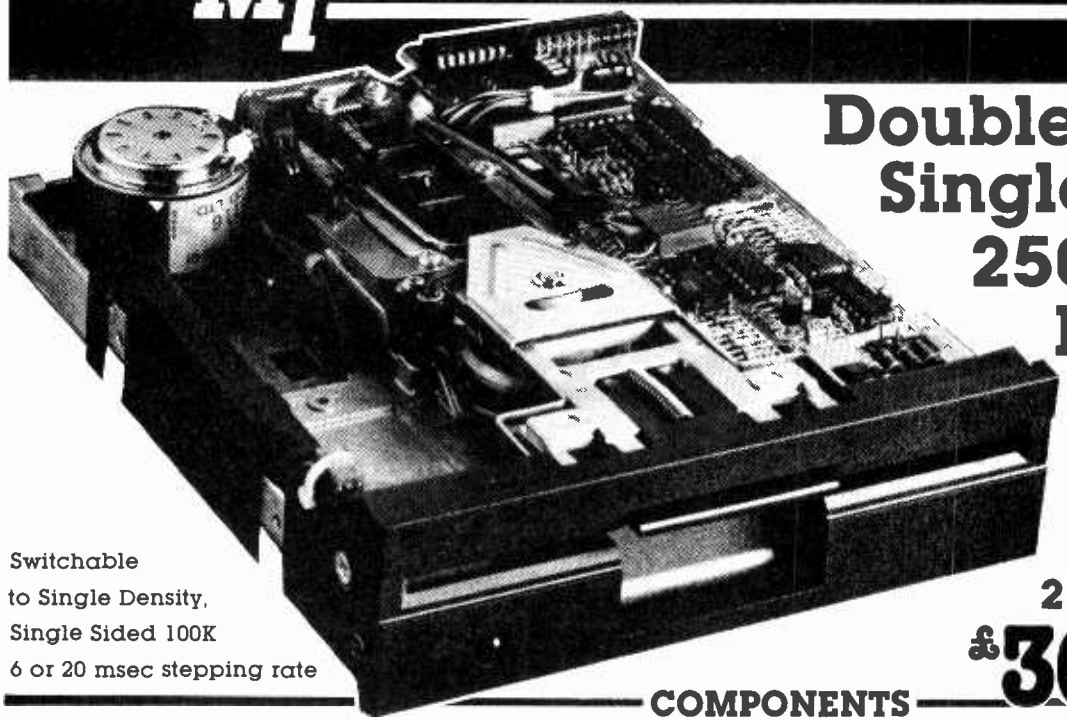

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74LS20	0.13
74LS27	0.12
74LS30	0.13
74LS32	0.13
74LS74A	0.15
74LS86	0.35
74LS93	0.35
74LS22	0.45
74LS123	0.45
74LS125	0.45
74LS138	0.25
74LS157	0.25
74LS161A	0.50
74LS163A	0.50
74LS166	0.75
74LS175	0.50
74LS191	0.50
74LS193	0.40
74LS241	0.50
74LS242	0.50
74LS243	0.50
74LS244	0.50
74LS245	0.75
74LS257	0.75
74LS273	0.30
74LS365	0.50
74LS367	0.50
74LS373	0.45
74LS374	0.45
74LS393	0.50
74LS465	0.75
74S04	0.25
74S734	2.00

C MOS

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4016	0.25
4049	0.25
4066	0.30
4070	0.20

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2764–25	3.00
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3764–20	2.50
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4864–2	2.00
6116–4	2.00
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INDUCTORS – AXIAL

4 7MH	0.05
22MH	0.05
33MH	0.05
100MH	0.05

CRYSTALS

1 8432MHz	2.00
3 579545MHz	0.50
4 00MHz	0.50
4 433619MHz	0.50
10.6875MHz	0.50
10 738635MHz	0.50
15.00MHz	0.50
10 00MHzOSC	4.50

I.C. SOCKETS – STD

20 PIN	0.15
24 PIN	0.15
28 PIN	0.15
40 PIN	0.25

I.C. SOCKETS – LOW PROFILE T.I.

16 PIN	0.10
18 PIN	0.10
28 PIN	0.20
40 PIN	0.25

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BC107	0.15
TIP2955	0.50
TLO81CP	0.35

DIODES

IN4004	0.05
IN4148	0.02
IN5402	0.10
BZX79C4V7	0.05
BZX79C5V1	0.05
BZX79C5V6	0.05
BZX79C12	0.05
BZX79C7V5	0.05

POTENTIOMETERS

1K HOR. PRESET	0.10
1K CERMET	0.25
22K HOR PRESET	0.12

SWITCHES

ML3KEYTOP	0.10
2 WAY ON–OFF DIP	0.15
NEON MAINS	0.75
4 POL DIL	0.25
8 POL DIL	0.55
TV TO COMPUTOR	0.75
MINI-SLIDE	0.15
C+K 8631 PUSH	0.25

RESISTORS 0.25W c/f

Measured in OHMs
All 0.01 each

1.0	180	33K
1.1	200	36K
1.2	220	39K
1.3	240	43K
1 5	270	47K
1.6	300	51K
1.8	330	56K
2.0	360	62K
2.2	390	68K
2.4	430	75K
2 5	430 M/F	82K
2 7	470	91K
3 0	510	100K
3 3	560	110K
3.6	620	120K
3.9	680	130K
4.3	750	150K
4.7	820	160K
5 1	910	180K
5.6	1K	200K
6.2	1KM/F	220K
6 8	1.1K	240K
7 5	1.2K	270K
8.2	1.3K	300K
9.1	1.5K	330K
10	1.6K	360K
11	1.8K	390K
12	2K	430K
13	2.2K	470K
15	2.4K	470K ½W
16	2.7K	510K
18	3K	560K
20	3.3K	620K
22	3.6K	680K
24	3.9K	750K
27	4.3K	820K
30	4.7K	910K
33	5.1K	1M
36	5.6K	1.2M
39	6.2K	1.3M
43	6.8K	1.8M
47	7.5K	2M
51	8.2K	2.2M
56	9.1K	2.4M
62	10K	3M
68	11K	3.6M
75	12K	4.3M
82	13K	4.7M
91	15K	5.1M
100	16K	5.6M
110	18K	6.2M
120	20K	6.8M
130	22K	7 5M
150	24K	8.2M
160	27K	9.1M
	30K	10M

CAPACITORS

CERAMIC PLATE

All 0.03 each

10NF
22NF
22NF DISC
47NF DISC
8 2 PF
15 PF
27 PF
33 PF
39 PF
47 PF
68 PF
100 PF
150 PF
220 PF
560 PF
1000 PF
1500 PF
4700 PF

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470 MF/25V	0.07
4700 MF/16V	0.35

ELECTROLYTICS – RADIAL

10MF/16V	0.05
10MF/63V	0.05
22MF/35V	0.08
47MF/16V	0.08
100MF/25V	0.10
470MF/10V	0.12
470MF/16V	0.12
2200MF/25V	0.20
4700MF/16V	0.25

POLYESTERS

22NF	0.06
100NF	0.06
047MF	0.06

SIBITATS

47NF	0.06
100NF	0.06

TANTLUMS

1MF35V	0.10
10MF35V	0.15
22MF16V	0.18

TRIMMERS

5.5–40PF	0.15

MISCELLANEOUS

3 5MM PCB MTG JACK SOCKET	0.12
PHONO SOCKET – NUT FIXING	0.14
BNC SOCKET – CHASSIS MTG	0.40
20 × 5MM PCB MTG FUSEHOLDER	0.10
20 × 5MM PCB MTG FUSEHOLDER COVER	0.10
20 × 5MM 3.15A QUICK BLOW FUSE	0.10
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ENLARGER EXPOSURE METER

Bring a little light to your darkroom operations with this meter, designed by Doug Bollen

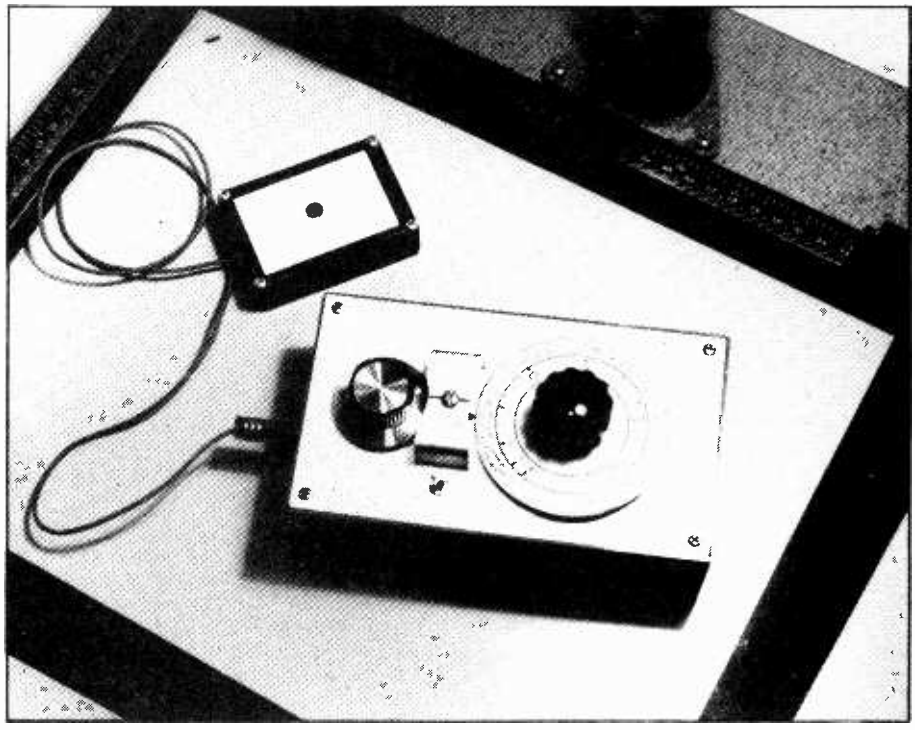
Despite fully automatic cameras and simplified colour processes, many amateur photographers still perform prodigious feats of mental arithmetic in dark places every time they make some minor adjustment to their enlarger. With monochrome prints it is a fairly simple matter to run off a test strip in open dishes to assess exposure before creating each finished print, and there is no colour balance to bother about. A colour test strip, on the other hand, can take all of fifteen minutes to produce, plus time to dry the drum. It uses a disproportionate amount of expensive colour chemicals, and several colour test strips may be needed to establish correct exposure and colour filtration for just one frame of a film.

There is no substitute for human evaluation in photography but a good exposure meter can reduce time and wastage of materials by establishing a reference point against which differing enlarger magnifications and film densities may be judged. The ideal exposure meter would have equal scale divisions which are readable in complete darkness, adjustment for a wide range of photographic paper sensitivities, good accuracy over the entire visible spectrum, high sensitivity to low light levels, no dependence on temperature or supply voltage, a very small light sensitive cell area and, of course, a very low cost.

Stop On Sight

It is in the nature of light sensors that they stubbornly defy attempts to achieve equal scale divisions, even when using moving-coil meters with specially shaped poles. Another problem is that light sensors tend to have a wide tolerance, typically ±40%, which makes conformity to a precalibrated scale on a mass produced instrument difficult. On casual inspection it might be thought that the requirement is for a linear time scale, say 1-100 seconds, but that is not the case. Exposure time and light intensity on cameras and other photographic instrument scales both proceed in a geometric series (because that is the way human vision works) where each basic division represents a doubling or halving of time or light. Light itself is not so easy to measure because a large number of variables have to be allowed for. However, a unit commonly employed to assess relative light levels is the arbitrary 'stop' for which doubling a reference exposure figure means halving the light and is designated +1, while halving the figure means doubling the light and is said to be −1. The overall accuracy of camera plus film stock is seldom better than 1/3 stop either way. An exposure meter should at least equal this performance over a substantial portion of its scale. In practice, the exposure meter can be conveniently calibrated in seconds in steps of 1, 2, 4, 8, 16 and so on and in equivalent stops, say −4 to +4.

A popular type of low-cost exposure meter circuit is shown in Fig. 1, where the voltage output from a Cadmium Sulphide cell (Light Dependent Resistor) and load resistor, R, is compared with the voltage at the slider of a conveniently calibrated potentiometer, RV. A comparative reading is taken at null point and adjustments are made by varying the enlarger lens aperture. This technique neatly avoids the need to calibrate the exposure



The prototype exposure meter

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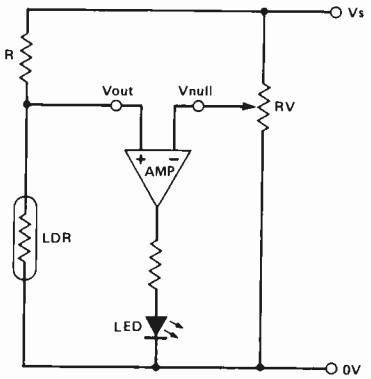

Fig. 1 Basic LDR bridge circuit.

meter, and adjustment of RV merely caters for a range of light intensities and paper speeds, but the critical user may find it limiting. This balanced bridge configuration does offer potential advantages, however. It is insensitive to changes of supply voltage, has good temperature stability and, if RV is individually calibrated for a particular CdS cell the resulting scale is roughly proportional to steps of 1 stop. There is some cramping of the scale at both ends of the pot track, but the scale divisions are symmetrical about track centre. As a point of interest, if R in Fig. 1 is replaced by a constant current source then the scale bears a close linear relationship to exposure time.

Properly calibrated, the Fig. 1 circuit would have an accurate, but fixed, pot scale which takes no account of differing photographic paper sensitivities. A computer plot was made of LDR voltage (Fig. 2) against R for measured cell resistance corresponding to lens f-stops. Doubling the R value produces a shift of one stop without changing the meter scale span, so a variable resistor for R will act as a paper sensitivity control. The plot also shows that the meter will cover 8 stops without too much cramping of extreme scale gradations, plus an additional 4 stops with adjustment of R. This is an arithmetic range of 1:4096 in light intensity.

Construction

The exposure meter is simple enough for a photographer with a limited knowledge of electronics to build. The complete novice should, however, study the art of soldering, and pay particular attention to the orientation of polarised components (IC1, C1, C2, C3, LED1, LED2 and B1). If any of these are the wrong way round, malfunction or disaster may follow! Make sure that RV1 and RV2 connections are correct or calibrated scales may be reversed (Figs. 4 and 5).

The PCB will fit inside a 3.5" wide by 2" deep slotted box, but if this size is not available, drill holes at the corners of the PCB and bolt to the bottom of any suitable box with stand-off spaces and the LEDs pointing straight up. The dial for RV2 should be as large as possible. Obtain a knob with a screw-on skirt and replace the skirt with a disc of perspex. A paper disc should be temporarily placed above the perspex to allow claibration (Fig. 1). It can be sandwiched between the perspex and an aluminium disc for protection after calibration. Aluminium was also used for the LED shield (Fig. 6). The knob for RV1 can be a standard 0 – 10 component. The LDR is simply glued inside a slim light-tight box over a hole slightly smaller than the LDR case.

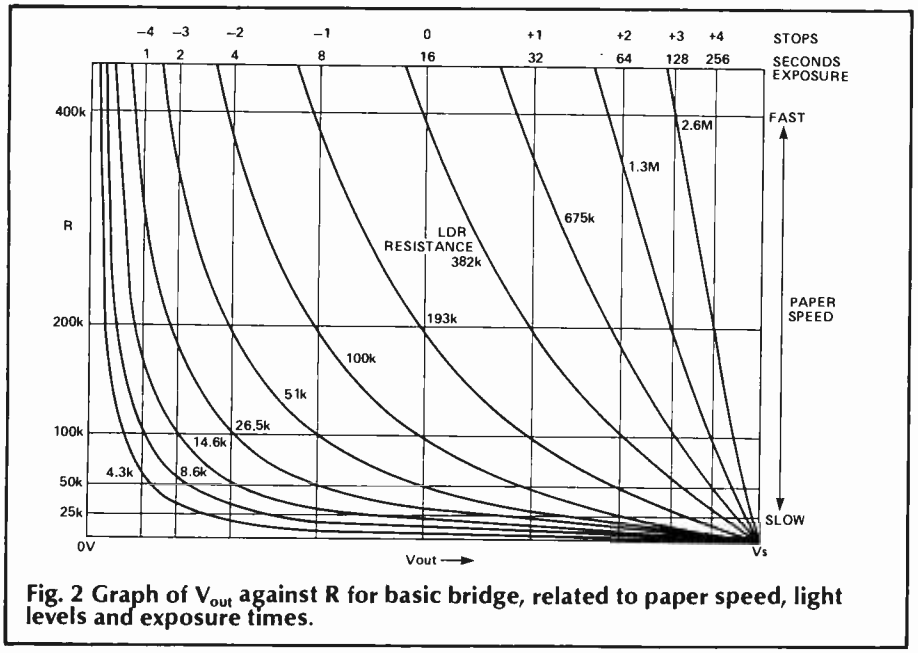

Fig. 2 Graph of V_{out} against R for basic bridge, related to paper speed, light levels and exposure times.

Testing And Calibration

Assemble the instrument, switch on and check that both LEDs are working. Plug the LDR, set RV2 to mid-track and point the LDR towards a source of low light. Adjust RV1 for balance. If balance cannot be obtained, the light level may be too high. Check that RV2 is rotated *anti-clockwise* to balance if there is a reduction in light, and RV1 similarly *clockwise*.

Lightly glue a rectangle of white card with a ¼" hole over the LDR aperture (this can later be reduced or increased if required). Place the sensor on the enlarger baseboard, set the head to mid height and the lens to maximum aperture. Set RV1 to 2. Now click stop the lens down and trim RV1 slightly to obtain a null. Mark the RV2 setting with a soft pencil and the figure zero. Without touching RV1, click stop the lens up and down and balance with RV2. At each balance point mark the paper disc. You should now have part of the scale marked. Return RV2 to mid-position zero and adjust head height and click stops to fill in the remainder of the scale (leaving RV1 where it is). Slight errors will occur where there is overlap with previous dial markings. Average these errors out over several successive settings and different overlaps. It should be possible at this stage to detect if a particular lens f-stop deviates from true. If errors greater than 1/3 stop are encountered, or if best accuracy is required, the exposure meter can now be double checked with a camera lens.

You'll need a camera with manual override and a means of holding the shutter open ('B' or 'bulb' setting). Tape the LDR box in the film plane with the sensor aperture central. Place the camera on the enlarger base board with the lens up and the focus on near. Use a piece of plain white paper to cover the lens. Do not strain the open camera back. Adjust camera f-stop, enlarger magnification and click-stop for

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null with RV2 at mid-point zero. Now vary the camera f-stop to check RV2 calibration.

When satisfied that the paper dial is accurately calibrated in stops −4 to +4 for the CdS cell you are using, it only remains to make an ink copy and interpolate intermediate settings from Table 1.

Using The Meter

There are many ways of using an enlarger exposure meter but only one will be described here: 'pegging the mid-tone'. After obtaining a test strip of a reference negative or transparency and deciding on the correct exposure for a given magnification and aperture — say, 16 seconds at stop 0 — measure the blackest and whitest areas of a new subject in stops and determine the mid-point. For example, a transparency may give +2 and −3 so the mid-point would be −0.5, which gives an exposure time of $16s \times 2^{-0.5}$, or $16s\sqrt{2}$, which equals 11.3s. Notice that the arithmetic mean, $(16s \times 2^{2} + 16s \times 2^{-3})/2 = 33s$, is hopelessly wrong.

Don't forget to allow for reciprocity failure (decrease of paper sensitivity) when making very long exposures at high magnifications or through very dense negatives. The correction is typically (x1.5) at 40s (x2.3) at 100s and (x3.5) at 200s.

STOPS	SECONDS
−4	1
−3.75	1.2
−3.5	1.4
−3.25	1.7
−3	2
−2.75	2.4
−2.5	2.8
−2.25	3.4
−2	4
−1.75	4.8
−1.5	5.6
−1.25	6.8
−1	8
−0.75	9.6
−0.5	11.2
−0.25	13.6
0	16
+0.25	19.2
+0.5	22.4
+0.75	27.2
+1	32
+1.25	38.4
+1.5	44.8
+1.75	54.4
+2	64
+2.25	76
+2.5	90
+2.75	100
+3	128
+3.25	153
+3.5	180
2.75	217
+4	256

(Note: timescale can be shifted relative to stop scale to suit application.)

Table 1. Stops related to exposure times.

HOW IT WORKS

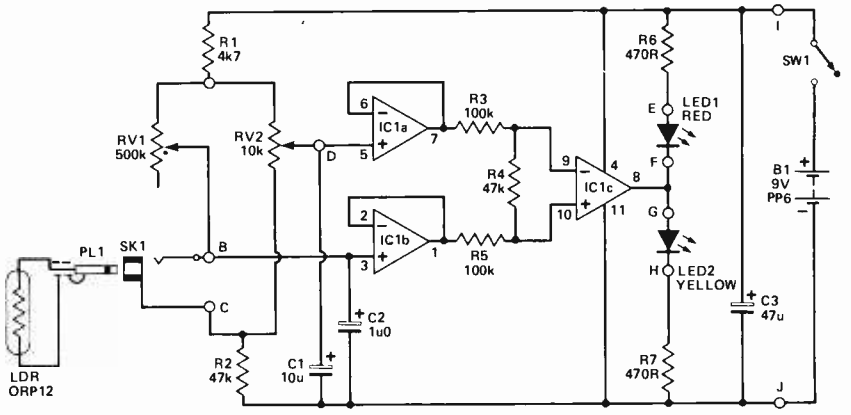


Fig. 3 Full circuit of exposure meter.

The circuit of Fig. 3 is the result of refinements made to the rudimentary LDR bridge circuit. RV1 is now the variable load resistor for the LDR. High input resistance op-amp buffers IC1a and IC1b ensure that there is negligible loading of either the LDR or calibrated pot RV2 when taking measurements. C1 and C2 filter out unwanted mains ripple. The purpose of R1 and R2 is to reduce the input level to IC1a and IC1b to prevent "bottoming" of amp outputs. IC1c acts as a simple comparator controlling the brilliance of red and yellow leds, LED1 and 2. At null point the overall light output changes from red to yellow, or visa versa, thus providing continuous 'off baseboard' illumination for RV1 and RV2 scales. When the battery voltage falls to about 6V the yellow led will extinguish to indicate battery low. The circuit of fig. 3 is virtually unaffected by battery voltage and so needs no regulator. The overall temperature coefficient of the circuit, including LDR, is +1/4 stop for a 10°C rise and maximum sensitivity has been estimated at around 0.1 lux. Depending on the light source efficiency of the enlarger used, CdS cell aperture can be fixed between 4 to 10 mm dia.

Any reasonable quality enlarger lens, or camera lens, can be used as a calibration source for the exposure meter, as will be outlined later. The enlarger exposure meter is perfectly suitable for spot measurements from black and white negatives and integrated measurements (through a diffuser) of 'average subject' colour shots. Spot measurements of coloured areas can also be made, but this requires some expertise, and three readings for each spot measurement through primary colour filters to achieve a meaningful result.

PARTS LIST

RESISTORS (all 1/4W, 10%)

R1,2	4k 7
R3,5	100k
R4	47k
R6,7	470R
RV1	500k lin
RV2	10k lin

CAPACITORS

C1	10µ 16V electrolytic
C2	1µ0 25V tantalum bead
C3	47µ 16V electrolytic

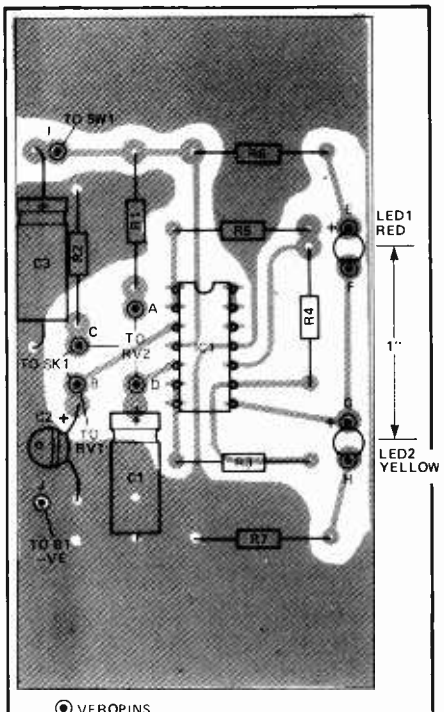
SEMICONDUCTORS

IC1	TL084
LED1	0.2" Red
LED2	0.2" Yellow
LDR	ORP12

MISCELLANEOUS

PL1,SK1	3mm Jack
B1	PP6
SW1	miniature on/off

PCB, connecting wire, PCB pins, spacers, battery clip, knobs, boxes, perspex, paper and aluminium discs to suit box (see text for details), small piece of aluminium, 14-pin DIL socket.



VEROPINS

Fig. 4 Component overlay

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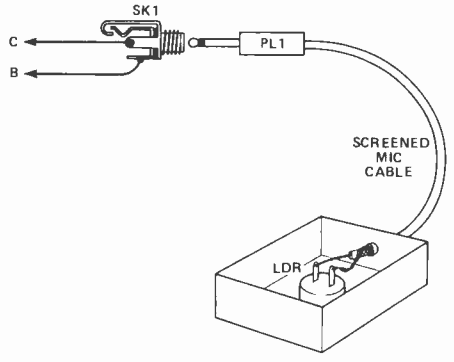


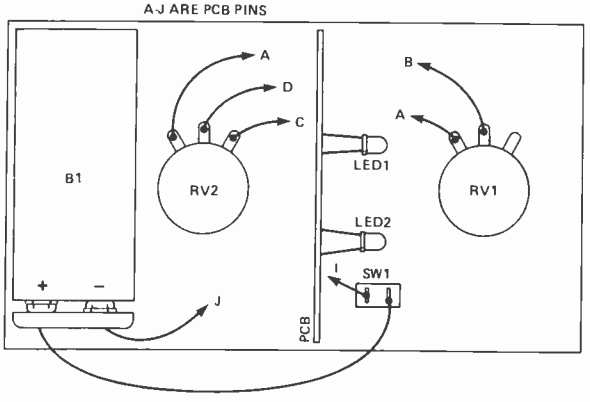


Fig .5 Front panel and LDR connections.

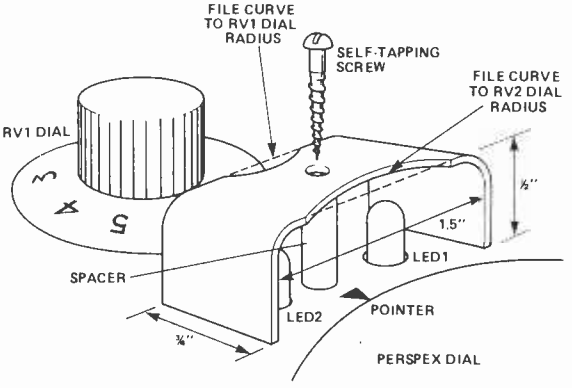


Fig. 6 Light shield.

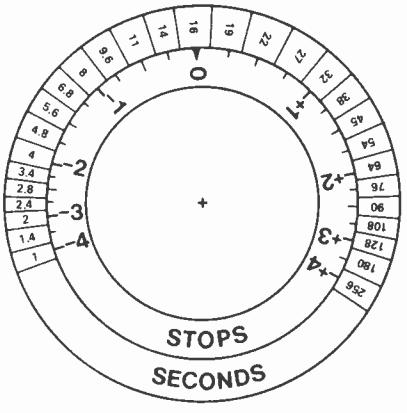
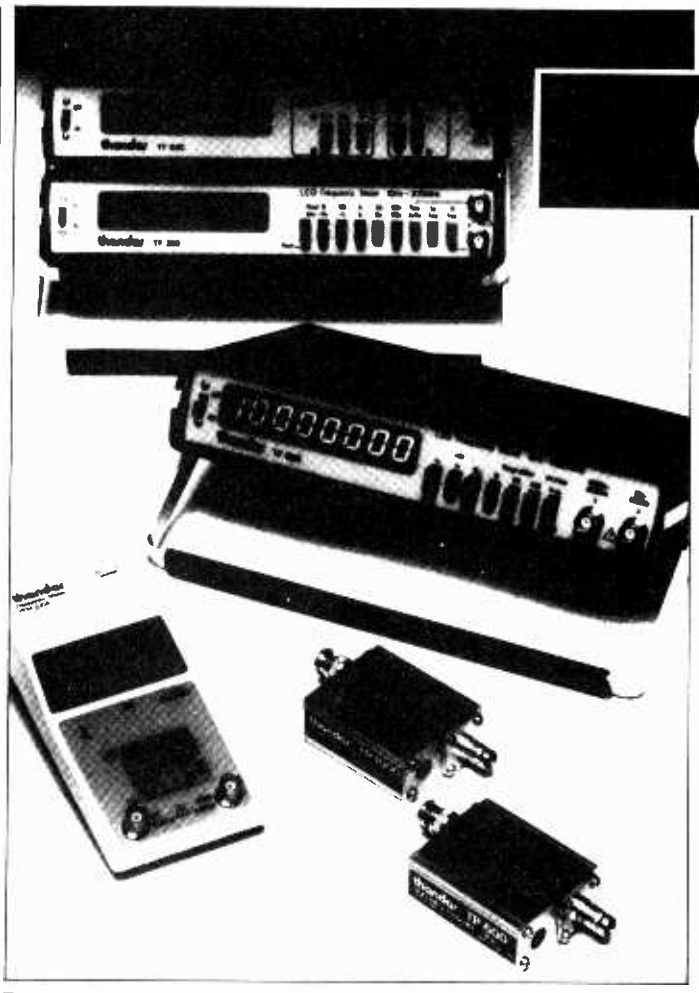


Fig. 7 Specimen scale.

ETI



COUNTERS

TF600
Bench/Portable: large 8 digit L.E.D. display; Frequency range 5Hz to 600MHz; Resolution 0.1Hz; Sensitivity 10mV rms; Timebase accuracy 2ppm. Battery or mains. Complete with mains adaptor.

TF200
Bench/Portable. 8-digit Liquid Crystal Display. Frequency range 10Hz-200MHz. Resolution better than 1ppm; Sensitivity typically 10mV rms. Timebase accuracy 0.3ppm. Battery life 200 hours. Frequency, time average period, totalize & reset; 2 ranges, 5 gate times. External clock facility. Complete with batteries.

TF040
Bench/Portable. 8-digit Liquid Crystal Display. Frequency range 10Hz-40MHz. Resolution 1Hz. Sensitivity 40mV rms. Timebase accuracy 0.5ppm. Battery life 80 hours. Frequency, totalize and reset, 2 gate times. Complete with batteries.

PFM200A
Pocket size. 8-digit L.E.D. display. Frequency range 20Hz-200MHz. Resolution 0.1Hz. Sensitivity typically 10mV rms. Timebase accuracy 2ppm. Battery life 10 hours. Frequency, 2 ranges, 4 gate times.

TP600 PRESCALER
Frequency range 40MHz-600MHz. Sensitivity 10mV rms. Powered direct by TF200 or TF040 (leads supplied).

TP1000 PRESCALER
Frequency range 100MHz-1000MHz. Sensitivity 25mV rms. Will extend TF200 and PFM200A capability beyond 1GHz.

For further information contact
Thandar Electronics Ltd, London Road, St Ives, Huntingdon, Cambs PE17 4HJ
Telephone (0480) 64646 Telex 32250

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ELECTRONICS LIMITED

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CYMBAL SYNTH

Beat your own drum with this status cymbal. Electronic noises off, and on, by D. Stone.

Over the years, ETI has published a number of drum and cymbal synthesizers, ranging from the ultra-sophisticated to the ultra-simple. This one, being a two chip affair, has the virtues of simplicity but is sufficiently adapable to provide a useful adjunct to any drum-kit. With a tunable noise output and a variable decay rate, the circuit could even be built into several units to form a more-or-less complete drum and cymbal kit — although, in all fairness, you'd be severely restricted as far as bass effects and 'touch sensitivity' go. The unit does allow pure white noise to be fed to the envelope generator, which means it can be used for gun-shots and similar effects. A degree of touch sensitivity is incorporated.

The prototype was built for live stage work, where it has proved very useful and rugged. If toughness is not a major criterion, the circuit could be built into any suitably sized and resonant container. The home or studio recordist could make good use of it as a crash cymbal or snare-type drum.

Construction

The construction of the unit is straightforward if the recommended PCB is used. The assembly should follow the usual format of passive components first, followed by the semi-conductors and Integrated Circuits. The use of IC Sockets is recommended to prevent damage to the chips by overheating and to ease the removal of chips should this become necessary. The microphone was fitted to the circuit board near IC1 in the prototype with double sided sticky fixing pads.

The prototype unit was housed inside an 8" Tambour. The Tambour has a removable drum skin which allows easy changing of the battery. Tambours can be bought from any good music shop. A base was fitted to the Tambour

HOW IT WORKS

The circuit associated with Q1 is the white noise generator, amplifying the noise produced in the diode D1 as a result of reverse leakage current. A germanium diode is used as the leakage current is higher than that of silicon for a given voltage, producing a higher noise signal level. This amplified signal is coupled by capacitor C1 to a further amplifying stage built around the op-amp, IC1a.

IC1b is a constant bandwidth, bandpass filter. The filter centre frequency is set by the dual-ganged potentiometer, RV1. This is a classic second order bandpass filter of the multiple-feedback tuned type, which turns the white noise into variable frequency range noise. SW2 is to choose either the filtered noise or the unfiltered white noise. The filtered noise is — inaccurately — described as pink.

The voltage controlled amplifier (VCA) is built around the 3080E transconductance op-amp, IC2. Output current is a function of the control current fed to pin 5 of the package and the difference in voltage between the two input pins. The output current of the device is converted into a signal voltage by R27 and the signal is capacitively coupled to the output by C13.

The signal from the microphone is first amplified by Q2 and then fed to a pulse amplifier built around IC1c. This section inverts the signal and amplifies it to give a negative going pulse at its output whenever a sound is picked up. The duration for which the pulse remains negative depends, to some extent, on the volume of the input signal to the mic. This gives some sensitivity to the impact of a beat. The negative going pulse is fed to Q3 which, with C12 and its associated circuit, forms a simple envelope generator.

When the pulse is received by Q3, the transistor turns on. C12 charges up rapidly through the transistor, D2 and R25, giving the fast attack which is characteristic of a drum. The transistor then turns off and C12 discharges through R25, RV2, D3 and R21. This gives a variable decay, considerably slower than the attack. The voltage is converted into a current by R26 and fed to pin 5 of IC2, the VCA.

C6 provides necessary supply capacity to eliminate any power thump which may find its way into the circuit when the drum is struck. C7 provides high frequency supply decoupling. A false signal earth is supplied in the form of a decoupled 4·5V rail. This rail is formed by C3,C4,R4 and R5, and eliminates the need for a two battery split rail supply.

There is a spare op-amp on IC1 available, should any adventurous constructor feel the need to expand the unit in some way.

PARTS LIST

RESISTORS (all 1/3W, 5%)	
R1,22	47k
R2,13,14	4k7
R3,12,17,21	1k0
R4,9	3k3
R6,7,10	270k
R11,25	470R
R15,18,19,20	100k
R16	390k
R23	39k
R24	220R
R26,27	10k
RV1	100k dual ganged log pot
RV2	47k lin pot
CAPACITORS	
C1,12	10µ 25V axial mounting electrolytic
C2,5,7,9,13	100n metallised polyester
C3,4	470µ 10V PCB mounting electrolytic
C6	2200µ 16V axial electrolytic
C8	10n metallised polyester
C10,11	47n metallised polyester
SEMICONDUCTORS	
D1	OA91
D2,D3	1N4148
Q1	BC108C
Q2	BC109C
Q3	BC179C
IC1	LM324
IC2	LM3080E
MISCELLANEOUS	
MIC1	Condenser Mic Insert
SW1	On/off switch
SW2	1-p 2-w switch

14 and 8 Pin DIL sockets ¼" jack socket, knobs, wire, 6BA hardware, casing, PP6 or PP3 battery and clips, PCB and PCB pins.

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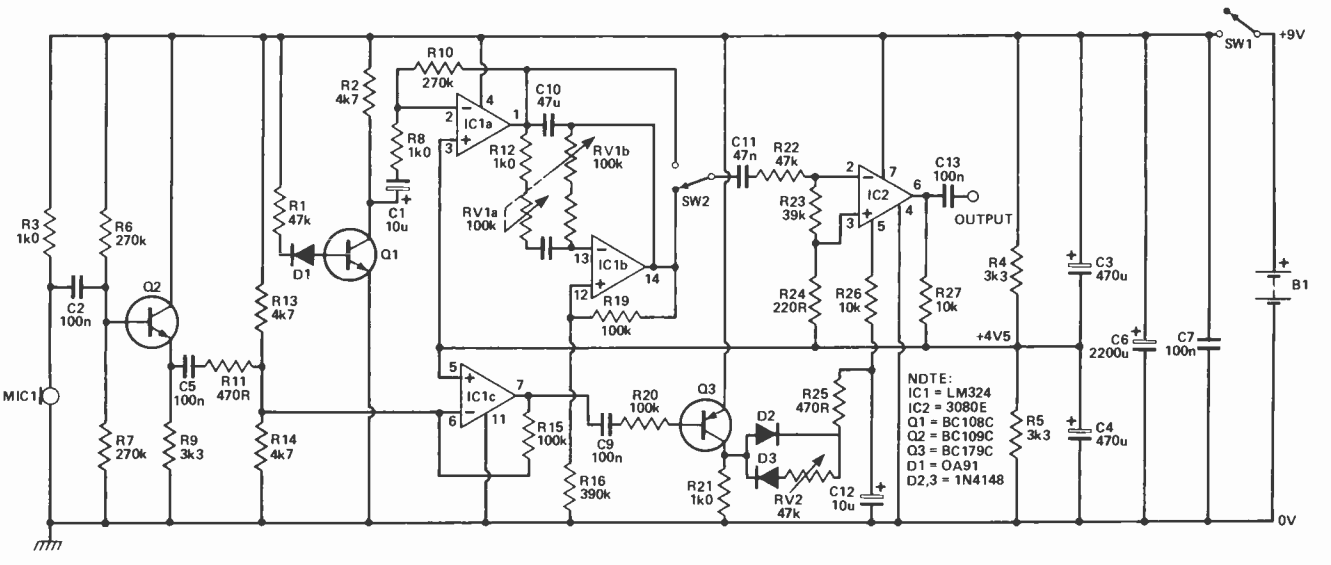

Fig. 1 Circuit diagram of the crash cymbal.

The PCB fits neatly inside a tambour case.

with white modellers' 'Plasticard'. The whole unit was then sprayed with enamel paint and labelled with rub down letters. As an alternative housing, for a number of these units, matching two litre ice-cream cartons could be used, and give a 'space-age' effect when painted in suitably futuristic hues. Mounting the units in playing positions is left to the reader.

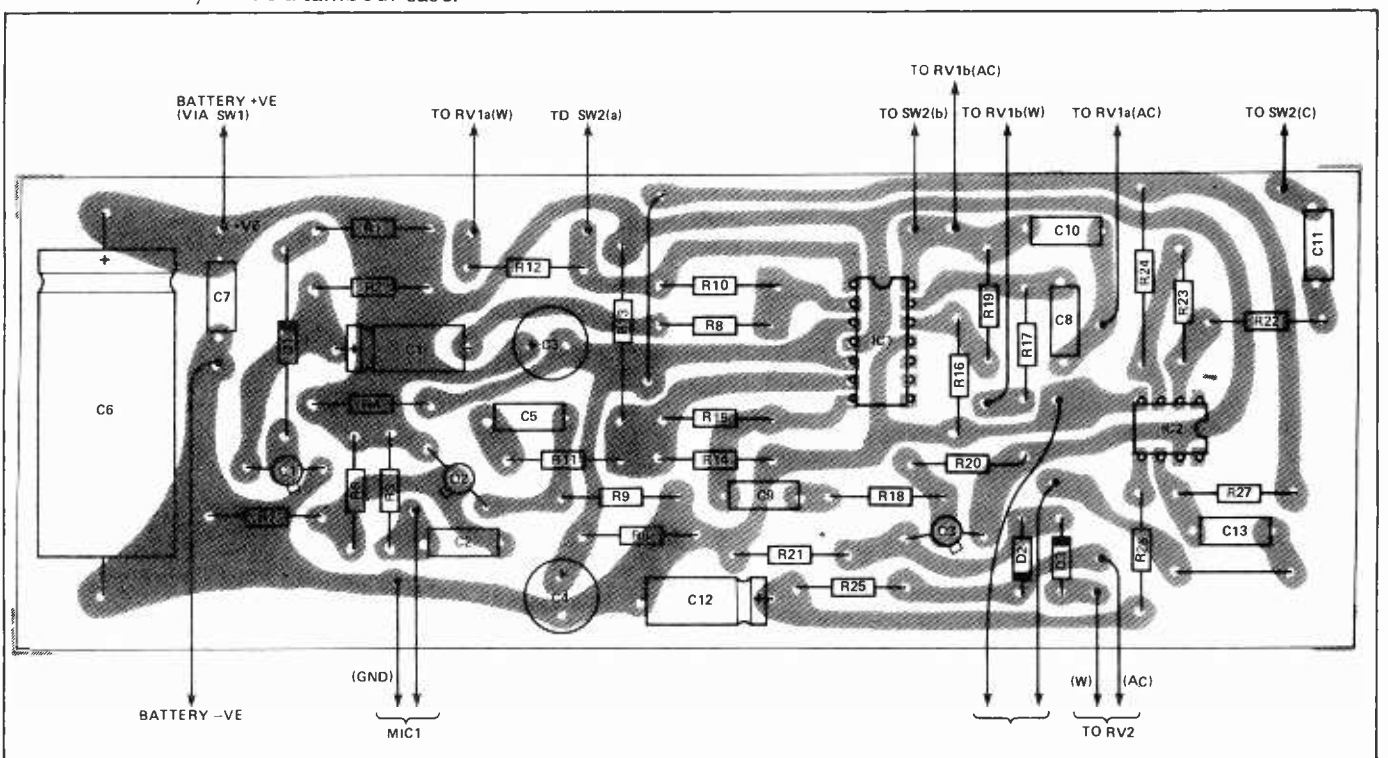

Fig. 2 Component overlay of the crash cymbal.

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THE SECOND LINE OF DEFENCE

Vivian Capel concludes his reflections on domestic security with a design for an alarm system which represents a radical departure from most current thinking — it's simple and effective and there's not an IC to be seen.

This alarm system was born of experience and developed through six models over several years. It was originally inspired by an unwelcome visitation, after which — following the time-honoured practice of bolting the stable door agter the horse had fled — the designer went to purchase a commercial system, only to discover snags in all the alarms then on offer.

The considerations that went into the design were all dealt with. The upshot was to go for a battery-operated device with a low current drain in the on-guard or stand-by mode and a moderate current drain when the alarm was sounding. For reasons that have already been well-rehearsed in these pages, the designer settled for a conventional loop circuit (perimeter) device in which the loop would consist of a number of magnetic door and window switches wired in series.

Defensive Postures

The current requirement is met in the alarm. In some systems, currents of several milliamps are common. In this circuit, the 'stand-by' current is around 0.1mA and the batteries, two 996 lantern units in series, with chocolate block connectors screwed on to the straightened end of the terminals for wiring up, can last up to two years with the alarm set every night.

The main circuit contains only one active component — a BC108 transistor. This configuration was arrived at after much pruning of an original, considerably more complicated, circuit. The object was to increase reliability without sacrificing any required feature or diminishing performance.

The circuit includes a facility for pressure pads to be placed at strategic points around the premises. These are normally open devices, so they cannot be included in the loop which triggers the alarm by being broken. As with most similar systems, the pressure pads are included in a separate circuit and are, therefore, optional.

The problem of leaving premises which have been armed is overcome in this circuit by means of a large-value capacitor fitted across the section of the loop which covers the entrance. This will give a delay of about eight seconds after the door is opened, and once the alarm has been set, before the bell is triggered. Obviously, this delay will operate on entry as well as exit and the alarm simply resets itself when the door is closed. This is useful to allow people out and in without the alarm going off, but might just allow a lucky or carefree burglar to stroll through the door with impunity. The obvious solution is probably the best: insert a key-switch in series with the delay capacitor and located in the front door. this should defeat all but the most determined burglar. The key-switch will take the capacitor out of circuit, thus removing the delay.

The alarm also features a panic-button facility, useful in case of attack in the home or for the elderly or infirm.

After considerable research and testing, the Tann Synchrome B6D12 bell was found to be the most suitable available. Current consumption averages out at 95mA, which gives a total consumption for two bells in

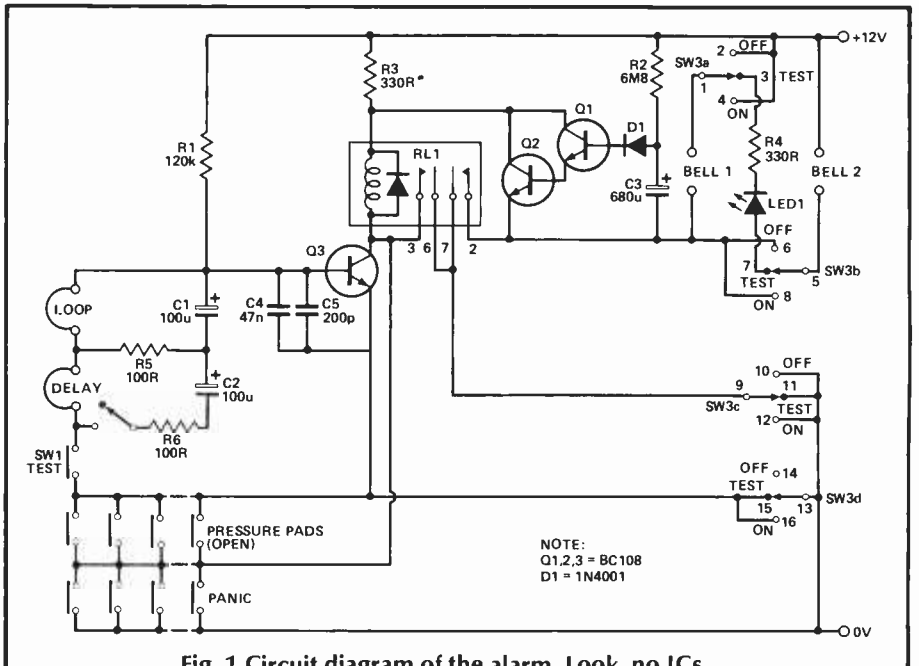

Fig. 1 Circuit diagram of the alarm. Look, no ICs. . .

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parallel of less than a torch bulb. The sound output is very high — about 88dB at 3m. Of course, any 12V bell or siren of suitably low current consumption and high sound output may be used in this application. RS stock a number, including an own-brand bell which is specified at 80mA and 88dB at 3m (RS 249-637) and a useful low current siren which is specified at 20mA and 107dB at 1m (RS 249-924). Maplin also stock a 12V bell (YK 85G) with a claimed current consumption of only 60mA. Remember that the 3m output figure is always 10dB less than the 1m figure. RS components can be ordered through any dealer with an account or through Crewe-Allen Ltd., whose address is given in Buylines. A good guide to bell or siren quality is British Standard BS 5839: 'Fire detection and alarm systems in buildings'. You should not have to pay much more than £12 for any suitable bell or siren.

False Alarms

Safeguards against false alarms are designed in to the circuit, and, in that respect, it is deceptively simple. One common problem with perimeter loops is that they can act as untuned aerials picking up all manner of signals which might be rectified by the semiconductor input and trigger it. Two bypass capacitors are wired across the base-emitter junction of the main circuit transistor, one a largish value for lower frequency RF and one a small, non-inductive type for higher frequencies. This gives a high degree of immunity from unwanted signals.

Another capacitor wired across the main loop itself gives a slight delay when the alarm is triggered by a break in the loop. With the stated value (100μF) this amounts to 0.8 seconds, enough to ensure that temporary breaks in the circuit — caused, for example, by the wind or by rattling doors moving magnets and their corresponding reed switches apart — do not trigger the alarm.

Components And Construction

The specified reed relay and key switches were all obtained from RS and are listed as such in the parts list. Flush contact and surface mounting reeds for alarm applications are also obtainable through Maplin (FK77J, £1.35, and YW47B, £1.95, respectively). Door loops (YW48C, £2.39), window foil (YW50E, £1.19), foil terminators (YM51, 65p), pressure mats (YB91Y, £3.55) and stair pressure mats (FK79L, £2.25) are also available from Maplin. In fact, Maplin will supply almost all the hardware you require, including panic buttons, heat detectors, vibration sensors and junction boxes.

The specified relay is an encapsulated DIP double pole type, dimensions 26x14x10mm, coil voltage 3.7-7.5V, coil resistance 375R and contact ratings 0.5A at 200V dc. It includes an ingtegral protection diode, RS 349-428 or Farnell 103-590 are suitable (the Farnell devices are Hamlin HE822A5032 types), for around £3. Other relays could be used, but this will probably require adjusting the PCB layout and, perhaps, the series resistor. A separate protection diode may also be necessary.

A suitable key switch for delay by-pass should be easiy available, since all that's required is an on-off device. However, if you want a key switch for the main unit, you will have to use a key switch mechanism and a pair of two-pole, six-way wafers. The key switch mechanism has 60° indexing and so skips every other contact on the wafers. The mechanisms and wafers are available from RS (339-651 and 327-771) or Farnell (147-143 and 146-035) at a total cost of around £6 or £7. Because of the skipping of contacts, numbers 1, 3 and 5 are used while 2, 4 and 6 are left blank. The mechanisms can be set to stop at position 5, giving the three needed positions. A cheaper but less secure alternative is to use an ordinaty 4-pole 3-way switch.

Construction is easy, there being few components. All of

HOW IT WORKS

The base of Q3 is tied to the emitter by the two loops, and is non-conductive in the stand-by mode. The only current passing in this condition is through R1, the 120k base resistor, which across 12 volts is 0.1mA. C4 and C5 are the RF bypass capacitors.

SW3d connects Q3 emitter to the negative rail when the alarm is on. If the main loop is opened, C1 starts to charge through R1 and takes 0.8 seconds. The base becomes positive and Q3 turns on, energizing the relay, RL1, in its collector circuit. One pole of the relay switch connects the bottom end of the relay coil to the negative supply through SW3c, thus latching it on and cutting out Q3. The other pole switches the supply to the bells through SW3a and SW3b.

When the delay loop is opened, the same action occurs but C2 charges, and being ten times the value of C1, takes 8 seconds to do so. If the loop is closed within this time it discharges C2 (through R6, for current limiting) which will start to charge again with any re-opening of the daly loop. SW1 is a normally-closed test button in series with the loops. Pressing it gives immediate triggering. SW2 switches C2 out of the circuit, thus avoiding the delay.

The open circuit which serves the normally-open pressure mats and panic buttons, connects the relay bottom end to the negative supply, thus energising it directly. In the event of Q3 failing and not triggering when an intruder enters, the pressure mats and panic buttons would still be on guard.

SW3c, which at first glance seems unnecessary, serves to delatch the relay when switching between positions, since the switch must be break-before-make. Without this there would be no way of switching off after the test button has been used without turning the circuit off.

In the test position, SW3a and b place the two bells in series with an LED and current limiting resistor R4. On triggering the circuit with the test button, the LED will light only if both bells and their wiring are continuous. The current is insufficient to sound them. As the relay, switching, and Q3 must also be in order to light the LED, it will not light before the button is pressed, so the loop, too is tested. Only pressure mats and panic buttons are not checked this way.

Q1 and Q2 are connected as a darlington pair across the relay coil and Q3 base-emitter junction via one pole of the relay switch. The relay is switched at 6 volts, obtained from the 12V supply via R3 which forms a potential divider with the relay coil (375r). When the relay is first energized, Q1 and Q2 do not conduct and have no effect. However, C3 starts to charge slowly through R2. When the voltage across it rises, D1 is biased on, the transistors begin to conduct and shunt the relay coil reducing the voltage across it. When the voltage drops to about 2V, the relay delatches, switching off the bells. The darlington pair are also disconnected from the negative supply, and this causes C3 to discharge quite rapidly into the base circuit of Q1.

The circuit is now reset and ready for any further action. If the loop is still open triggering will be almost immediate, so the bells will continue to ring. Time for the bells to switch off is about 10 minutes. If a shorter or longer time is required the value of C3 should be decreased or increased accordingly.

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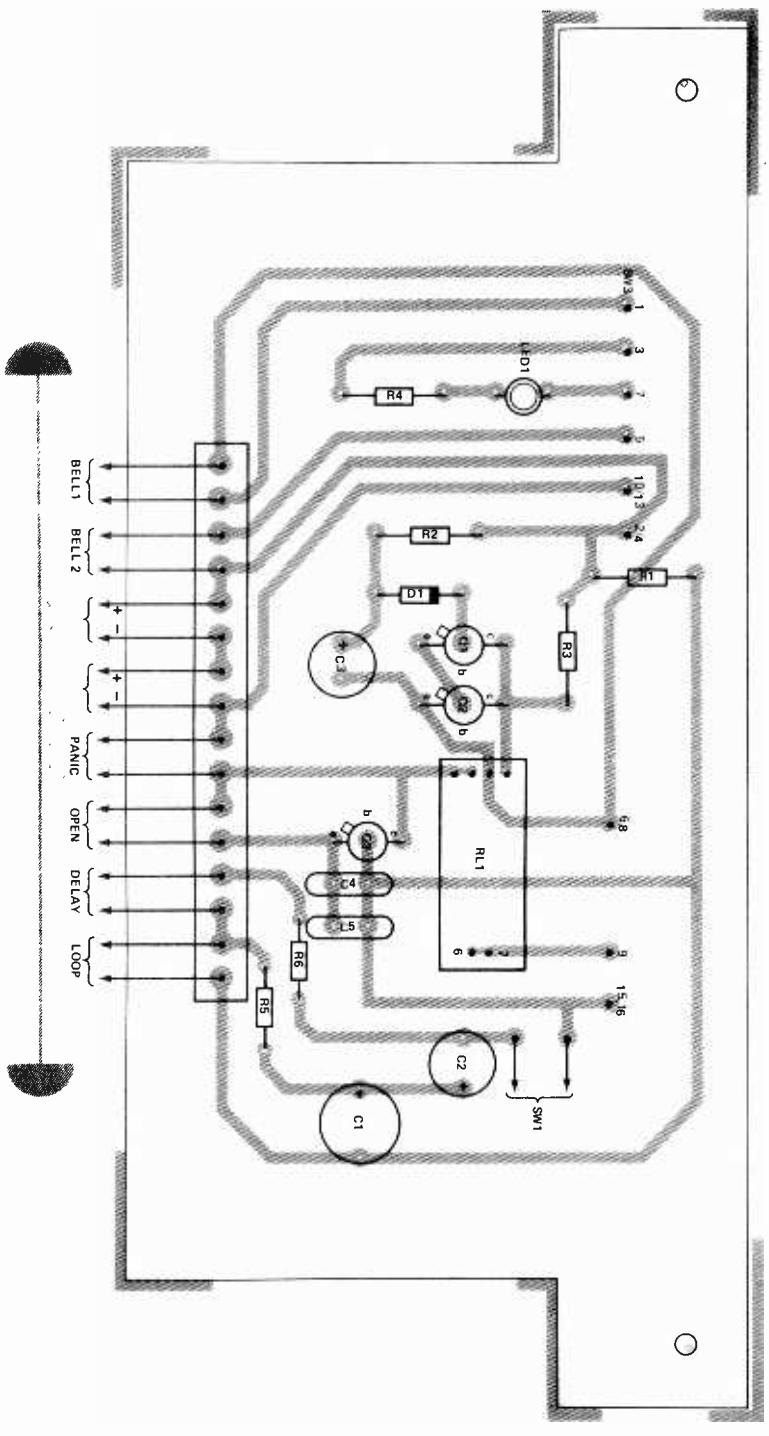

Fig. 2 Component overlay of the alarm. Note the pin-out of RL1.

them go on the PCB except the loop and panic switches, LED and test button. Connections are made using PCB terminal strips.

Operation

After installation, shut all controlled doors and windows and turn all shunt switches to the open position. Turn the switch to 'test'. The LED should not light up. If it does, the loop is not continuous. Check and correct. Once the LED does not light up, leave the switch on 'test' and press the 'test' button. This gives a silent test of the bells. The LED should light on this test to show that the bell circuits are coninuous.

PARTS LIST

RESISTORS (all ¼W 5%, unless stated)	
R1	120k
R2	6M8
R3, R4	330R (½W)
R5, R6	100R
CAPACITORS	
C1	100μ 25V radial
C2	1000μ 25V radial
C3	680μ 25V radial
C4	47n
C5	200p
SEMICONDUCTORS	
Q1, Q2, Q3	BC108
D1	1N4001

MISCELLANEOUS (see text)
SW1 normally closed push-button switch
SW2 key switch
SW3 4-pole, 3-way rotary switch or key switch (see text)
RL1 double-pole DIP reed relay (see text)
Two 12V low-power bells or sirens, 4 off 4-way
PC terminal blocks, case, PCB, bell pushes, pressure pads, flush or surface mounted magnetic switches and connecting wire as required.

BUYLINES

The problem components are all discussed in the text at some length. The addresses of the suppliers mentioned there are:
RS Components, PO Box 99, Corby, Northants, NN17 9RS (0536 201234)
Farnell Electronic Components, Canal Road, Leeds LS12 2TU (0532 636311)
Maplin Electronic Supplies, PO Box 3, Rayleigh, Essex, SS6 8LR (0702 552911).

Maplin sell to individuals and they have a number of shops whose addresses are given on the Maplin ad in this issue. RS and Farnell components should be obtainable through any supplier who maintains an account with these companies. RS components are also available on order from Crewe-Allen, 51 Scrutton St., London EC2.

ETI

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DIGITAL SOUND SAMPLER

In the latest episode of this everyday story of sample folk, Paul Chappell looks into the technique we'll be using to convert sound into numbers.

The first stage in designing any digital sound sampler is to determine how to do the analogue-to-digital conversion. For all the reasons rehearsed in ETI, September 1985, we've decided to use a companding A-to-D converter. This will give us effective 12-bit resolution in an 8-bit system — good enough for the quality reproduction of sampled sounds. Last month's article, 'The Sample Life', goes into some of the finer theoretical points of the companding A-D converter, so I won't repeat them here.

The conversion circuit looks a bit complicated (Fig. 1) and you will note that it uses a companding *D-A* converter, the Am6070 or DAC88. Why didn't we use a single IC? The answer, my friends, is that nobody makes one, so we have to make our own from the DAC and a few other ICs.

Conventional Conversion

The circuit is not particularly revolutionary. To tell you the truth, I pinched it straight from a data sheet since I can't see any way to improve it. The only change I have made is to specify a precision comparator in place of the 311 type suggested in the data. In normal (non-companding) A-to-D conversion, the only results of comparator offset voltage would be to shift the DC level of the converted signal by a few tens of mV and to cause the onset of clipping to occur maginally earlier than otherwise. Nothing to worry about.

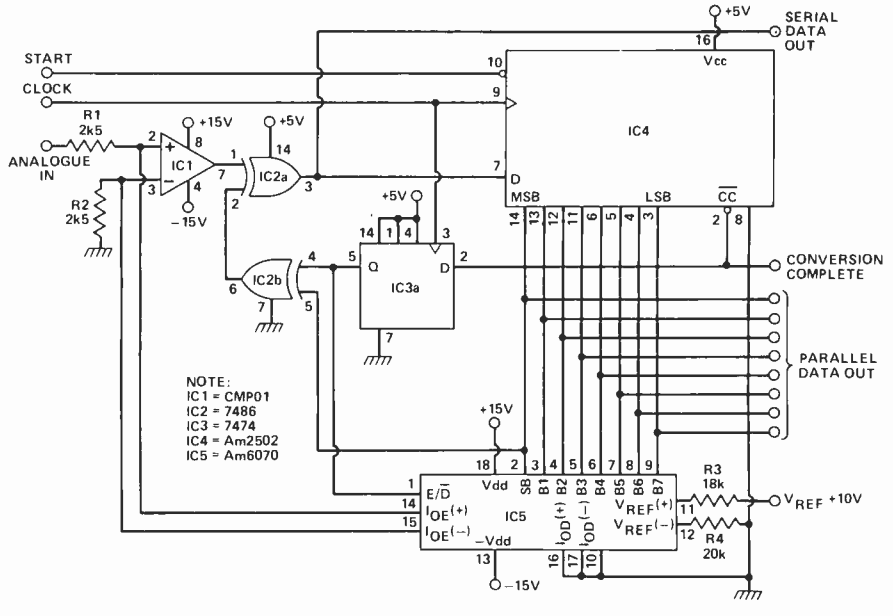

Fig. 1 Circuit diagram of the companding A-to-D converter.

HOW IT WORKS

The SAR, IC4, is a general purpose register for A-D conversion and does not make any special provision for sign and magnitude representation, so a little extra circuitry is needed to use it to set the sign bit correctly. Conversion begins when a logic 0 is applied to START, IC4 pin 10. The SAR sets its outputs to 01111111 for the first trial on the next rising edge of the clock. At the same time, the Q output of IC3a, half a 7474, is set to 0 (because CONVERSION COMPLETE will be low after the previous conversion cycle and will not go high until the clock falls again).

The low on the IC3a, pin 5, sets the ENCODE/DECODE (E/D) input of the converter, IC5, pin 1, to 'decode', cutting off any current to the encode outputs $I_{OE(+)}$ and $I_{OE(-)}$ (IC5, pins 14 and 15). This means that the comparator, IC1, is comparing the input voltage directly with ground (via R1) and will switch high if the input is positive and low if it is negative. If you work through the logic levels on the EXCLUSIVE OR gates — IC2a and IC2b — you'll see that this is passed unchanged to the input of the SAR, IC4 pin 7.

The next time the clock goes high, this value is clocked into the MSB position of the SAR (IC4 pin 14), giving the correct sign bit. At the same time the next bit is set to 0 for the first voltage level trial. The 7474 will also change state because CONVERSION COMPLETE, IC4 pin 2, will have gone high. The encode outputs will now be allowed to pass a current as the D-A conversion takes place, and the conversion continues as described.

One slight complication is that if the input voltage is negative, we begin the trials with the lowest possible voltage (highest magnitude but negative sign) and work upwards. This means that the comparator output must be inverted. The EXCLUSIVE ORs (IC2) take care of this.

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In companding conversion, however, it's a different story. A DAC88 is going to cost you around £16 and you are paying your money for the precision with which it will handle small signals. To make the best use of it, you want small signals to be firmly centred on the high resolution section, or chord, of the DAC's conversion characteristic. As this chord consists of quantisation steps spaced 0.025% of full scale apart, the entire chord will only stretch 3.75mV for a 1V FS. Beyond this point the quantisation steps double in size, resolution is halved and quantisation noise doubled. A small voltage offset cuts the small-signal performance by 50%!

I am a bit dubious about using a 311 in this situation. It has a maximum voltage offset of 7.5 mV and even if this is trimmed out it will still drift with temperature and time. Another reason for being doubtful about the 311 is that for a fairly fast conversion rate — a 1MHz clock, say — its slow response time is pushing the performance of the whole loop quite close to its limits. If we do a quick sum of the delays around the loop, the total of the gate delay for the 7486, setup and propagation delay in the 2502 comes to roughly 80ns; settling time for the DAC will be about 50ns, leaving a little over 400ns for the 311 to respond. Typical response time for the 311 is given as 200ns, which seems OK. Looking into the situation a little more closely (and remembering Auntie Static's warning about 'typical' figures) we find that this will be very much slower in conditions of small overdrive voltage — the time when we are particularly concerned that it should be at its best!

The contribution of R1 and R2 to any error is far less than it may seem at first sight. With an ideal converter, changes in value would only alter the effective gain of the converter. With a real comparator, offset voltages can be introduced by variations in the input bias currents. These can be kept to a minimum by keeping R1 and R2 low in value: 1% tolerance is perfectly adequate to keep offset from this source far below that from other causes.

Approximate Truth

The converter circuit produces an output in sign and magnitude form. The most signifcant bit of the binary word will be a 1 if the instantaneous voltage is above 0V, 0 if it is below. The remaining seven bits represent the 'distance' of the input from 0V.

Just suppose for a moment that we have a voltage which is rising from 0V to full scale, which we'll say is 1V just to make the sums easy. As the voltage is positive, the sign bit will be a 1. The next three bits represent the chord number. Initially we will be on the highest resolution chord, so they will all be 0. The remaining four bits represent the step within the chord and at 0V these will also be 0.

The first chord goes in steps of 0.025% of full scale — 250μV steps with a 1V FS, so that when the input reaches 250μV bit 0 will be set to 1. As the input voltage rises, the lower four bits continue to count up in 250μV steps until at 3.75mV they are all set to 1. As you would expect, the next step is for the count to advance from 10001111 to 10010000, but instead of 250μV it takes a 500μV rise to get there because we are now in the second chord and the step size has doubled. The lower four bits count in 500μV steps until 10011111, the end of the second chord, and it now takes a 1mV rise to reach the next count; we are in the third chord. The fourth chord goes in 2mV steps — and so on, until at a count of 11111111 we reach the sixteenth step of the eighth chord, which will be the 1V full scale.

The circuit performs the conversion by a process called successive approximation. In essence this consists of first setting up the highest possible number in the SAR, or successive approximation register, (ignoring the sign bit for a moment, this will be 1111111). Starting with the most significant bit, each bit is taken low in turn, the code is converted by the DAC and the resulting analogue voltage is compared with the input. If the input is higher, the bit being tested is set back to a 1 again. If the input is lower, it is left at 0. In this way, after testing and setting all seven bits, the closest number *above* the value of the input will be left in the SAR and the conversion will be complete.

A Quick Sample

As a quick sample, let's take a four-bit linear conversion with a full-scale of 1.5V. Let's suppose the input is 701mV (you'll see why later). The first step is to set the MSB to 0, giving 0111. This is converted to an analogue voltage (700mV) and compared with the input. The input is higher, so the MSB is set back to a 1. The next bit is then set to 0 giving 1011, the analogue voltage (1V) is left at 0. The next trial is with 1001; the input is still lower so this bit too is left at 0. The final trial is with 1000; the input is still lower so the LSB is also left at 0. The conversion is complete and we have our digital code: 1000.

If you've got a calculator and enough patience, you can convince yourself that this will also work with companded conversion. In fact it will work with any non-linear conversion as long as the DAC is monotonic.

Thankful

You may also have noticed that we rejected the first trial of 700mV, and ended up with a code representing 800mV for an input of 701mV. As I mentioned before, the successive approximation technique gives the nearest value above the input. In linear conversion it is usual to give a half step offset to the converted wave to restore the correct DC level. In companding conversion the situation is more complicated as the offset will alter from chord to chord. Thankfully, the DAC88 takes care of this internally. **ETI**

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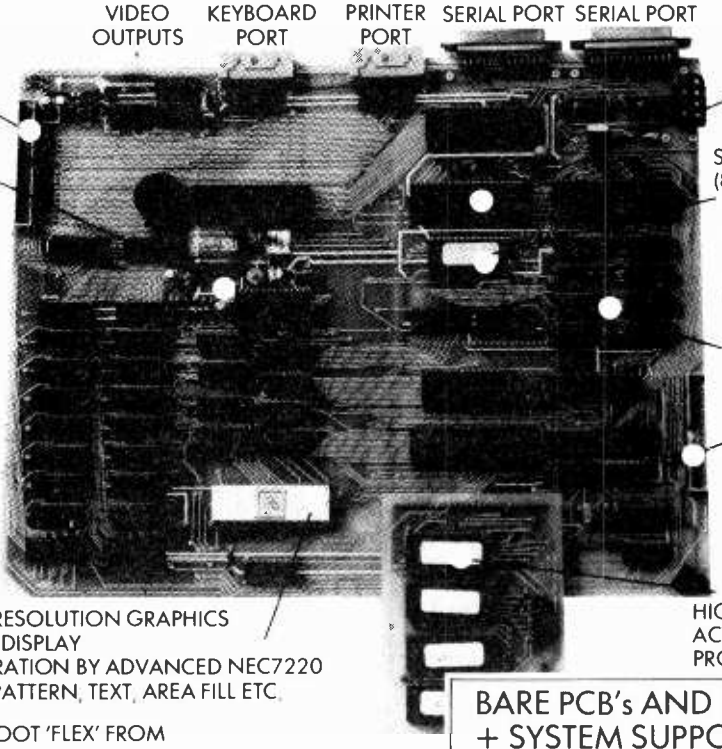

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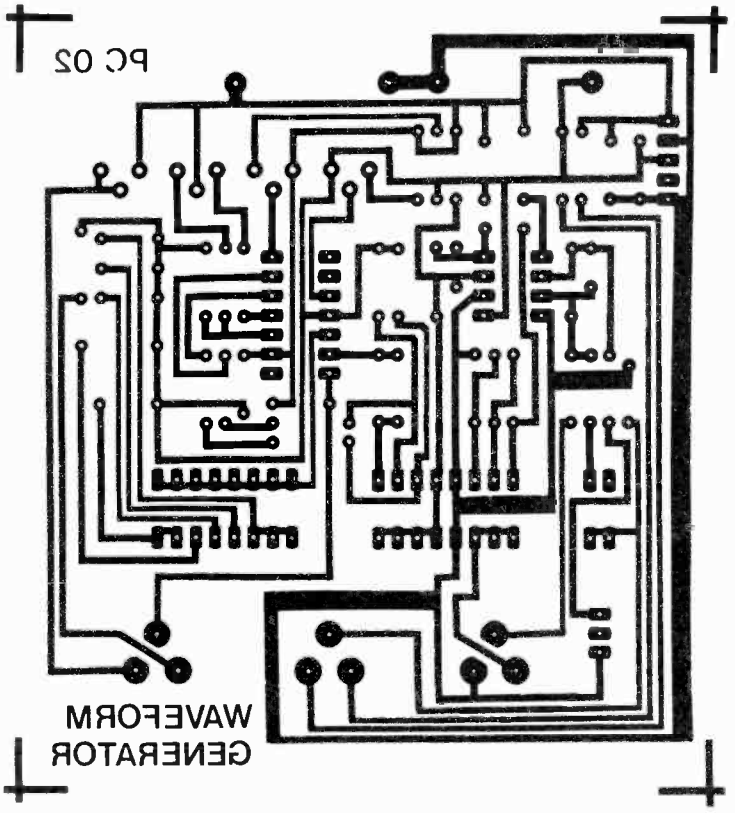

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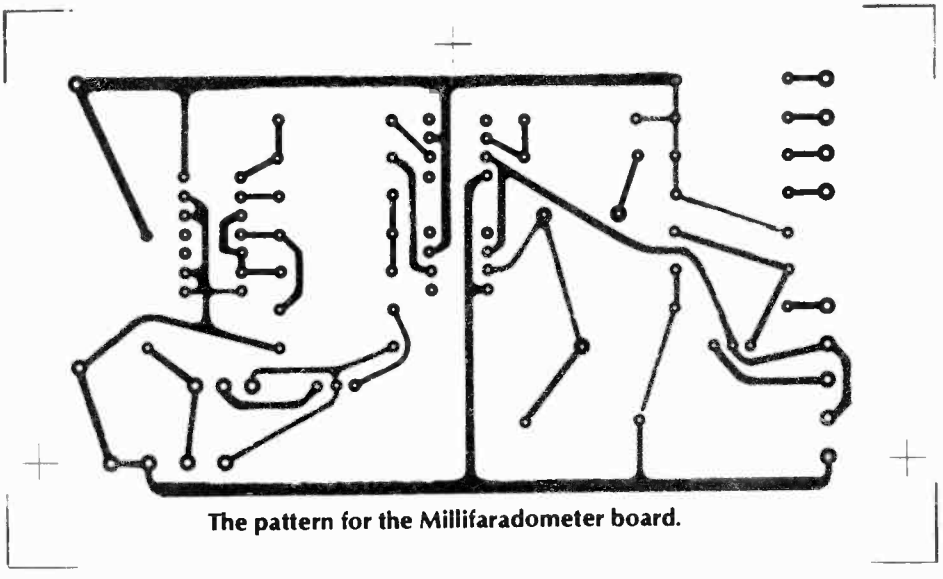

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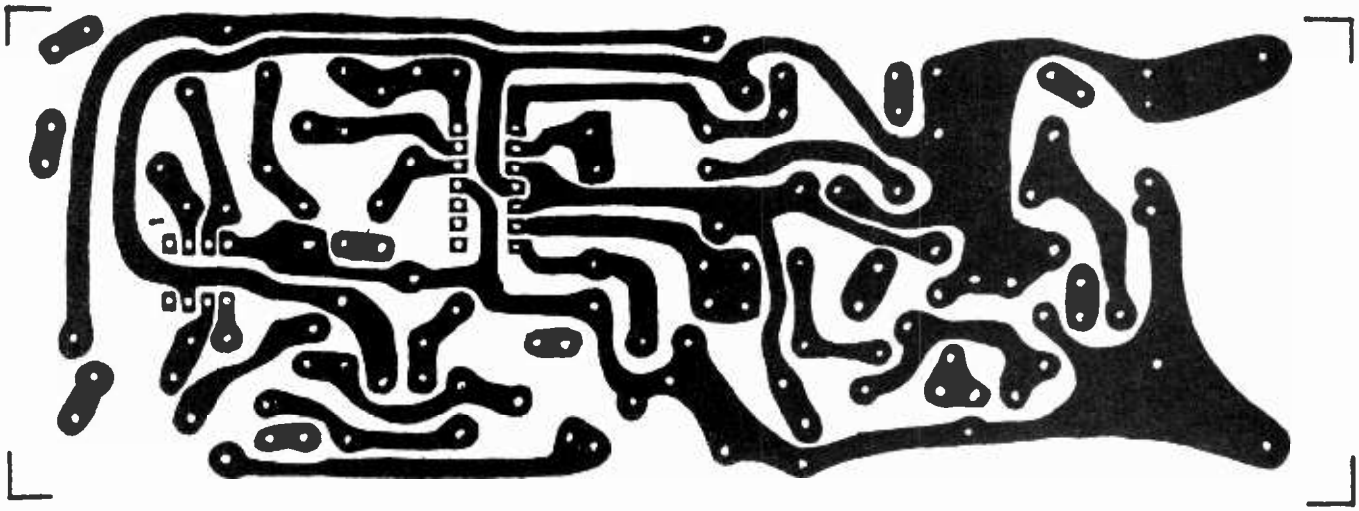

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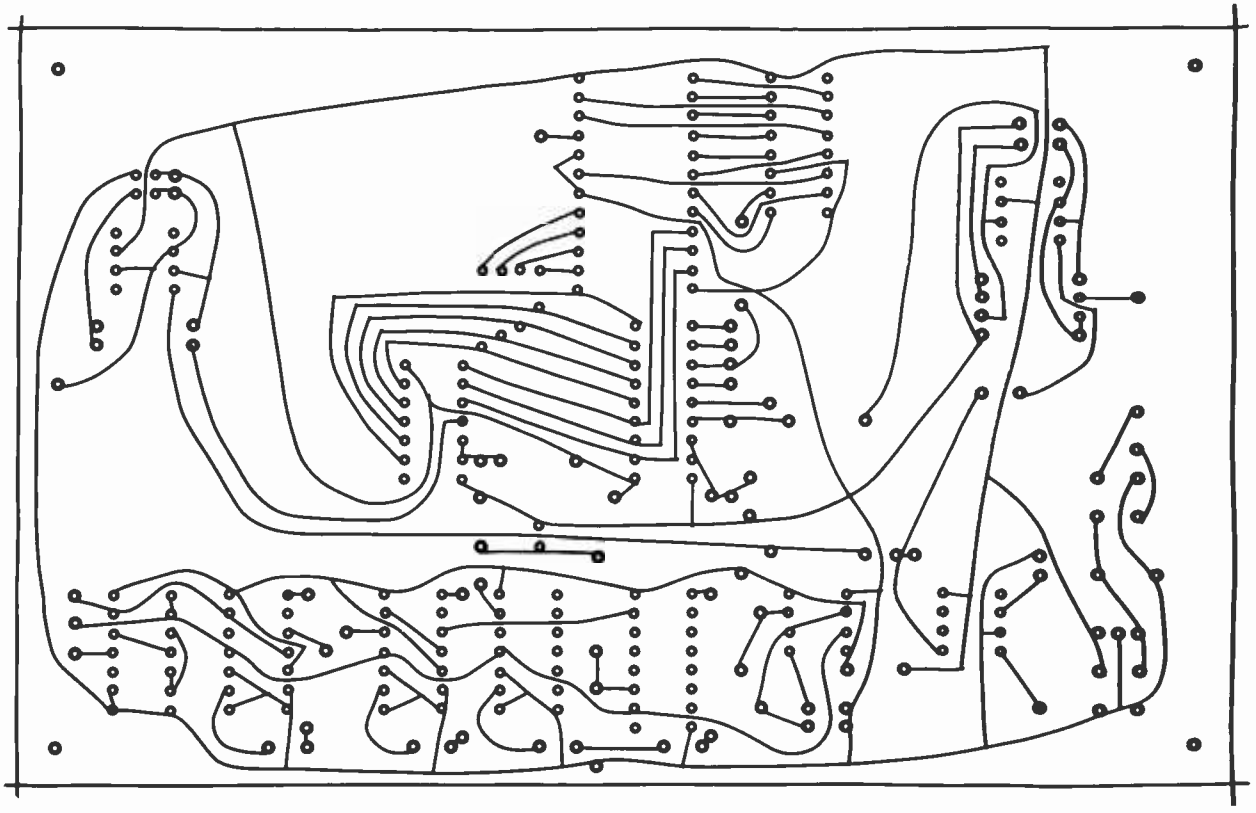

The foil pattern for the memory 'scope display PCB.

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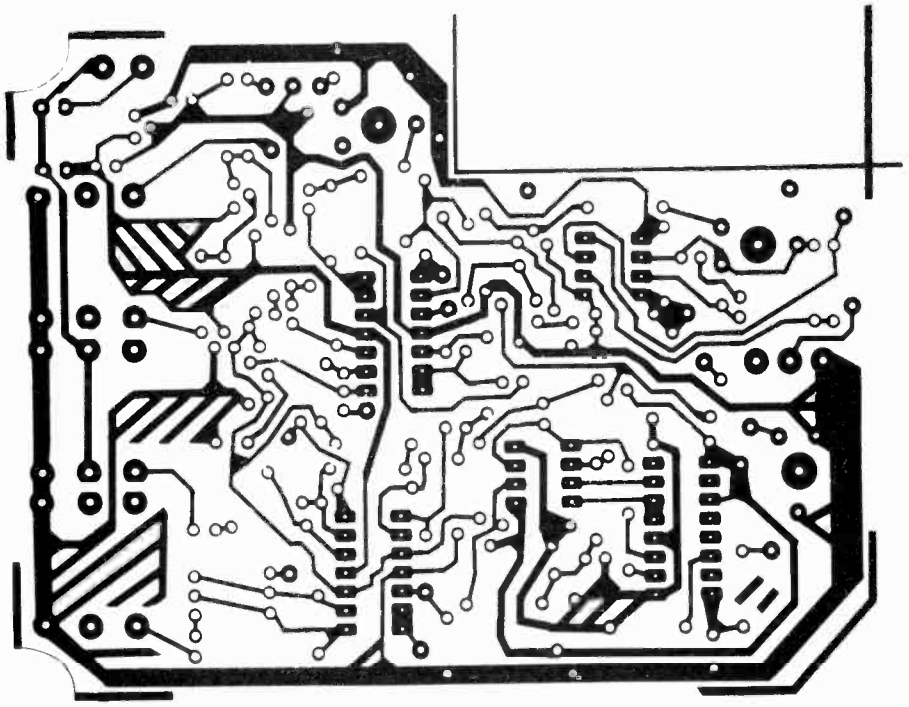

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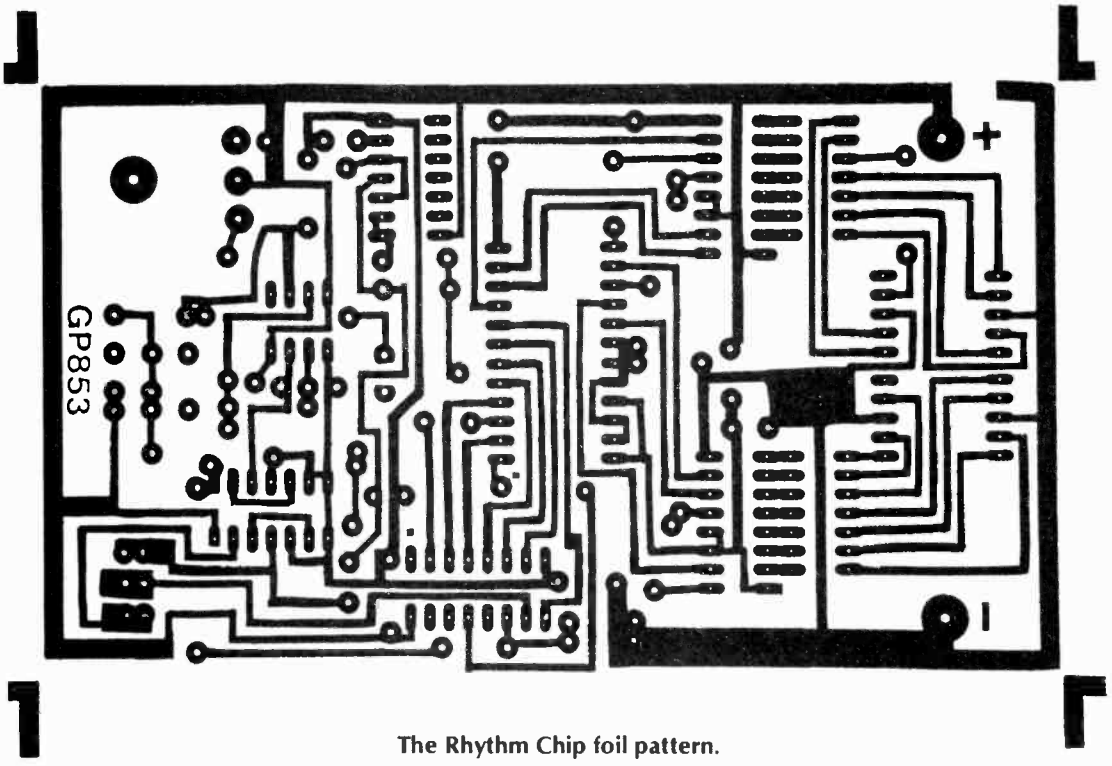

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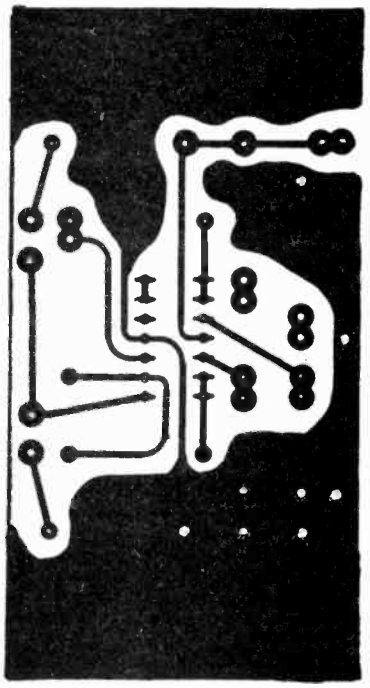

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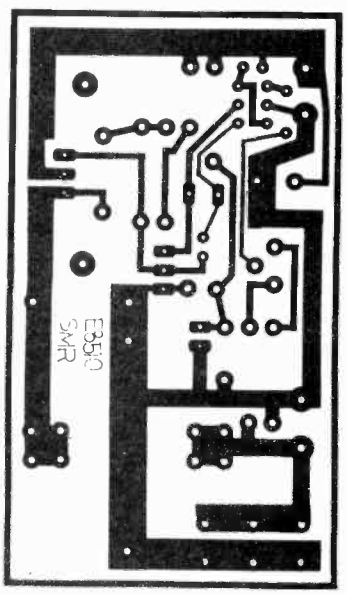

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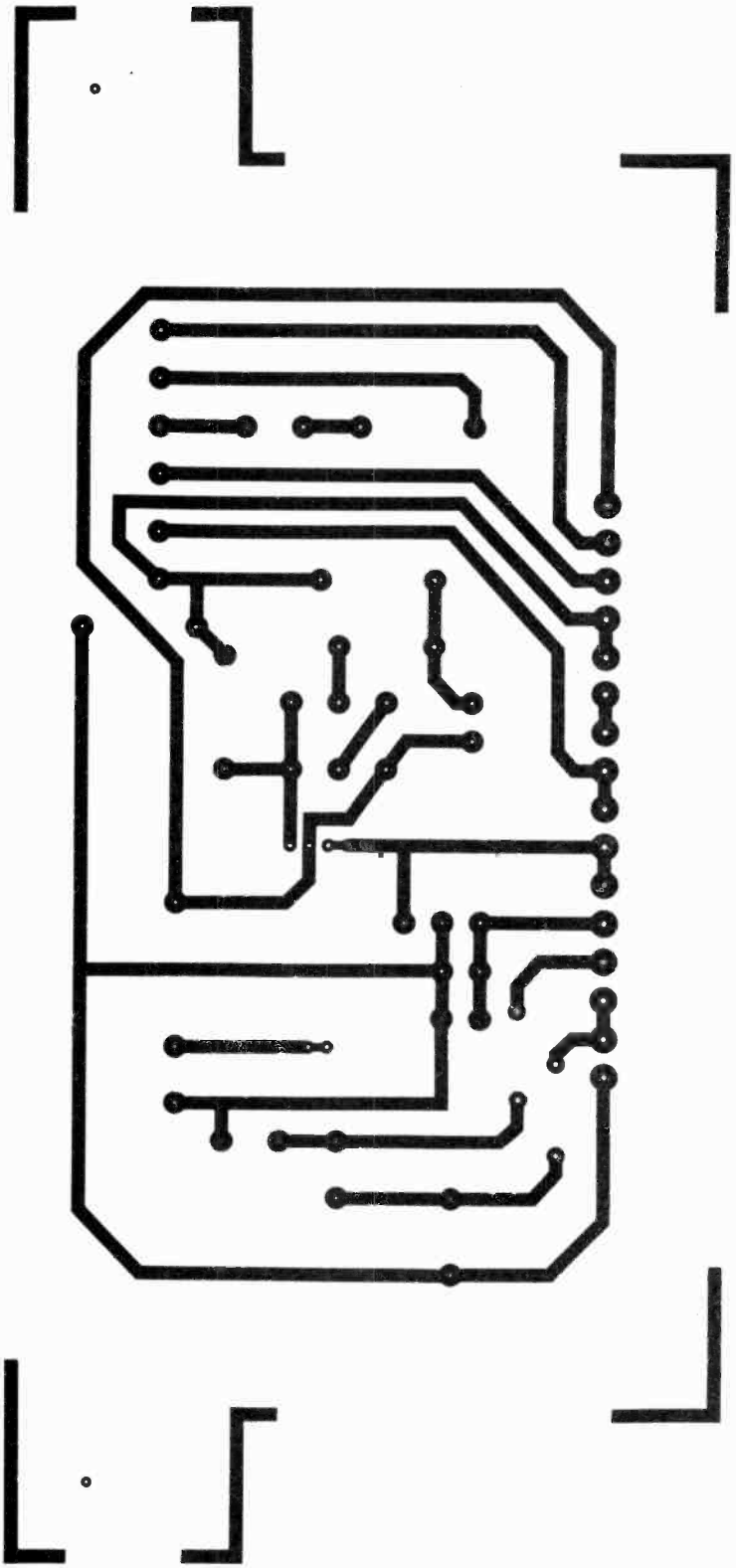

The foil pattern for the Second Line of Defence alarm system.

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TRAINS OF THOUGHT

For many years railway modellers have been installing 12V lamps in their coaches connecting them to power pickups on the wheels and running illuminated trains — very effective if the room lighting is turned down to simulate dusk! This arrangement, however, suffers from three disadvantages:
(1) lamp brightness varies with train speed and is nil when trains are stopped;
(2) the lighting cannot be turned off;
(3) modern coaches mostly use polystyrene construction, with horrific consequences if it comes in close contact with a hot lamp!
Using command-control systems such as Hornby's Zero-1 eliminates the first problem and makes constant brightness possible. An accessory control module overcomes the second problem but the third is more difficult.

For those of us who use conventional (albeit electronic) control system, two methods of coach lighting are possible. The first is to superimpose on the track a high-frequency AC voltage, eg., 6V at 30 kHz. The high frequency has minimal effect on the loco motors which are primarily inductive devices. Placing a 470n capacitor in series with each lamp effectively isolates it from the DC — or quasi DC — output from the controller, while the AC passes ready through — 470n offers only about eleven ohms resistance at 30kHz — and lights the lamps. Switching on and off the AC supply will control the lights with minimal effect on the locos.

There are just two problems — both potentially disastrous. First, building a circuit that is capable of delivering up to 1A, 6V AC at 30 kHz is not easy. If you can get away with a small output transistor like the BFY51 all well and good, but watch our for thermal runaway with larger types such as the ubiquitous 2N3055. Push-pull output at such frequencies is best accomplished using the rather more expensive (but delightful to handle) VMOS devices.

Secondly, although the AC cannot interfere with the loco motors directly it can interfere with the controller and vice-versa. Turning the controller on full can short-circuit the AC voltage so that the lamps fail and the AC generator goes up in smoke. If the controller is an electronic type with a feedback loop, the AC gets into the feedback loop where it can cause all sorts of interesting phenomena, including making the trains dance jigs!

The solution is a choke in series with the controller and AC generator, but you will need a push-pull VMOS output and a split power supply.

The alternative approach is to run the coach lamps off an array of rechargeable batteries, eg., NiCads, concealed somewhere in the train and recharged from the track voltage (when available). Switching on and off is best accomplished by on-train reed switch/bistable combinations activated by temporarily placing magnets near the passing train.

The problem this time is regulating the voltage picked up from the track down to the 6V or so that can be delivered by NiCads. Normal voltage regulators generate far more heat than can be dissipated within the confines of a polystyrene coach; the best solution is a switching regulator which runs cold. Such circuits can be devised quite simply using the inexpensive 555 timer IC. The batteries are best concealed in a brake van such as the Lima full brake.

There is no simple answer to the problem of stopping the lamps from melting the train! It is best to keep the lamps as far from polystyrene structures as is practicable and under-run them by using a lower-than-rated supply. The light will be yellowish but this doesn't really matter and it does extend the life of the lamps. Now that blue LEDs are available (if expensive) it should not be too long before white-light LEDs are with us. That should make life a lot easier for those whose railway modelling includes light entertainment.

Roger Amos

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OPEN CHANNEL

As you read this column, a decision is being made regarding the future of British and European television systems which could bring them into broad alignment with other systems throughout the world. The benefits of a single world standard in television broadcasting are fairly obvious: programmes made in one country could be retransmitted in another without reformatting of any kind, television receivers would not be unique to individual countries but could be transported (and sold) anywhere without modification. This all sounds great in theory, but what about the practice?

Present world television systems fall into three types. The European systems are based on the PAL standard (Phase Alternation by Line), the French SECAM system (Sequentiel Couleur A Memoire), and the American NTSC system (National Television Systems Committee). The quality of picture in these standards varies considerably: the NTSC standard, for instance, is badly affected by weather conditions, with colour hue changing as the phase of the received signal changes.

Until now, television standards have been designed to provide a system which is only as good as the customer wants. British television systems, for example, have progressed in steps - first there was a 405-line system, then the present 625-line system. In both cases, television receivers could be built using the available technology at a price the viewer was prepared to pay. Considering the complexity of television receivers, it is quite remarkable that they are as cheap as they are - due to mass-production, no doubt.

Given the steps forward in electronics, micro-miniaturisation, and communications since the three main standards were initiated, it seems sensible that any new standard should be more complex. But dare we aim for the ultimate performance possible in any television system given the present technology, or should we just create a new standard which again provides only what the viewer wants, but which we may later discard when further technological developments have taken place?

The Japanese think that the first type of standard is required. They have put a great deal of research and development into a standard called high-definition television (HDTV), which uses a picture of 1125 lines and creates a viewed image of remarkable detail and clarity. This standard is so good that the Americans have been persuaded to adopt it too, which means that virtually the whole world will use HDTV - apart from Europe perhaps.

The problem with Europe is that a standard has already been developed which, although not producing quite such good picture quality as HDTV, still gives enormous quality improvements over existing PAL standards. As far as most of the broadcasting authorities in Europe are concerned, this new standard (C-MAC) is good enough for the foreseeable future of European television broadcasting. By the time C-MAC has outlived its capabilities, new technological developments will probably allow an even greater jump forward (3D television? 'smelly-vision'?) than can be obtained by

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HDTV now.

In effect, C-MAC pushes forward the present PAL system, utilising it more efficiently. It's not really a new standard at all, merely an adaptation of what we presently have. Nevertheless, C-MAC pictures, in an enhanced form, are of excellent quality and compare well with high-quality 35mm cinema film. The system can give a wider aspect ratio - 5:3 - and stereo sound.

But that's not all. Enhanced C-MAC can be transmitted easily over DBS satellite channels: HDTV as yet can't. The bandwidth of an HDTV signal (30 MHz) is greater than the total bandwidth of proposed satellite capabilities. The HDTV engineers say they will be able to compress the signal, but it is unlikely that any great savings in bandwidth will be possible - the most we can hope for is that a single satellite channel will be able to transmit a single HDTV signal whereas at present three PAL channels can be broadcast over one DBS channel.

Another technical problem arises because Europe has a mains supply system which alternates at 50 Hz while American and Japanese systems alternate at 60 Hz. Mains alternation frequency drastically affects television reception because the receivers rely on the mains frequency for various timing controls. As a result, the worldwide 'standard' isn't as standard as you may at first think.

Also, we have to consider what will happen if Europe chooses the HDTV route. The Japanese are already known to be gearing up to mass-production of HDTV receivers. If all television receivers worldwide will be to that standard, they will literally be able to flood the whole market with their equipment, instantly. The European manufacturers may not have that opportunity. And what about the cost; prices as high as £1500 or more have been quoted for HDTV receivers. C-MAC television receivers would be priced at around the same figures as existing PAL receivers.

So, what's the answer? Well, the decision is actually out of our hands, and is about to be made for us. By the end of October a meeting of the CCIR (the International Radio Consultative Committee) will decide which system is to be adopted in Europe. Even though HDTV is undoubtedly a better standard than C-MAC, and even though a worldwide standard is useful, I personally don't think it is the best solution for Europe.

Keith Brindley

ALF'S PUZZLE

Whenever we are puzzled by some complex bit of electronics theory, Alf is always on hand to help. 'What's a sine wave, Alf?' we ask. 'A pure frequency,' Alf ripostes without hesitation. 'What are other waves made of?' we inquire searchingly. 'Sine waves,' Alf replies confidently.

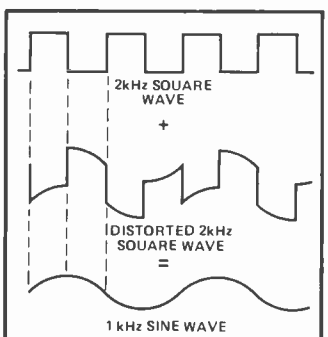
The other day, our Alf was trying to repair a faulty square wave generator. One of the outputs was normal, the other was distorted. Imagine the surprise with which our basement brains responded when he added the two waves together and found they made a sine wave!

Alf knows that a square wave contains more harmonics than it knows what to do with, and reckons that the distorted version must have an harmonic or two knocking about as well. How on earth could all those frequencies add up to a wave with no harmonics at all?

What made matters worse was that his generator was producing 2KHz square waves and the sine wave was at 1KHz, a frequency which shouldn't have been there at all! Where on earth was it coming from?

The answer to last month's puzzle:

If you connect a load between +ve and OV in a power supply circuit, you're okay. The voltage remains fairly constant across the smoothing capacitor and gets topped up each half cycle of the mains. That's the situation with the 12V supply on its own, but try and connect a resistor from the 12V rail to an even higher voltage (say the 24V rail in last month's diagram), and it's a different story. This is exactly what Alf did by providing the 24V rail and connecting the LED and associated circuitry from it to the 12V rail. Now the bridge on the 12V supply becomes reverse biased and there is nothing to stop the voltage of the original capacitor across the 12V supply rising as high as it likes. This is what happens in Alf's circuit when the switch is pressed.



Alf's waveforms

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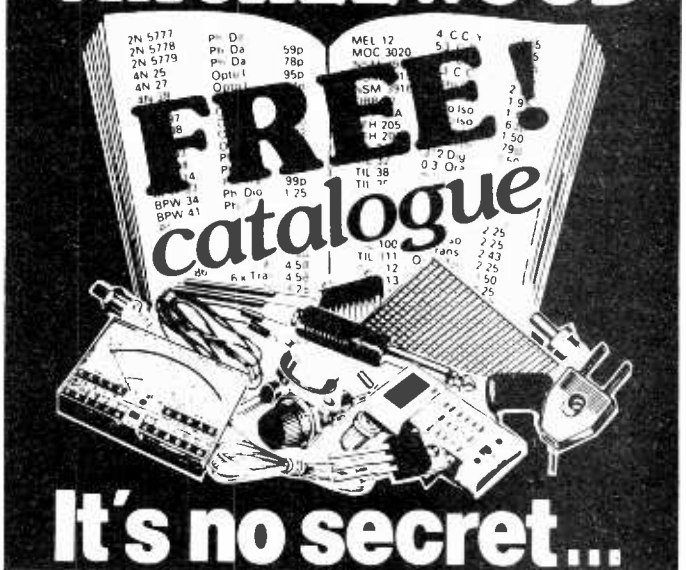

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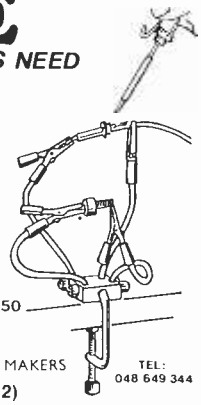

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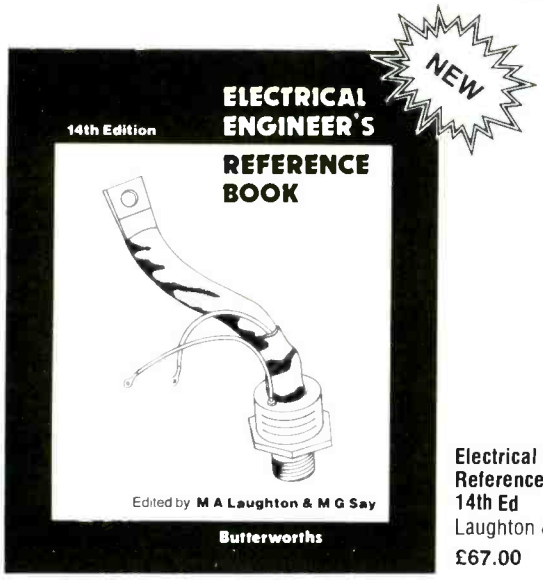

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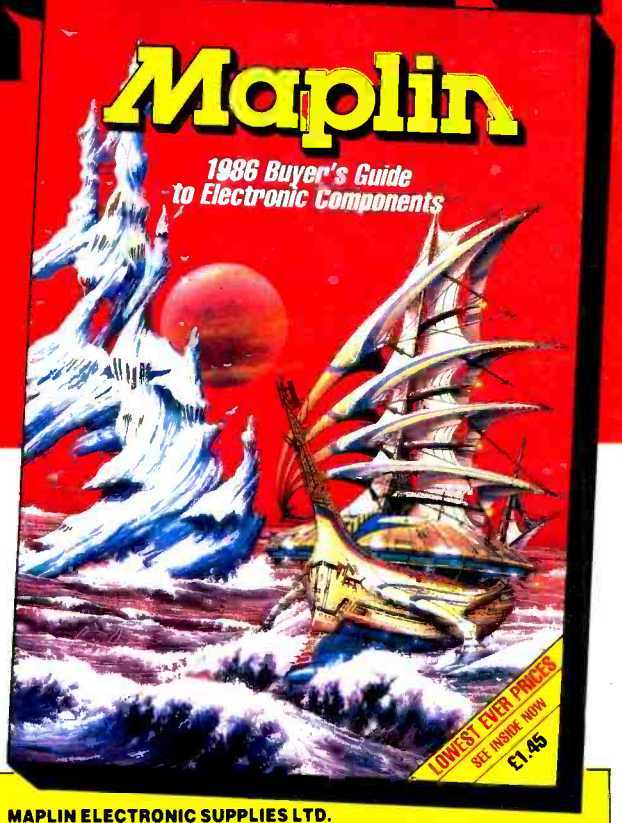

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