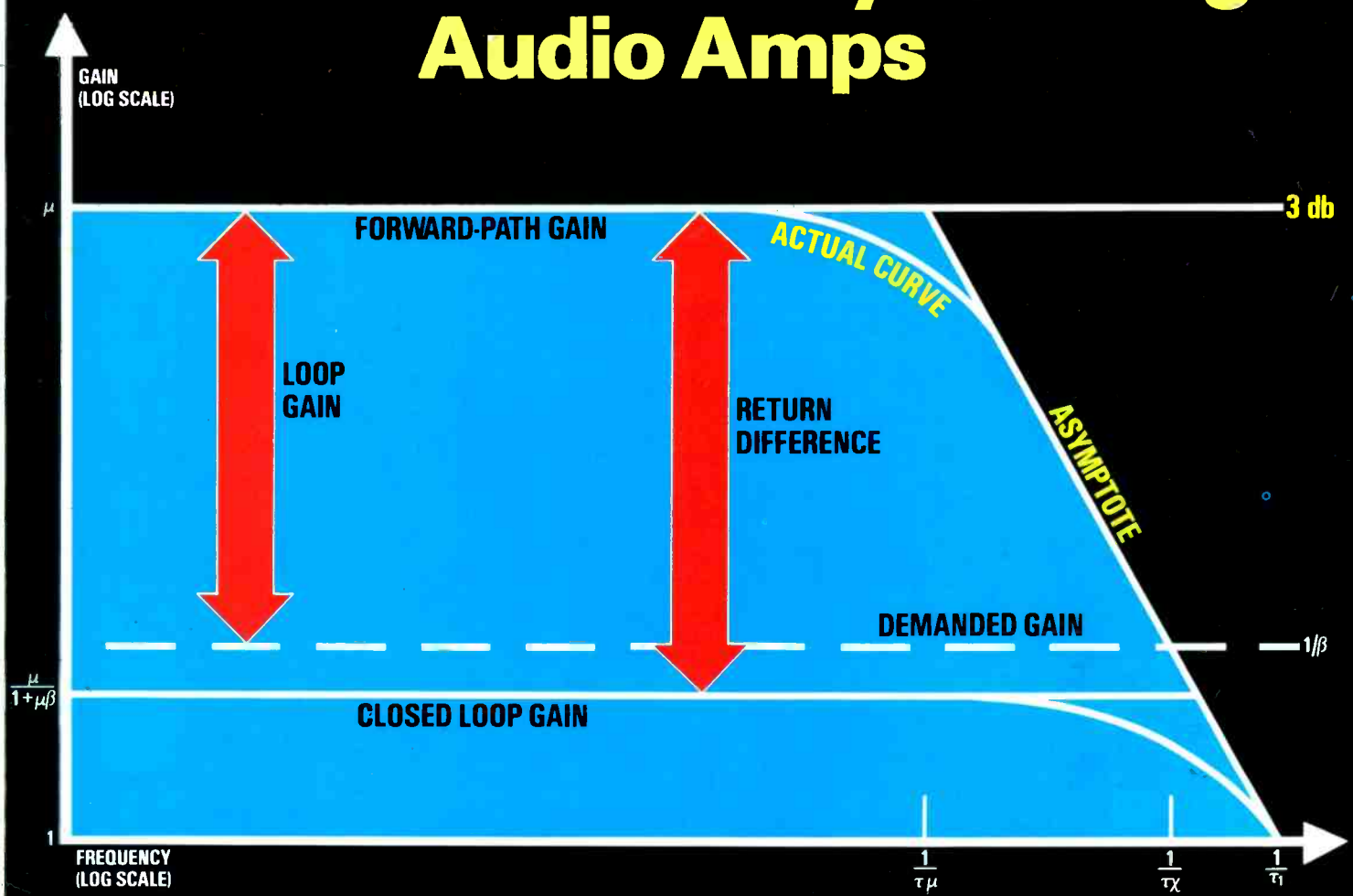
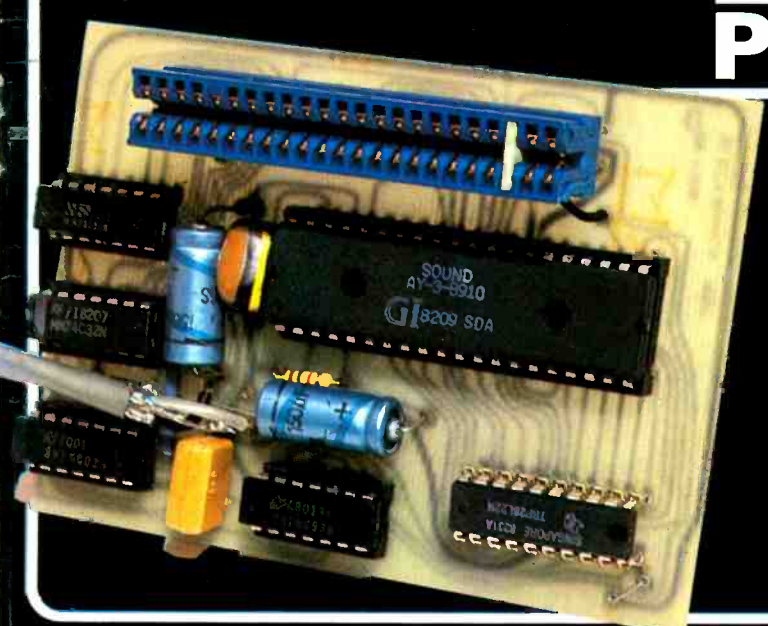
AN ARGUS SPECIALIST PUBLICATION

electronics today

INTERNATIONAL APRIL 1983 85p

NDFL – A New Way To Design Audio Amps





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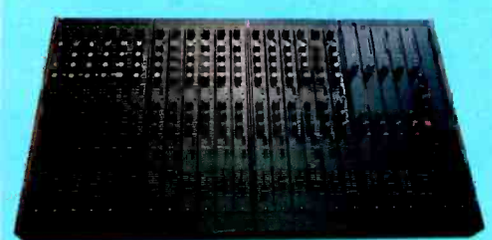
BIG NEWS ABOUT OUR LATEST ADVANCES IN ROBOTICS SEE INSIDE BACK COVER

DJ90 Stereo Mixer — this is a really versatile new mixer that enables the constructor DJ to produce a professional performance every time. There are two stereo inputs for magnetic cartridges, a stereo auxiliary input and mike input. Other 'plus' features are auto-panning for fast or slow slider controls, multi-mixing, ducking, interrupt, input modulation, in short everything . . . the whole works — AND — under £100 complete! Complete kit **£97.50** + VAT

TRANSCENDENT 2000 — Although only a 3 octave keyboard the '2000' features the same design ingenuity, careful engineering and quality components of its larger brethren. The kit is well within the scope of the first time builder — buy it, build it — play it! You will know you have made the right choice.
Complete kit **£165.00** + VAT



SALES COUNTER
Collect your order from the factory. Open 9-12/1-4.30 Mon-Thurs. Easy parking, no waiting

This versatile modular mixer, featured as a constructional article in Practical Electronics can be built up to a maximum of 24 inputs, 4 outputs and an auxiliary channel. Each input channel has Mic and Line inputs, variable gain, bass and treble controls and a parametric middle frequency equalizer. There are send and return jacks, auxiliary, pan and fader controls and output and group switching. The output channels have PPM displays and record and studio outputs. The auxiliary channel also has a PPM display and there is a headphone monitor jack and a built-in talk-back microphone. The mixer modules plug into base units each of which takes up to 6 channels. To eliminate hum the power supply is in a separate cabinet.

Digital Delay Line — With its ability to give delay times from 1.6 mSecs to up to 1.6 secs. Many powerful effects including phasing, flangine, A.D.T., chorus, echo &

vibrato are obtained. The basic kit is extended in 400 mS steps up to 1.6 secs. Simply by adding more parts to the PCB. Compare with units costing over £1,000!
Complete kit (400 mS delay) **£130** + VAT
Parts for extra 400 mS delay **£9.50** + VAT

KIT PRICES

Input channel	£19.90	Base unit and wooden front	£27.50
Output channel	£18.50	Pair of mahogany end cheeks	£12.50
Auxiliary channel	£22.50	Power Supply and cabine	£19.50
Blank Panel	£3.00		

All prices are VAT exclusive

Free Soldering Practise Kit on request with your first kit — useful tips, well illustrated.

MPA 200 — a low price, high power 100W amplifier, its smart styling, professional appearance and performance, make it one of our most popular designs. With adaptable inputs the mixer accepts a very etyot sources yet straightforward construction makes it ideal for the first time builder. Complete kit **£45.90** + VAT.

Chromatique 5000 — a 5 channel lighting system powerful enough for professional discos yet controllable for home-effects. Sound to light, strobe to music level, random or sequential effects — each channel can handle up to 500W yet minimal wiring is needed with our unique single board design. Complete kit **£43.50** + VAT

ETI VOCODER — 14 channels each with independent level control, for maximum versatility and intelligibility. Two input amplifiers — for speech/excitation — each with level control and tone control. The Vocoder is a powerful yet flexible machine that is interesting to build and thanks to our easy to follow construction manual, is within the capability of most enthusiasts. Complete kit **£175.00** + VAT

SP2 200 twice the power with two of the reliable, durable and economic amps from the MPA 200 fed by separate power supplies from a common toroidal transformer. Superb finish and quality components throughout — up to (even over) the standard of high prices factory-built units! Complete kit **£64.90** + VAT

TRANSCENDENT POLYSYNTH — A four octave polyphonic synthesiser with outstanding design characteristics and versatility and performance to match.
Complete kit **£275.00** plus VAT (single voice)
Extra voice (up to three more) **£42.00** plus VAT

Component packs for most kits are available See our great free catalogue, full details of all our range

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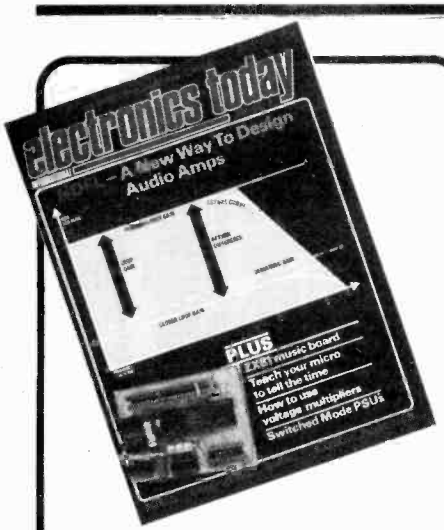

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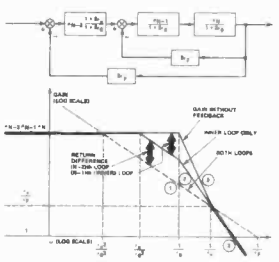
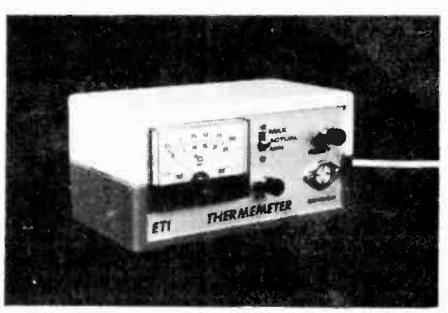
FEATURES



PROJECTS



INFORMATION

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ELECTROLYTIC CAPACITORS: (Values in uF) 500v: 10uF 52p; 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 28p; 1000 70p; 2200 99p; 50V: 68 20p; 100 17p; 220 24p; 40V: 6.8 15p; 22 9p; 33 12p; 330, 470 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; 2200 50p; 3300 76p; 4700 92p; 16V:
47, 68, 100 9p; 125 12p; 330 16p; 470 20p; 680 34p; 1000 27p; 1500 31p; 2200 36p; 4700 79p.

TAG-END CAPACITORS: 64V: 2200 139p; 3300 198p; 4700 245p; 50V: 2200 110p; 3300 164p; 40V: 4700 160p; 25V: 2200 90p; 3300 99p; 4000, 4700 98p; 10,000 320p; 15,000 345p; 16V: 22,000 350p

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 42p; 470n 52p; 680n 1uF 68p; 2u2 82p.
160V: 10nF, 12n, 39n, 100n 11p; 150n, 220n 17p; 330n, 470n 30p; 680n 38p; 1uF 42p; 1u5 46p; 2u2 48p; 4u7 58p.
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 28p
680n 30p
1uF 34p 2u2 50p

POLYESTER RADIAL LEAD CAPACITORS: 250V
10n, 15n, 22n, 27n 6p; 33n, 47n, 68n, 100n 7p; 150n, 220n 10p; 330n, 470n 13p; 680n 19p; 1u 23p; 1u5 40p; 2u2 46p.

FEED-THROUGH CAPACITORS
1000pF/450V 8p

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 30p; 33, 47 40p; 100 75p; 10V: 15, 22, 28p; 33, 47 35p; 100 65p; 6V: 100 42p.

POTENTIOMETERS: Rotary, Carbon; Track 0.25W Log & Lin values.
500Ω, 1KΩ & 2KΩ (Linear only) Single Gang. 30p
5KΩ-2MΩ Single Gang Log & Lin 30p
5KΩ-2MΩ Single Gang D/P Switch 78p
5KΩ-2MΩ Double Gang 89p

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

CERAMIC CAPACITORS 50V:
Range: 0-5pF to 10nF 4p. 15nF; 22nF; 33nF; 47nF 5p. 100nF/30V 7p. 200nF/6V 8p.

PRESET POTENTIOMETERS
0.1W 50Ω 5MΩ Miniature
Vertical & Horizontal 7p
0-25W 100Ω 3-3MΩ horiz. larger 10p
0-25W 200Ω 4-7MΩ vert. 10p

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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 60p each

RAM FOR BBC MICRO 4816AP 100ns 225p

MINIATURE TRIMMERS Capacitors
2-6pF, 2-10pF 22p; 2-25pF, 5-60pF 30p; 10-88pF 35p.

RESISTORS Carbon Film Hi-Stab. 5%, miniature

	RANGE	Val	1-99	100+
¼W	2Ω2-4M7	E24	2p	1p
½W	2Ω2-4M7	E12	2p	1p
1W	2Ω2-4M7	E12	6p	4p
2% Metal Film		E24	6p	4p
1% Metal Film		E24	8p	6p

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 25p
8 Commoned: (9 pins) 150Ω, 180Ω, 270Ω, 330Ω, 1K, 2k2, 4K7, 10K, 22K, 47K & 100K 28p.

TRANSISTORS

AC126/7	35	BC213L	10	BF196/7	12	MPF104	30	TIS88A	50	2N3614/5	190	2SC1678	140
AC141/2	30	BC214	10	BF198/9	18	MPF105	30	TIS90/91	30	2N3663	15	2SC1679	190
AC176	28	BC214L	10	BF200	80	MPF106	40	UC734	65	2N3702/3	10	2SC1923	50
AC187	32	BC237/8	14	BF224A	25	MPSA05	25	VK101	80	2N3704/5	10	2SC1945	225
AC188	32	BC256B	30	BF224B	28	MPSA08	25	VN10KM	55	2N3706/7	10	2SC1963	90
ACY19/21	75	BC307B	14	BF245	30	MPSA12	32	VN46AF	78	2N3708/9	10	2SC1957	80
ACY22/41	75	BC308	16	BF256A	35	MPSA55	30	VN66AF	80	2N3710/11	10	2SC1969	140
AD142	120	BC318	80	BF256B	46	MPSA56	30	VN88AF	94	2N3713	140	2SC2028	85
AD149	79	BC327/8	15	BF257/8	32	MPSA70	30	VN89AF	98	2N3771	170	2SC2029	210
AD161	42	BC337/8	16	BF259	35	MPSU02	58	ZTX107/8	11	2N3772	195	2SC2078	170
AD162	42	BC441/61	34	BF274	42	MPSU05	55	ZTX109	12	2N3773	210	2SC2091	85
AF115/6	80	BC477	40	BF336/7	40	MPSU06	55	ZTX212	28	2N3819	22	2SC2314	85
AF118	80	BC516/7	40	BF394	27	MPSU52	65	ZTX300	13	2N3820	38	2SC2166	165
AF124/26	70	BC547/8	12	BF451	35	MPSU55	50	ZTX301	16	2N3822/3	45	2SC2335	225
AF139	40	BC549C	14	BF594/5	30	MPSU56	80	ZTX302	16	2N3824	65	2SC2547	30
AF178	75	BC556/7	16	BFR39/40	23	MPSU66	80	ZTX303	25	2N3866	88	2SC2612	225
AF186	70	BC558/9	16	BFR41/79	23	MPU131	62	ZTX304	17	2N3903/4	16	2SD234	74
AF239	55	BCY30	60	BF494/5	30	OC26	170	ZTX314	25	2N3905/6	18	2SK45	90
ASZ21	125	BCY34	65	BFR41/79	23	OC28/35	220	ZTX326	30	2N3906	17	2SK288	225
BC107	10	BCY35	60	BFR80/81	25	OC36/41	75	ZTX341	30	2N4037	46	2SJ83	225
BC107B	12	BCY39/40	65	BFR98	105	OC71/72	40	ZTX451	23	2N4058	10	2SJ85	225
BC108	10	BCY41/42	14	BFX29	28	OC81/82	50	ZTX500	14	2N4061/2	10	3N128	112
BC108B	12	BCY45	60	BFX81	46	OC83/84	40	ZTX501/2	16	2N4064	118	3N140	112
BC109	10	BCY58/59	35	BFX84	28	OC170/71	60	ZTX503	18	2N4234/6	48	40315	90
BC109B	12	BCY70/71	16	BFX85/6	28	OC200	50	ZTX504	28	2N4264	24	40316	95
BC109C	12	BCY72	20	BFY18	60	OC42	50	ZTX531	25	2N4286	15	40324	100
BC114/5	22	BCY78	24	BFY50/51	23	OC70	40	ZTX550	25	2N4289	18	40326/7	70
BC117/8	20	BD112	125	BFY52	23	OC75/76	40	2N697	23	2N4314	70	40347	98
BC137/9	40	BD114	190	BFY53	32	TIP29A	32	2N698	40	2N4400	18	40348	120
BC140	30	BD121	95	BFY55/6	32	TIP29C	38	2N699	48	2N4427	80	40360	60
BC142/3	30	BD124	115	BFY64	35	TIP30A	35	2N706A	19	2N4871	65	40361/2	70
BC147	9	BD131/32	48	BFY81	120	TIP30C	37	2N708	19	2N4898	135	40407/8	75
BC147B	10	BD133	70	BFY90	80	TIP31A	38	2N918	35	2N4901	175	40411	285
BC148	9	BD135	45	BRY39	40	TIP31B	38	2N1131/2	24	2N4921	85	40412	90
BC148B	10	BD136/37	40	BSX20	20	TIP31C	38	2N1302	45	2N4922	70	40467A	130
BC149	9	BD138/39	40	BSX26/29	34	TIP32A	38	2N1671B	160	2N5135/6	20	40468	85
BC149C	10	BD140	40	BSX78	45	TIP32C	42	2N2160	285	2N5138	18	40594	105
BC153/4	27	BD144/45	198	BSY26	30	TIP33A	65	2N2217	45	2N5172	18	40603	110
BC157/8	10	BD158	55	BSY95A	25	TIP33C	78	2N2218A	25	2N5179	45	40673	75
BC159	11	BD205/6	110	BU105	170	TIP34A	74	2N2219A	28	2N5180	45	40671/2	80
BC160	45	BD222	85	BU206	190	TIP34C	88	2N2220A	28	2N5190/1	75		
BC167A	10	BD245	45	BU206	200	TIP35A	110	2N2221A	28	2N5194	80		
BC168C	10	BD378	70	BU208	200	TIP35C	128	2N2222A	25	2N5305/8	30		
BC169C	10	BD434	55	BUY69C	225	TIP36A	130	2N2303	45	2N5457/8	38		
BC170	16	BD517	75	E421	250	TIP36C	140	2N2368	25	2N5459	30		
BC171/2	11	BD645	80	MD8001	250	TIP41A	88	2N2369A	18	2N5485	38		
BC173	11	BD695A	125	MJ491	175	TIP41B	62	2N2476	80	2N5777	45		
BC177/8	16	BD696A	125	MJ2955	70	TIP42A	55	2N2483/4	27	2N5879	190		
BC179	20	BDY56	180	MJE170	160	TIP42B	58	2N2646	45	2N6027	32		
BC181	20	BDY60	160	MJE180	150	TIP120	70	2N2904/5	28	2SA671	250		
BC182/3	10	BF115	35	MJE340	54	TIP121/2	73	2N2906/7	28	2SA715	60		
BC184	10	BF154/8	25	MJE370	100	TIP141/2	105	2N2907A	28	2SC495	70		
BC182L	10	BF167	29	MJE371	100	TIP147	120	2N2926G	10	2SC496	70		
BC183L	10	BF173	27	MJE520	95	TIP2955	80	2N3011	28	2SC1061	200		
BC184L	10	BF177	25	MJE521	95	TIP3055	60	2N3053	25	2SC1096	85		
BC188 6/7	25	BF178	30	MJE2955	98	TIS43	32	2N3054	58	2SC1162	30		
BC212	10	BF179	35	MJE3055	70	TIS44/5	45	2N3055	48	2SC1173	125		
BC212L	10	BF184/5	38	MPF102	40	TIS46	45	2N3252	48	2SC1306	100		
BC213	10	BF194/5	12	MPF103	30	TIS48	50	2N3302	30	2SC1307	160		
						TIS59/74	60	2N3441/2	140	2SC1449	85		

RF CHOKES Miniature PCB type
1uH, 2u2, 4u7, 10u, 22u, 33u, 47u, 100u, 220u, 330u, 470u 30p
1mH, 1m5, 2m2, 4m7, 10mH 35p
22m, 33m, 43m 60p
100m 75p

COMPUTER ICs

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1802CP	650	8225	£11	TMS9929	£20
2114L-300n	90	8226	250	TMS9995	£12
2114L-200n	95	8228	220	ULN2003	75
2147	425	8243	270	UPD7002	425
2532	300	8250	850	Z80CPU 2.5	299
2564	£8	8251A	250	Z80ACPU 4M	300
2708	225	8253	400	Z80 CTC	250
2716-5V	225	8255	225	Z80A CTC	280
2732	350	8256AC	£35	Z80B	875
2764	425	8257-5	400	Z80 DART	495
3242	590	8259	395	Z80A DART	550
4027	190	8271	£30	Z80 DMA	675
4116-150n	85	8279	385	Z80 DART	698
4116-200n	80	8284	350	Z80 PIO	260
4118-250	325	8288	£10	Z80 PIO	275
4164-200n	425	8P8304BN	250	Z80 SIO-1	850
4334-3 = CMOS		8T26A	99	Z80A SIO	£9
2114-3	325	8T27	150		
4532-3	350	8T28A	120		
4532-4	350	8T31	350		
4816-100ns	225	8T95	90		
5101-450	220	8T97N	90		
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6116L 120	500	9602	220		
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6502A	450	AM26LS33A	125		
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6505	600	AY-5-2376	600		
6520PIA	100	AY-5-2376	600		
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6530	£11	COM8116	700		
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6545RTC	899	DS3691N	290		
6551ACIA	650	DS88LS120N	255		
6592PC	£20	DS8820	110		
6800	220	DS8830	110		
6802	250	DS8831	125		
6803	850	DS8832	250		
6804	180	E9365	£38		
6805	670	E9366	£38		
6808	520	FD1771	£15		
6809	630	FD1791	£22		
6810	115	FD1795	£28		
6820	110	FD1799	£28		
6821	110	FD1797	£28		
68B54	780	HD26501	75		
6840	375	IM6402	380		
6843	£12	INS8060N	1050		
6845	650	INS8154N	£9		
6847	650	MC1488	55		
6850	110	MC1489	55		
6854	599	MC14411	690		
68B21	220	MC14412	725		
6875	500	MC3446	250		
6800	£78	MC3447P	315		
74C922	420	MC3486	175		
8080A	250	MC3487	175		
8085A	350	MC6845	625		
8088	£18	MC6846	625		
8118-10	225	MK3886-2M	£7		
8123	125	MM5280D	695		
8155	350	MM5303	635		
8156	350	MM5307	1275		
81LS95	80	MM5387A	475		
81LS96	80	MM58174	700		
81LS97	80	MM74C922	420		
81LS98	85	RO-3-2513L	650		
8202	£25	RO-3-2513U	650		
8205	225	SFF96364	800		
8212	110	SPO256AL2	£18		
8214	425	TMS2716-3V	725		
8216	100	TMS4416-2	475		
		TMS4500	£14		
		TMS4532-3	350		

LINEAR ICs

555CMOS	80	ICL7611	99	MC1469	300	TCA965	145	7413	18
702	75	ICL7660	248	MC1494	694	TDA1004	290	7414	24
709C 8 pin	35	ICL8038CC	300	MC1495	350	TDA1008	310	7416	20
710	48	ICL8211A	150	MC1496L	70	TDA1022	499	7417	20
741 8 pin	14	ICM7205A	1150	MC1596	225	TDA1024	115	7420	15
747C 14 pin	65	ICM7207	475	MC1648	290	TDA1034	350	7421	20
748C 8 pin	38	ICM7215	1050	MC1709G	90	TDA1490	350	7422	20
753 8 pin	185	ICM7216AJ	£22	MC3302	60	TDA2002	325	7423	20
810	159	ICM7216B	£22	MC3340P	120	TDA2004	495	7425	18
9400CJ	360	ICM7216C	£22	MC3360P	120	TDA2020	320	7426	18
AD7581	£11	ICM7217A	750	MC3401	65	TDA2030	295	7427	15
AY-1-1320	225	ICM7224	785	MC3403	75	TDB0701	420	7428	28
AY-1-5050	99	ICM7240	300	MC3405	150	TL170	50	7430	14
AY-1-5051	160	ICM7555	80	MC3423	180	TL061CP	40	7432	22
AY-1-6720	210	ICM7556	150	MC4016	001	TL062CP	60	7433	22
AY-3-1270	730	LA3350	250	MF10	350	TL064CN	98	7437	25
AY-3-1350	360	LA4031P	340	MFC6040	75	TL071CP	24	7438	22
AY-3-8910	450	LA4032	295	MK50398	635	TL072CP	45	7440	15
Booklet for AY-3-8910	150	LA4400	350	ML924	275	TL074CN	100	7441	55
AY-3-8912	625	LA4422	320	MSM5526	820	TL081CP	24	7442	32
AY-5-1230	450	LC7130	340	NE515	275	TL082CP	45	7443	90
AY-5-1317A	630	LC7120	300	NE529	225	TL083CP	75	7444	90
AY-5-1350	388	LC7137	395	NE531	140	TL084CN	90	7445	65
CA3011	130	LF347	150	NE534	150	TL091CP	55	7446	60
CA3012	175	LF351	48	NE543K	225	UA2240	120	7447	40
CA3014	275	LF353	95	NE544	210	UA78540	230	7448	46
CA3018	88	LF355	85	NE555	16	ULN2003	75	7450	16
CA3019	80	LF356	95	NE556	45	ULN2004	75	7451	16
CA3020	210	LF357	110	NE560	325	ULN2283	100	7453	16
CA3023	210	LF398	475	NE561	398	UPC575	275	7454	16
CA3028A	95	LM10	325	NE562B	410	UPC1025H	375	7460	16
CA3035	255	LM301AO	24	NE564	420	UPC1182	320	7470	35
CA3036	270	LM307	45	NE565A	120	UPC1156H	275	7472	24
CA3043	275	LM308T	95	NE566	165	UPC1366	195	7473	28
CA3045	385	LM311	70	NE567V	140	XR2206	300	7474	20
CA3046	70	LM318N	160	NE570	410	XR2207	375	7475	25
CA3048	220	LM319	215	NE571	400	XR2211	575	7476	25
CA3059	285	LM324A	30	NE5532	145	XR2216	675	7480	40
CA3075	213	LM334Z	90	NE5534A	160	XR2266	360	7481	120
CA3080E	70	LM335Z	128	OM335	750	ZN414	80	7482	65
CA3081	190	LM339	47	RC4136D	60	ZN419E	180	7483	38
CA3086	48	LM348	84	RC4558	45	ZN423E	130	7484	70
CA3089E	215	LM349	116	S566B	225	ZN424E	130	7485	60
CA3090AQ	375	LM358	60	SAB3209	425	ZN425E	345	7486	20
CA3123E	165	LM377	175	SAB3210	325	ZN426E	300	7489	170
CA3130	90	LM379	480	SAB3271	485	ZN427E	600	7490	20
CA3140	40	LM380	75	SAB4209	595	ZN428E	410	7491	35
CA3160	95	LM381N	145	SG3402	295	ZN429E	210	7492	25
CA3161	180	LM382	115	SL490	350	ZN459	570	7493	25
CA3162E	460	LM384	180	SN76013	350	ZN1034E	200	7494	35
CA3189	200	LM386	90	SN76023ND	240	ZN1040E	665	7495	35
HA1336W	240	LM387	120	SN76131	125	ZNA234E	850	7496	35
HA1388	255	LM389	95	SN76227N	95			7497	90
ICL7106	690	LM393	100	SN76477	420			74100	80
ICL7107	975	LM558	75	SN76488	480			74104	50
		LM725CN	325	SP8629	299			74105	55
		LM733	70	TA7130	150			74107	20
		LM1458	45	TA7204	175			74109	25
		LM1871	325	TA7205	90			74110	35
		LM2917	195	TA7222	160			74111	55
		LM301	24	TA7120	160			74112	170
		LM307	45	TA7310	125			74116	50
		LM3302	75	TAA621AX1	295			74118	55
		LM3900	50	TAA661A	190			74119	60
		LM3909N	85	TAA700	275			74120	80
		LM3911	125	TAA900	395			74121	25
		LM3914	250	TAD100	159			74122	35
		LM3915	250	TBA120S	70			74123	35
		LM3916	250	TBA540Q	275			74125	35
		LM13600	110	TBA560Q	330			74126	35
		LS7220	280	TBA641BX or BX11	290			74128	35
		M253AA	1150	TBA651	190			74132	30
		M51513L	230	TBA800	80			74136	28
		M51515L	320	TBA810	95			74141	55
		M51516L	475	TBA820	80			74142	175
		MB3712	220	TBA920Q	200			74143	210
		MB3756	440	TBA950	300			74144	210
		MC1204	250	TBA990Q	350			74145	60
		MC1301	79	TBA540	275			74147	75
		MC1303	98	TC9109	775			74148	60
		MC1304P	260	TCA220	350			74150	60
		MC1310P	150	TCA270Q	380			74151	40
		MC1445	250	TCA280A	220			74153	40
		MC145106	695	TCA940	175			74154	55
								74155	40

TTL74

7400	11
7401	11
7402	11
7403	12
7404	13
7405	16
7406	20
7407	20
7408	14
7409	14
7410	14
7411	16
7412	18

74156	40	S74	75	LS113	20
74157	30	S86	65	LS114	22
74159	80	S112	80	LS122	36
74160	60	S114	80	LS123	36
74161	40	S132	110	LS124	90
74162	40	S133	60	LS125	24
74163	40	S138	100	LS126	25
74164	40	S139	115	LS132	30
74165	48	S157	225	LS133	30
74166	48	S158	210	LS136	24
74167	160	S188	140	LS138	25
74170	125	S189	140	LS139	28
74172	250	S194	195	LS145	70
74173	80	S195	195	LS147	100
74174	54	S201	250	LS148	75
74175	55	S225	240	LS151	40
74176	40	S241	250	LS153	40
74177	45	S244	290	LS155	30
74178	80	S251	170	LS156	36
74179	80	S257	170	LS157	25
74180	40	S262	850	LS158	30
74181	115	S287	225	LS160	32
74182	60	S288	210	LS161	37
74184	90	S289	200	LS162	35
74185	95	S301	350	LS163	35
74188	280	S412	380	LS164	43
74190	48	S470	325	LS165	60
74191	46	S471	620	LS166	62
74192	46	S472	1150	LS168	84
74193	45	S475	800	LS170	70
74194	40	S571	620	LS173	50
74195	40			LS174	36
74196	46	**74LS**		LS175	36
74197	40	LS00	11	LS181	90
74198	80	LS01	11	LS183	105
74199	84	LS02	11	LS190	36
74221	54	LS03	12	LS191	36
74246	120	LS04	12	LS192	36
74247	120	LS05	12	LS193	37
74248	120	LS08	12	LS194	35
74249	120	LS09	12	LS195	35
74251	65	LS10	12	LS196	45
74259	160	LS11	12	LS197	48
74265	55	LS12	13	LS200	275
74273	160	LS13	15	LS202	275
74276	120	LS14	25	LS221	55
74278	100	LS15	12	LS240	55
74279	60	LS20	12	LS241	55
74283	50	LS21	12	LS242	55
74284	165	LS22	12	LS243	55
74285	155	LS26	12	LS244	60
74290	105	LS27	13	LS245	70
74293	60	LS28	14	LS247	50
74297	238	LS30	13	LS248	65
74298	100	LS32	13	LS249	55
74351	195	LS33	16	LS251	30
74365	30	LS37	15	LS253	32
74366	30	LS38	16	LS257	30
74367	30	LS40	13	LS258	35
74368	30	LS42	28	LS259	55
74390	75	LS47	35	LS260	22
74393	90	LS48	45	LS261	100
74430	95	LS49	50	LS266	20
		LS51	14	LS273	54
74C		LS54	14	LS275	125
74C244	195	LS55	14	LS279	30
74C245	195	LS63	120	LS280	90
74C373	240	LS73	18	LS283	40
74C374	245	LS74	18	LS290	40
74C922	420	LS75	20	LS293	40
74C923	500	LS76	18	LS295	75
		LS78	18	LS298	80
74S		LS83	38	LS299	150
74S00	30	LS85	42	LS300	175
S02	30	LS86	18	LS302	175
S03	30	LS90	24	LS320	200
S04	30	LS91	80	LS323	180
S05	80	LS92	32	LS324	168
S08	80	LS93	23	LS325	295
S20	40	LS95	40	LS328	240
S32	70	LS96	85	LS327	240
		LS107	40	LS347	95
		LS109	23	LS348	90
		LS112	22	LS362	62
				LS363	62

DIODES

AA119	15
AA129	20
AAY30	15
BA100	15
BAX13	20
BY100	24
BY126	12
BY127	12
CR033	250
OA9	40
OA47	12
OA70	12
OA79	15
OA81	20
OA85	15
OA90	8
OA91	8
OA95	8
OA200	8
OA202	8
1N914	4
1N916	5
1N4001/2	5
1N4003	6
1N4004/5	6
1N4006/7	7
1N4148	4
1N5401	15
1N5404	16
1N5406	17
1N5408	19
1S44	9
1S921	9
6A/100V	40
6A/400V	50
6A/800V	65

BRIDGE RECTIFIERS

1A/50V	18
1A/100V	20
1A/400V	25
1A/600V	34
2A/50V	30
2A/200V	40
2A/400V	46
2A/600V	65
6A/100V	83
6A/400V	95
6A/600V	125
10A/200V	215
10A/600V	298
25A/200V	240
25A/600V	395
BY164	56
VM18 DIL	50

75 SERIES

75107/8	95
75110	90
75114/5	150
75121/2	130
75150	125
75154	125
75182/3	99
75188/9	65
75322	140
75324	380
75361/3	150
75365	150
75450	86
75451/2	52
75454	70
75491/2	65

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

TRIACS

3A 200V	54
3A 400V	56
8A 100V	60
8A 400V	69
8A 800V	115
12A 100V	78
12A 400V	82
12A 800V	135
16A 100V	103
16A 400V	105
16A 800V	220
25V 500V	220
25A 800V	295
T2800D	120

SCR THYRISTORS

5A/40V	32
5A 400V	40
5A 600V	48
8A 300V	80
8A 600V	90
12A 100V	78
12A 400V	95
12A 800V	188
BT106	150
BT116	180
C106D	38
TIC44	24
TIC45	29
TIC47	35
2N5062	32
2N5064	38
2N4444	130

NOISE Diode
Z5J 195p

VARICAPS

BA102	50
BB105B	40
BB106	40
BB109B	45
MVAM2	165

DIAC
ST2 25

SWITCHES

TOGGLE: 2A, 250V.

SPST	33p
DPDT	44p

SUB-MIN TOGGLE

SPST on/off	54p
SPDT c/over	60p
SPDT centre off	85p
SPDT biased both ways	105p
DPDT 6 tags	75p
DPDT centre off	88p
DPDT biased both ways	145p
DPDT 3 positions on/on/on	185p
3-pole 2 way	205p

SLIDE 250V:

DPDT 1A	14p
DPDT 1A c/off	15p
DPDT ½A	13p

PUSHBUTTON 6A
with 10mm Button

SPDT latching	99p
DPDT latching	145p
SPDT moment	99p
DPDT moment	145p
Mini Non Locking Push to Make	15p
Push to Break	25p

DIL SWITCHES
(SPST) 4 way 70p; 6 way 85p; 8 way 90p; 10 way 145p.
(SPDT) 4 way 190p.

ROTARY SWITCHES:
(Adjustable Stop type)
1 pole/2 to 12 way; 2p/2 to 6 way; 3 pole/2 to 4 way; 4p/2 to 3 way 45p

ROTARY: Mains DP 250V 4 Amp on/off 88p

ROTARY: (Mak-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; 6-/2 way 85p
Mains DP 4A Switch to fit 45p
Spacers 4p. Screen 6p

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

Decade Switch Module	220p
B.C.D. Switch Module	275p
Mounting Cheeks (per pair)	75p

ETI PROJECTS We stock most of the parts

JUMPER LEADS (Ribbon Cable Assembly)

Length	14 pin	16 pin	24 pin	40 pin
Single ended DIP (Header Plug) Jumper				
24 inches	145p	165p	240p	380p
Double ended DIP (Header Plug) Jumper				
6 inches	185p	205p	300p	465p
12 inches	198p	215p	315p	490p
24 inches	210p	235p	345p	540p
36 inches	230p	250p	375p	595p

IDC Female Header Socket Jumper Leads 24"

	20 pin	26 pin	34 pin	40 pin
Single ended	160p	200p	260p	300p
Double ended	290p	370p	480p	525p

VEROBOARD 0.1in

	clad	plain
2½ × 3¾	85p	
2½ × 5	100p	—
3¾ × 3¾	100p	—
3¾ × 5	115p	—
3¾ × 17	390p	98p
4¾ × 17	495p	275p
Pkt. of 100 pins	55p	
Spot face cutter	150p	
Pin insertion tool	185p	

VERO WIRING PEN + spool 340p
Spare spool 75p
Combs 8p

FERRIC CHLORIDE
1 lb bag Anhydrous 195p + 50p P&P

VQ Board 180
DIP Board 350
Vero Strip 374

PROTO DECs

Veroblock	405p
S-Dec	350p
Eurobreadboard	520p
Bimboard 1	575p
Superstrip SS2	1350p

DALO ETCH RESIST PEN Plus spare tip 90p

ULTRASONIC TRANSDUCER
40KHz 325 pr

COPPER CLAD BOARDS

Fibre glass	Single sided	Double sided	S.R.B.P
6" × 6"	90p	110p	9.5" × 8.5"
6" × 12"	150p	195p	

DIL SOCKETS

	Low Prof	Wire Wrap
8pin	8p	25p
14pin	10p	35p
16pin	10p	42p
18pin	16p	52p
20pin	20p	60p
22pin	22p	65p
24pin	25p	70p
28pin	28p	80p
40pin	30p	99p

EDGE CONNECTORS

	.1"	.156
2 × 15 way	—	140p
2 × 18 way	180p	145p
2 × 22 way	199p	200p
2 × 23 way	175p	—
2 × 25 way	225p	220p
2 × 28 way	190p	—
2 × 30 way	245p	—
2 × 36 way	295p	—
2 × 40 way	315p	—
2 × 43 way	395p	—
2 × 75 way	550p	—

ANTEX SOLDERING IRON

C-15W	465p	CX17W	475p
CCN-15W	486p	CX25W	510p
Spare tips, assorted sizes			65p
Spare elements			210p
Iron Stand with sponge			165p

SIL SOCKET 0.1" pitch 20 way 85p

TRANSFORMERS:

3-0-3V; 6-0-6V; 9-0-9V; 12-0-12V; 15-0-15V @ 100mA 98p
pcb mounting. Miniature, Split Bobbin
3VA: 2x6V-0.25A; 2x9V-0.15A; 2x12V-0.12A; 2x15V-0.1A 200p
6VA: 2x6V-0.5A; 2x9V-0.3A; 2x12V-0.25A; 2x15V-0.2A 270p
Standard Split Bobbin type:
6VA: 2x6V-0.5A; 2x9V-0.4A; 2x12V-0.3A; 2x15V-0.25A 220p
12VA: 2x4.5V-1.3A; 2x8V-1A; 2x9V-0.6A; 2x12V-0.5A; 2x15V-0.4A; 2x20V-0.3A 295p (35p p&p)
24VA: 2x6V-1.5A; 2x9V-1.2A; 2x12V-1A; 2x15V-0.8A; 2x20V-0.6A 330p (60p p&p)
50VA: 2x6V-4A; 2x9V-2.5A; 2x12V-2A; 2x15V-1.5A; 2x20V-1.2A; 2x25V-1A; 2x30V-0.8A 485p (60p p&p)
Specially wound for Multirail Computer PSUs 50VA: Outputs +5V/5A; +12V, +25V, −5V, −12V at 1A 575p (60p p&p)
100VA: 2x12V-4A; 2x15V-3A; 2x20V-2.5A; 2x25V-2A; 2x30V-1.5A; 2x50V-1A 920p (75p p&p charge to be added over and above our normal postal charge).

VOLTAGE REGULATORS

1A	TO220 +ve		Plastic −ve	Casing
5V	7805	40p	7905	45p
12V	7812	40p	7908	80p
15V	7815	40p	7912	45p
18V	7818	40p	7915	45p
24V	7824	40p	7918	45p
			7924	45p

100mA TO92 Plastic package

5V	78L05	30p	79L05	80p
6V	78L06	30p	—	
8V	78L08	30p	—	
12V	78L12	30p	79L12	80p
15V	78L15	30p	79L15	80p

LM300H	170p	TAA550	50p
LM304H	170p	TDA1412	150p
LM305H	140p	78H05 +5V/5A	550p
LM309K	135p	78H12 +12V/5A	
LM317K	320p		580p
LM317KP	98p	78HG +5V to +25V	
LM323K	450p	5A	599p
LM337	175p	79HG +2.25V to 24V	
LM723 Var	38p	5A	885p

SOLDERCON PINS

Ideal for making SIL or DIL Sockets

100 pins	75p
500 pins	350p

ALUM BOXES

3 × 2 × 1"	85p
4 × 2½ × 2"	85p
4 × 2½ × 2½"	103p
4 × 4 × 2"	105p
4 × 4 × 2½"	120p
5 × 4 × 1½"	99p
5 × 4 × 2"	120p
5 × 2½ × 1½"	90p
5 × 2½ × 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

IDC CONNECTORS

	PCB Plugs with latch Pins	pins Strt	Angle	Female Header Plug	Female Card Edge Connect
10 way	90p	99p	85p	120p	
16 way	130p	150p	110p	—	
20 way	145p	188p	125p	195p	
26 way	175p	200p	150p	240p	
34 way	205p	236p	168p	320p	
40 way	220p	250p	190p	340p	
50 way	235p	270p	200p	395p	
60 way	—	—	230p	495p	

EURO CONNECTORS

	Female Socket Strt. Pins	Angle Pins	Male Strt. Pins	Plug Angle Pins
DIN41617				
31 way	170p	—	—	175p
DIN41612				
2 × 32 A + B	275p	320p	220p	285p
DIN41612				
2 × 32 A + C	295p	340p	240p	300p
DIN41612 3 × 32 A + B + C	360p	385p	260p	395p

DIL PLUG (Header) Solder IDC

14pin	40p	99p
16pin	49p	105p
24pin	88p	178p
40pin	250p	255p

ZIF DIL SOCKETS

24 pin	575p
28 pin	620
40 pin	976p

RIBBON CABLE price per foot

	Grey	Color
10 way	15p	28p
16 way	25p	40p
20 way	30p	50p
24 way	40p	65p
34 way	60p	85p
40 way	70p	90p
50 way	100p	135p

'D' CONNECTORS miniature

	9 way	15 way	25 way	37 way
Male				
Solder lugs	80p	105p	160p	250
Angle pins	150p	210p	250p	385p
PCB pins	128p	138p	195p	295p
Female				
Solder lugs	105p	160p	280p	335p
Angle pins	165p	215p	288p	440p
PCB pins	150p	180p	240p	420p
Covers	90p	85p	98p	100p

IDC 25 way 'D' Plug 385p; Socket 450p

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

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0-100µA	
0-500µA	
0-1mA	
0-5mA	
0-10mA	
0-50mA	
0-100mA	
0-500mA	
0-1A	
0-2A	
0-25V	
0-50V AC	
0-300V AC	
"S"	
"VU"	

£25p each

CRYSTALS

32.768KHz	100
100KHz	235
200KHz	288
455KH	370
1MHz	275
1.008M	275
1.28MHz	392
1.6MHz	395
1.8NHz	395
1.8432M	200
2.0MHz	225
2.4576M	200
3.278M	150
3.5794M	98
3.6864M	300
4.0MHz	150
4.032MHz	290
4.80MHz	200
4.194304M	200
4.433619M	100
5.0MHz	160
5.185MHz	300
5.24288M	380
6.0MHz	140
6.144MHz	150
6.5536MHz	225
7.0MHz	150
7.168MHz	250
7.68MHz	200
8.0MHz	150
8.08333M	385
8.86723M	175
9.00MHz	150
10.0MHz	175
10.24MHz	200
10.7	150
12.0NHz	175
12.528M	300
14.31814M	170
16.0MHz	200
18.0MHz	180
18.432M	150
20.0MHz	200
19.968MHz	150
24.0MHz	170
24.930MHz	325
26.69M	150
27.648M	170
27.145M	180
38.66687M	175
48.0MHz	170
100.0MHz	295
118.0MHz	250

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Miniature, enclosed, PCB mount.
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RL-91 205Ω Coil; 12V DC, 10V5 to 19.5V), 10A at 30V DC or 250V AC 185p
DOUBLE POLE Changeover. 6A 30V DC or 250V AC
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RL6-114 740Ω Coil, 24V DC (22V to 37V) 200p

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Centronics Parallel 36 Way IDC	495
Centronics 36 Way IDC Female	520p

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4001	10	4076	50	4543	70
4002	12	4077	13	4544	150
4006	50	4078	15	4548	40
4007	14	4081	13	4549	375
4008	32	4082	13	4553	245
4009	24	4085	50	4554	180
4010	24	4086	60	4555	35
4011	10	4089	125	4556	35
4012	16	4093	20	4557	320
4013	20	4094	70	4558	120
4014	46	4095	95	4559	395
4015	40	4096	70	4560	160
4016	20	4097	200	4561	104
4017	32	4098	75	4562	495
4018	45	4099	110	4566	165
4019	25	4160	95	4568	250
4020	42	4161	99	4569	175
4021	40	4162	99	4572	38
4022	40	4163	99	4580	460
4023	13	4174	89	4581	250
4024	32	4175	105	4582	99
4025	13	4194	105	4583	90
4026	80	4408	790	4584	40
4027	20	4409	790	4585	60
4028	39	4410	725	4597	330
4029	45	4411	675	4599	290
4030	15	4412	775	40085	90
4031	125	4415	480	40097	45
4032	80	4419	280	40098	42
4033	125	4422	770	40100	215
4034	140	4435	850	40101	130
4035	45	4440	999	40102	140
4036	275	4450	350	40103	175
4037	115	4451	350	40104	95
4038	110	4490	350	40105	105
4039	250	4500	675	40106	35
4040	40	4501	28	40107	60
4041	40	4502	80	40108	198
4042	40	4503	40	40109	80
4043	40	4504	75	40110	198
4044	40	4505	185	40114	240
4045	105	4506	35	40161	194
4046	46	4507	35	40163	50
4047	40	4508	130	40174	45
4048	40	4510	46	40175	50
4049	25	4511	45	40181	220
4050	25	4512	50	40182	90
4051	45	4513	199	40192	75
4052	60	4514	115	40193	70
4053	50	4515	115	40194	70
4054	85	4516	65	40195	75
4055	85	4517	275	40244	195
4056	85	4518	40	40245	195
4057	1915	4519	30	40257	185
4058	435	4520	50	40373	180
4060	45	4521	80	40374	180
4061	1195	4522	125	45106	585
4062	985	4526	70		
4063	85	4527	65		
4066	24	4528	70		
4067	245	4529	150		
4068	14	4530	90		
4069	16	4531	130		
4070	13	4532	70		
4071	13	4534	400		
4072	13	4536	275		
4073	15	4538	80		
		4539	90		

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TIL209 Red	10
TIL211 Grn	14
TIL212 Yel.	14
TIL220 .2" Red	12
.2" Green, Yellow or Amber	14
0.2" Bi colour Red/Green	65
Green/Yellow	78
0.2" Tri colour Red/Green/Yellow	85
Hi-Brightness Red	59
Flashing red 0.2" red	55
Square LEDs, Red, Green, Yellow	30
Rectangle LEDs	Stackable
Red, Green or Yell	18
Triangular LEDs Red	18
Green or yellow	22
LD271 Infra Red	46
SFH205 Detector	118
TIL32 Infra Red	58
TIL78 Detector	60
TIL38	45
TIL100	80
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ILD74	99
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TIL313 .3" CC	105
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TIL322 .5" CC	115
DL704 .3" CC	99
DL707 .3" CA	99
FND357 Red	120
FND500	115
.3" Green CA	150
.5" Green CA	215
.3" ±1 Red CA	150
.3" ±1 Green CA	150
DVM176	22
LCD 3½ Digits	495
LCD 4 Digits	530
LCD 6 Digits	625

NEONS
Rectangular, nut fixing
Red, Amber, Green 30p
REFLECTIVE Optical Switch type TIL139 170p
SLOTTED Optical Switch similar to RS Comp.'s 185p

OPTO

LS400C	255
OCP71	120
ORP12	88
ORP61	85
2N5777	45
BPX25	195
BPW21	295
BPX65	270

COMPUTER CORNER

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NEXT MONTH

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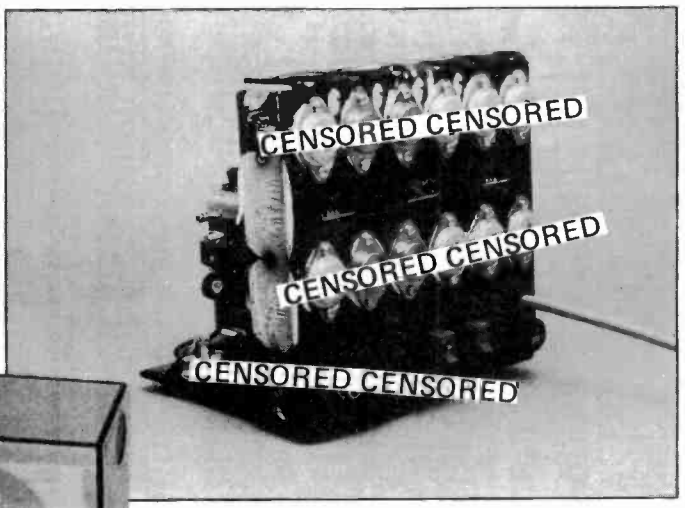
AUDIO BUYING GUIDE

The special audio buying guide will tell you which system to buy to suit your pocket. There will be good, sensible advice on all aspects of system choice and upgrading, but none of the 'buy a Lynotrio Cystemdek for £10,000 and listen to it through Granny's hearing aid until you've paid off the mortgage' variety. Incidentally, we've inserted the CENSORED stickers for your own good, to prevent you from going out and buying any gear until you've read the guide (and bought next month's ETI, of course).



PROJECTS GALORE!

In case there are a few die-hards out there who still want to build their own gear (Heaven forbid!), we'll be including the odd project or two.....

- **An entirely new type of power amp** using NDFL techniques
- **A Balanced Input Preamplifier** to overcome noise problems on long signal cable runs
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- **A Power Supply** that can be used as a stand-alone unit, or to upgrade a good amplifier to the dizzy heights of super-fi
- **The PseudoROM**, a bit (well, 65536 of 'em to be precise) that looks like ROM until you move the switch..... very useful for operating system development, which is exactly why we built one.

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TIC106C 48p
4A TIC106D 88p
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3A TIC116C 71p
TIC116D 73p
TIC116M 80p

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TIC126B 72p
2A TIC126C 73p
TIC126D 77p
TIC126M 95p

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1N4007 7p
1N4009 20p
1N4148 6p
1N4150 18p
1N4448 22p
1N4517 22p
1N5172 30p
1N5176 34p
1N5400 12p
1N5401 13p
1N5402 14p
1N5403 15p
1N5404 16p
1N5405 17p
1N5406 18p
1N5407 19p
1N5408 20p
1N5024 52p
1N5625 60p
1N5626 62p
1N5627 68p
1S44 10p
1S131 50p
1S134 58p
1S421 1.00
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1S941 11p
1S961 22p
AA118 28p
AA129 57p
AA144 25p
AAY30 44p
AAY33 46p
AAZ17 27p
BA100 22p
BA102 25p
BA115 25p
BA133 40p
BA138 30p
BA142 20p
BA144 15p
BA155 15p
BA156 38p
BA182 40p
BA201 18p
BA202 25p
BA316 25p
BA317 25p
BA318 30p
BAV10 18p
BAV19 15p
BAV20 15p
BAV49 15p
BAX13 10p
BAX16 11p
BAY38 20p
BAY44 15p
BAY93 10p
BB103B 70p
BB103G 70p
BB104B 80p
BB104G 80p
BB105 52p
BB105A 57
BB105B 58p
BB109G 65p
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BY127 22p
BY134 52p
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ITT923 15p
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OA47 20p
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OA91 10p
OA95 20p
OA200 20p
OA202 20p
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SPD9000 75p
SPD9002 95p

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W02 (200) 28p
W04 (400) 28p
W08 (800) 40p

2 amp type
Square with hole
S01 (100) 37p
S02 (200) 40p
S04 (400) 40p
S08 (800) 55p

6 amp type
Square with hole
PW01 (100) 50p
PW02 (200) 78p
PW04 (400) 85p
PW06 (600) 90p

25 amp type
Metal clad with hole
K01 (100) 2.20
K02 (200) 2.30
K04 (400) 2.80
K06 (600) 3.40

Proprietary Bridges
B40C1500 1.20
B80C3700 1.80
BY164 56p
BY179 92p

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400 500mW
E24 Series
2.4-47V 8p

1.3 Watt
E24 Series
3.3-82V 15p

2.5 Watt
E24 Series
7.5-75V 1.10

5W wire ended following voltages only
3V3, 3V6, 4V3, 4V7, 5V6, 7V5, 8V2, 8V7, 9V1, 10V, 12V, 20V, 33V, 51V, 62V, 68V 1.26

10W Pos. Stud
Following voltages only
7V5, 13, 18, 20, 24, 27, 30, 33, 68, 82, 91, 100, 110 1.26

20W Pos. Stud
(BZY93 series)
E24 values
7V5-75V 2.00

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2N5777 78p
2N5778 88p
2N5779 1.09
4N25 1.10
BP100 1.40
BP104 1.00
BPX25 2.47
BPX29 2.47
BPX48 6.76
BPX60 4.75
BPX61 3.48
BPX63 2.93
BPX79 4.60
BPX86 4.15
CQX13 40p
COX23 53p
COX33 48p
LD30A 15p
LD36A 12p
LD37A 12p
LD52A 12p
LD56A 15p
LD57A 15p
LD52C 30p
LD56C 30p
LD57C 36p
LD86A 18p
LD86A 22p
LD87A 22p
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TIL32 71p
TIL63 1.95
TIL64 1.95
TIL65 2.25
TIL66 2.30
TIL67 2.35
TIL78 60p
TIL81 1.60
TIL99 1.35
TIL116 1.10
TIL138 2.40
TIL139 2.40
TIL209 15p
TIL211 19p
TIL212 19p
TIL224 32p
TIL228 42p
TIL312 1.95
TIL313 1.65
TIL401 3.50
TIL403 3.80
TIL406 4.10

NEW OPTO DEVICES
inc. Superbright
see next column

D CONNECTORS
25 WAY
Solder type
Male 1.80
Fmale 2.05
Angled PCB
Male 2.45
Fmale 2.90
Covers 99p

GLASS FUSES
100mA-5 Amp
State value in amps and we will supply nearest to above
20mm slow 17p
20mm quick 10p
1.25" slow 17p
1.25" quick 10p

ICE MULTI-METERS
Microtest 80
£16.00
Supertest 680R
£32.00

NEW OPTO DEVICES
New LEDs
Now in stock
R = red
G = green
Y = yellow
Large diffused
1 + 50 +
R5D 8p 7p
G5D 15p 12p
Y5D 15p 12p
Small diffused
R2D 8p 6p
G2D 12p 10p
Y2D 12p 10p
Micro 0.1"
R1D 25p 22p
G1D 27p 25p
Y1D 27p 25p
Large clear
R5C 12p 10p
G5C 17p 13p
Y5C 17p 13p
Super bright
Large (100 times brighter)
R5U 38p 29p
G5U 42p 34p
Y5U 42p 34p
Tri-colour flat
RGY8 83p 78p

LINEAR ICs
AY1-5050 95p
AY3-8910 5.39
AY3-8912 5.59
AY510103A 3.00
AY5-2376 5.89
CA3000 4.80
CA3001 4.95
CA3002 4.60
CA3005 3.15
CA3007 4.92
CA3010 1.30
CA3012 1.75
CA3013 4.12
CA3014 2.36
CA3015 2.62
CA3018 75p
CA3018A 2.00
CA3020 2.00
CA3020A 3.90
CA3021 3.20
CA3022 1.12
CA3026 1.52
CA3028A 1.21
CA3028B 2.53
CA3029 1.44
CA3030A 2.97
CA3033 5.44
CA3034 5.18
CA3036 2.75
CA3039 1.50
CA3041 3.47
CA3042 3.47
CA3043 3.92
CA3046 95p
CA3047 4.60
CA3048 2.99
CA3049 3.21
CA3050 4.11
CA3051 3.80
CA3052 2.92
CA3053 1.00
CA3054 1.98
CA3059 2.80
CA3060 4.09
CA3062 13.84
CA3065E 2.85
CA3068 4.23
CA3070 3.20
CA3071 3.20
CA3075 2.25
CA3076 3.42
CA3078T 2.25
CA3080 1.89
CA3080A 3.95
CA3080E 70p
CA3081 1.90
CA3085 1.35
CA3086 55p
CA3088E 2.35
CA3089E 1.85
CA3090AQ 3.70
CA3130E 67p
CA3130T 1.20
CA3140E 98p
CA3140T 85p
HA1366W 2.40
HA1388 2.54
ICL7106 7.40
ICL7107 9.50
ICL7611 1.19
ICL8038 2.99
ICM7555 80p
LC7120 3.20
LC7130 3.20
LC7137 400p
LF351 47p
LF353 92p
LF355 83p
LF356 92p
LF357 1.09
LF13201 2.99
LF13331 3.30
LF347 1.50
LF13741H 68p
LF13741N 58p

LM10CH 4.25
LM11CH 4.50
LM114 6.75
LM137K 11.52
LM301AH 1.00
LM301AN 25p
LM305AH 2.90
LM305H 88p
LM307H 1.05
LM307N 56p
LM308AH 3.15
LM308AN 2.14
LM308H 95p
LM308N 88p
LM309K 2.80
LM310H 1.95
LM310N 1.89
LM311H 1.04
LM311N 70p
LM317K 2.80
LM317MP 1.04
LM317T 1.50
LM318H 2.40
LM318N 1.49
LM319H 2.48
LM319N 2.10
LM320 — See 79XX Series Volt. Regulators
LM323K 28p
LM337K 4.75
LM337MP 1.85
LM337T 1.99
LM339AN 1.60
LM339N 47p
LM340 — See 78XX Series Volt Regulators
LM345K 8.80
LM348N 62p
LM349N 1.16
LM350K 4.80
LM358N 1.44
LM360N 3.98
LM376N 65p
LM377N 1.88
LM378N 3.40
LM379S 4.78
LM380N14 75p
LM380N8 1.50
LM381AN 2.26
LM381N 1.40
LM382N 1.12
LM383T 3.40
LM384N 1.40
LM386N1 88p
LM386N4 1.20
LM388N 2.43
LM391N60 1.70
LM391N80 1.93
LM392N 76p
LM393N 96p
LM394H 3.80
LM396K 13.52
LM709N8 54p
LM709CH 1.00
LM710CH 89p
LM710CN 52p
LM711CH 1.38
LM711CN 70p
LM722CH 1.21
LM723CN 40p
LM725CH 3.40
LM725CN 3.19
LM733 69p
LM741CH 98p
LM741CN 15p
LM741CN14 80p
LM747CN 98p
LM748CH 1.00
LM748CN 35p
LM1303N 1.20
LM1304N 2.50
LM1305N 3.10
LM1307N 2.75
LM1310N 1.45
LM1330N 2.25
LM1458 44p
LM1496 1.08
LM1800 3.24
LM1801 2.98
LM1812 8.00
LM1818 2.98
LM1820 2.15
LM1828 4.79
LM1830 2.44
LM1845 4.12
LM1848 2.89
LM1850 2.75
LM1871 4.39
LM1872 4.38
LM1886 7.44
LM1889 3.77
LM2907N 2.75
LM2907N8 2.50
LM2917N 1.89
LM2917N8 1.89
LMC524 6.77
LM3301 1.60
LM3302 74p
LM3401 86p
LM3403 75p
LM3405 1.45
LM3900 48p
LM3905 1.25
LM3909 79p
LM3911 1.20
LM3914 1.79
LM3915 1.99
LM3916 2.19
LM4250CH 2.63
LM4250N 2.39
LM13600 1.09
MB3712 1.99
MB3756 3.80
MB8719 1.95
MS3200 8.54
MC1303 =
LM1303N
MC1304 =
LM1304N
MC1305 =
LM1305N
MC1307 =
LM1307N
MC1310 =
LM1310N
MC1330 =
LM1330N
MC1352 1.75
MC1456 1.80
MC1458 =
LM1458
MC1466L 6.77
MC1495L 3.75
MC1496 =
LM1496

MC3340 1.45
NE531N 1.36
NE543N 2.50
NE540 4.95
NE544N 1.80
NE555 16p
NE556 45p
NE558 1.89
NE560 3.25
NE565 1.18
NE566 1.49
NE567 1.37
NE570 3.75
NE571 3.75
NE5534A 1.25
OM335 7.20
PLL02A 4.95
PLL03A 12.75
RC4136 59p
RC4194 3.95
RC4195 2.95
S566B 2.59
SAD1024A poa
SAS560 2.59
SAS570 2.50
SAS580 2.59
SAS590 2.59
SFF96364 7.99
SL470 3.47
SL490 3.47
SL610C 4.00
SL611C 4.00
SL612C 4.00
SL620C 6.00
SL621C 6.00
SL623C 10.00
SL630C 6.00
SL640C 6.00
SL641C 6.00
SN76001N 2.80
SN76008 3.90
SN76018 3.90
SN76003N 2.95
SN76013N 2.95
SN7023N =
SN76033N
SN76033N 2.95
SN76110 2.25
SN76115 2.65
SN76116 2.75
SN76226 3.45
SN76228 2.90
SN76477 4.49
SN76530 1.80
SN76550 80p
SN76666 2.90
SO41P 1.60
SO42P 1.60
TA7210 1.49
TA7204 1.95
TA7205 89p
TA7222 1.45
TA7223 3.74
TA7310 1.49
TAA263 3.99
TAA300 3.95
TAA320 2.05
TAA350 3.60
TAA521 1.50
TAA522 2.47
TAA550 72p
TAA560 2.35
TAA570 2.35
TAA621AX1 2.75
TAA661A 1.50
TAA661B 1.70
TAA700 2.80
TAA930 2.50
TAA9308 2.63
TAA970 2.45
TAA991D 2.45
TAD100 2.00
TBA120AS 75p
TBA311 1.50
TBA341 2.05
TBA395 1.65
TBA396 1.50
TBA450 1.95
TBA460 1.53
TBA500 2.97
TBA500Q 3.11
TBA510 2.95
TBA510Q 3.05
TBA520 2.57
TBA520Q 2.75
TBA530 2.55
TBA530Q 2.78
TBA540 2.72
TBA540Q 2.74
TBA550 3.25
TBA550Q 3.27
TBA560C 2.87
TBA570 2.37
TBA570Q 2.48
TbA581 3.11
TBA641 3.00
TBA651 1.90
TBA673 4.15
TBA700 2.38
TBA700Q 2.47
TBA720AQ 2.60
TBA750 2.25
TBA750Q 2.46
TBA790A 2.11
TBA800 78p
TBA810 95p
TBA820 79p
TBA820M 75p
TBA920 1.95
TBA9200 1.97
TBA950 2.25
TBA990 2.65
TBA990Q 2.74
TCA105 3.00
TCA160C 2.67
TCA220 3.44
TCA270 2.44
TCA440 2.20
TCA450 2.66
TCA640 4.15
TCA650 4.15
TCA660B 4.15
TCA730 4.80
TCA740 4.80
TCA750 4.85
TCA760 2.75
TCA800 3.50
TCA8600Q 3.80
TCA830S 1.90
TCA910 2.19
TCA940 1.68
TDA1002 3.38
TDA1003 3.94

TDA1004 2.87
TDA1005 3.94
TDA1010A 2.25
TDA1022 4.95
TDA1024 1.19
TDA1034 3.20
TDA2020 2.99
TDA2030 2.85
TDA2522 4.20
TDA2530 3.30
TDA2540 4.10
TDA2541 4.10
TDA2560 4.10
TDA2571 4.40
TDA2581 3.75
TDA2590 5.20
TDA2591 4.73
TDA2640 6.15
TDA2610 3.90
TDA2611A 2.50
TDA2640 3.84
TDA3000 2.76
TL061 40p
TL062 60p
TL064 98p
TL071 36p
TL072 50p
TL074 1.30
TL081 50p
TL082 75p
TL083 85p
TL084 89p
TL170 49p
TL430 3.99
TL494 3.99
UAA170 1.69
UAA180 1.69
ULN2003 89p
UPC575C2 2.46
XR1456 2.75
XR2206 2.92
ZN414 79p
ZN419 2.25
ZN1034 1.98
ZN1040 6.68
ZTK22 89p
ZTK33 89p

TTL
7400 10½p
7401 11p
7402 11p
7403 12p
7404 12p
7405 16p
7406 16p
7407 16p
7408 14p
7409 14p
7410 15p
7411 16p
7412 14p
7413 16p
7414 17p
7416 17p
7417 17p
7420 15p
7421 20p
7422 20p
7423 20p
7425 18p
7426 18p
7427 18p
7430 14p
7432 17p
7433 21p
7437 19p
7438 19p
7440 15p
7441 66p
7442 27p
7443 66p
7444 66p
7445 46p
7446 50p
7447 36p
7448 40p
7450 15p
7451 15p
7453 15p
7454 14p
7460 15p
7470 30p
7472 25p
7473 23p
7474 18p
7475 22p
7476 24p
7480 40p
7481 1.19
7482 63p
7483 38p
7484 63p
7485 60p
7486 18p
7490 1.70
7491 20p
7492 25p
7493 24p
7494 24p
7495 34p
7496 34p
7497 85p
74100 80p
74104 50p
74105 59p
74107 20p
74109 25p
74110 29p
74116 59p
74118 53p
74119 57p
74120 59p
74121 25p
74122 30p
74123 34p
74125 50p
74126 29p
74128 55p
74132 29p
74136 72p
74141 55p
74142 1.75
74143 1.95
74144 1.95
74145 38p
74147 89p
74148 55p
74150 49p
74151 35p
74153 35p
74154 49p
74155 40p
74156 40p
74157 30p

74159 75p
74160 40p
74161 40p
74162 40p
74163 40p
74164 40p
74165 40p
74166 48p
74170 1.17
74172 2.50
74173 48p
74174 54p
74175 49p
74176 39p
74177 45p
74178 88p
74180 40p
74181 1.15
74182 55p
74184 90p
74185 90p
74186 4.69
74188 2.50
74190 45p
74191 45p
74192 45p
74193 45p
74194 40p
74195 40p
74196 40p
74197 48p
74198 77p
74199 77p
74221 53p

74LS TTL
74LS00 11p
74LS01 11p
74LS02 11p
74LS03 12p
74LS04 12p
74LS05 12p
74LS08 12p
74LS10 12p
74LS11 12p
74LS12 12p
74LS13 19p
74LS14 22p
74LS15 12p
74LS20 12p
74LS21 12p
74LS22 12p
74LS27 12p
74LS28 14p
74LS30 12p
74LS32 13p
74LS33 14p
74LS37 14p
74LS38 14p
74LS40 12p
74LS42 28p
74LS47 36p
74LS51 14p
74LS54 14p
74LS55 14p
74LS73 18p
74LS74 18p
74LS75 18p
74LS76 18p
74LS78 18p
74LS80 1.20
74LS83 35p
74LS85 39p
74LS86 16p
74LS90 22p
74LS92 25p
74LS93 24p
74LS95 36p
74LS96 50p
74LS107 20p
74LS109 23p
74LS112 20p
74LS113 22p
74LS114 22p
74LS122 25p
74LS123 34p
74LS124 89p
74LS125 24p
74LS126 25p
74LS132 33p
74LS136 24p
74LS138 24p
74LS139 27p
74LS145 70p
74LS147 99p
74LS148 69p
74LS151 30p
74LS153 39p
74LS154 79p
74LS155 29p
74LS156 36p
74LS157 27p
74LS158 28p
74LS160 30p
74LS161 35p
74LS162 35p
74LS163 40p
74LS165 50p
74LS168 84p
74LS169 95p
74LS170 70p
74LS173 55p
74LS174 39p
74LS175 39p
74LS181 88p
74LS183 1.20
74LS190 36p
74LS191 36p
74LS192 36p
74LS193 37p
74LS194 32p
74LS195 32p
74LS196 46p
74LS197 46p
74LS221 50p
74LS240 55p
74LS241 56p
74LS242 56p
74LS243 56p
74LS244 56p
74LS245 70p
74LS247 50p
74LS248 55p
74LS249 55p
74LS251 30p
74LS253 32p
74LS257 29p
74LS258 33p
74LS259 55p
74LS261 99p
74LS266 18p
74LS273 53p
74LS275 1.25
74LS279 30p

74LS280 95p
74LS283 4.70
74LS290 45p
74LS293 40p
74LS295 75p
74LS298 79p
74LS299 1.55
74LS323 1.55
74LS324 1.45
74LS325 2.85
74LS326 2.30
74LS327 2.30
74LS347 95p
74LS348 88p
74LS352 59p
74LS353 59p
74LS362 7.25
74LS365 27p
74LS366 27p
74LS367 27p
74LS368 27p
74LS373 59p
74LS378 89p
74LS386 1.14
74LS390 46p
74LS393 42p
74LS395 87p
74LS396 1.90
74LS398 2.70
74LS399 1.59
74LS445 1.30
74LS490 1.95
74LS540 88p
74LS541 88p
74LS640 99p
74LS641 99p
74LS643 99p
74LS644 99p
74LS668 1.19
74LS669 99p
74LS670 99p
74LS673 5.50
74LS674 9.99

74S TTL
74S00 30p
74S02 32p
74S04 32p
74S08 75p
74S20 60p
74S30 60p
74S32 70p
74S40 1.45
74S64 1.02
74S65 1.02
74S74 75p
74S85 2.99
74S86 1.75
74S112 90p
74S113 90p
74S124 2.95
74S132 1.09
74LS133 60p
74S138 1.25
74S139 1.48
74S140 2.50
74S151 2.75
74S153 2.75
74S163 3.00
74S174 2.50
74S175 3.20
74S188 3.50
74S189 3.50
74S194 3.50
74S200 4.50
74S201 4.00
74S225 5.25
74S261 3.00
74S262 8.50
74S287 2.99
74S288 1.99
74S289 1.57
74S301 3.20
74S470 3.25
74S471 6.25
74S473 12.50
74S474 3.25
74S475 8.25
74S571 9.00
74S573 9.00

74H TTL
74H00 1.45
74H01 1.45
74H04 1.55
74H05 1.55
74H10 1.45
74H11 1.45
74H20 1.45
74H21 1.45
74H30 1.45
74H40 1.55
74H50 1.45
74H53 1.65
74H54 1.45
74H55 1.40
74H60 1.70
74H62 1.75

74L TTL
74L02 1.00
74L10 1.70
74L47 3.27
74L74 1.20
74L85 4.20
74L86 1.50
74L93 2.30
74L98 2.99

74C CMOS/TTL
74C00 27p
74C04 29p
74C10 28p
74C14 89p
74C20 28p
74C30 36p
74C42 96p
74C48 1.40
74C73 54p
74C76 57p
74C83 1.74
74C85 1.34
74C86 1.10
74C89 5.95
74C90 1.06
74C93 1.44
74C95 1.00
74C107 60p
74C151 2.85
74C154 4.95
74C157 2.28
74C160 1.84
74C161 1.16
74C162 1.18
74C163 65p

74C164 1.16
74C165 2.00
74C173 98p
74C174 85p
74C175 75p
74C192 89p
74C193 89p
74C194 89p
74C195 70p
74C200 10.00
74C221 1.20
74C901 1.91
74C902 71p
74C903 2.30
74C904 1.84
74C905 10.88
74C907 1.91
74C908 1.87
74C911 9.58
74C912 8.00
74C914 2.88
74C915 1.99
74C918 2.50
74C920D 8.50
74C922 4.50
74C923 5.00
74C925 6.00
74C926 6.58
74C928 6.00
74C929 5.20
74C930J 7.80
74C932 3.12

40 CMOS
4000 10p
4001 10p
4002 11p
4006 48p
4007 16p
4008 32p
4009 24p
4010 24p
4011 10p
4012 15p
4013 20p
4014 46p
4015 39p
4016 20p
4017 32p
4018 44p
4019 25p
4020 44p
4021 39p
4022 39p
4023 12p
4024 32p
4025 12p
4026 77p
4027 20p
4028 37p
4029 43p
4030 14p
4031 1.19
4032 80p
4033 1.20
4034 1.29
4035 59p
4036 2.48
4037 1.30
4038 39p
4040 40p
4041 40p
4042 39p
4043 46p
4044 41p
4045 99p
4046 44p
4047 39p
4048 39p
4049 22p
4050 23p
4051 44p
4052 49p
4053 49p
4054 83p
4055 83p
4056 89p
4059 4.35
4060 42p
4063 79p
4066 22p
4067 2.22
4068 14p
4069 13p
4070 13p
4071 13p
4072 13p
4073 13p
4075 13p
4076 44p
4077 13p
4078 13p
4081 12p
4082 12p
4085 49p
4086 53p
4089 1.20
4093 20p
4094 69p
4095 75p
4096 75p
4097 2.88
4098 74p
4099 90p

For higher numbers in 40 Series, substitute 74C for 40 prefix. eg 40107 = 74C107

4k CMOS
4502 50p
4503 29p
4507 33p
4508 1.19
4510 46p
4511 48p
4512 39p
4514 1.10
4515 1.10
4516 50p
4518 39p
4519 29p
4520 48p
4521 90p
4526 59p
4527 68p
4528 46p
4532 69p
4534 4.28
4536 2.58
4538 65p
4539 99p
4543 65p

4553 2.28
4555 35p
4556 35p
4560 1.49
4566 1.49
4569 1.59
4584 38p
4585 78p

COMPUTER ICs
CPUs
1802 7.00
2650A 11.98
8502 3.24
6800 2.74
6802 2.88
6809 8.80
8035 3.48
100mA To5
8080A 2.79
8085A 3.49
8900 57.75
9980 21.00
SCMP1 17.66
Z80A 3.15

MEMORIES
2101 4.00
2102AL2 1.35
2111-1 3.00
2114 (200ns) 8.5p
2532 3.80
2708 2.25
2564 11.95
2708 11.95
2716 (5V) 2.11
2764 9.75
4044 4.50
4060 9.50
4116 (200ns) 75p
4118-3 3.25
4164 4.50
5101(450nS) 1.95
5204 7.51
6116 4.40
6514 3.30
6810 1.15
7489 4.20
74189 4.00
74LS289 3.25
74LS188 2.25
74LS287 3.05
74LS288 1.50

ZERO INSERTION DIL SOCKETS
24 pin 3.89
40 pin 5.30

LOGIC ICs including COMPUTER SUPPORT
ADC0804 3.95
ADC0816 14.90
ADC0817 10.06
AY5-2376 5.90
ICM7555 80p
INS1671 20.00
INS1771 20.00
INS1791 30.00
MC1466L 6.50
MC1488 56p
MC1489 56p
MC4024 3.25
MC4044 3.25
MK50250 10.00
MK50398 9.95
MM5303 6.25
MM5307 12.75
MM5357 22.50
MM57105 14.00
MM57109 12.00
MM57160 9.00
MM58167 9.00
MM58174 11.80
RO2513LC 6.99
RD2513UC 7.60
SAA5000 3.00
SAA5010 7.10
SAA5012 7.10
SAA5020 5.50
SAA5030 9.00
SAA5040 16.00
SAA5041 15.00
SAA5050 8.50
SAA5052 8.50
TMS6011 3.95
ULN2003A 65p
BT26 1.35
BT28 1.35
BT95 1.35
BT97 1.35
81LS95 90p
81LS96 1.20
81LS97 90p
81LS98 1.20
6522 3.19
6532 6.95
6821 1.12
6845 10.00
6847 10.00
6850 1.35
6852 2.49
6875 4.85
8131 3.75
8154 9.42
8155 3.50
8212 1.10
8216 1.08
8223 1.88
8224 1.10
8226 2.50
8228 2.50
8238 5.75
8243 4.68
8250 8.65
8251 3.10
8253 7.88
8254 10.00
8255 2.48
8257 4.00
8259 4.00
8279 4.48
8304 4.50
8544 1.56
8601 1.20
8678CABN 19.50
8832 2.48
8833 2.35
9097 3.00
9099 3.00
9601 5.50
9602 2.50
Z80ACTC 2.65
Z80ADART 8.00

Z80AUMA 10.00
Z80APIO 2.80
ZN425E8 3.30
ZN426E8 3.30
ZN427E8 5.90
ZN428E8 4.05

VOLTAGE REGULATORS
(See also Linear ICs)
Positive
100mA
78L05A 30p
78L12A 30p
78L15A 30p
78L24A 30p
100mA To5
78L05CH 80p
78L12CH 80p
78L15CH 80p
78L24CH 80p
600mA TO202
7805M 47p
7812M 47p
7815M 47p
7824M 47p
1 Amp T0220
7805T 39p
7812ST 39p
7815T 39p
7824T 39p
1.5 Amp T03
7805K 1.39
7812K 1.39
7815K 1.39
7824K 1.39
Negative
100mA TO92
79L05 59p
79L12 59p
79L15 59p
500mA T0202
7905M 59p
7912M 59p
7915M 59p
7924M 59p
1 Amp T0220
7905T 44p
7912T 44p
7915T 44p
7924T 44p
1.5 Amp T03
7905K 1.89
7912K 1.99
7915K 1.99
7924K 1.99
Variable
L200 (2A Pos) 2.50
LM137K 12.00
LM309K 1.35
LM317K 3.42
LM317MP 95p
LM317T 1.75
LM337K 4.60
LM337MP 1.73
LM337T 1.75
LM345K 3.80
LM350K 4.50
LM396K 13.52

DESOLDERING PUMP
High Quality
High Suction
Aluminium
Anodised with Screw in Teflon Nose £4.45
Spare Nose 85p
1,000s SOLD
GREAT VALUE!

GRAPHIC PROCESSORS
EF9365 44.00
EF9366 44.00

HEATSINKS
CLIP-ON
TO1 (AC128) 18p
TO5 (BFY51) 18p
TO18 (BC109) 18p
TO220 (TIP29) 36p
Many other sinks in stock including power sinks. Please phone

Rechargeable Batteries
Guaranteed minimum 500 charges
HP2 (1.2AH) 2.10
HP2 (4AH) 4.75
HP7 (½AH) 99p
HP11 (1.2AH) 2.29

Chargers
TYPE N
Adjustable to 6 of any HP type
Above £15.59
TYPE P
PP3 £5.50
TYPE A
HP7 (Up to 4 at a time) £5.85

QUARTZ CRYSTALS
Please enquire about types not listed
32.768KHz 99p
100KHz 2.49
200KHz 2.79
1.000MHZ 2.99
1.008MHz 2.74
2.000MHz 2.29
2.097152MHz 3.99
3.2768MHz 1.99
4.00MHz 1.49
4.194394MHz 3.00
4.433619MHz 1.10
5.00MHz 1.75
6.00MHz 1.99
6.9375MHz 3.99
8.00MHz 1.75
10.00MHz 1.75
18.00MHz 1.99
20.00MHz 1.99
27.648MHz 2.80
48.00MHz 1.75
100.00MHz 6.50

5.5 MHz
Ceramic filter 90p

VALVES
DY86/87/802 1.32
ECC82 1.22
ECC83 1.22
ECC84 1.22
EF86 1.80
EL34 2.89
EL84 2.50
KT66 10.75
KT88 12.90
PC900 1.75
PCC84 3.00
PCC85 3.40
PCC89 1.89
PCF86 2.30
PCF201 3.00
PCF801 2.57
PCF802 2.11
PCL82 1.80
PCL85 2.20
PCL86 2.10
PCL805 2.20
PD510 4.95
PFL200 2.99
PL504 2.11
PL508 2.36
PL519 7.75
PL802 4.17
PY88 1.62
PY500A 2.63
6L6 2.59

PLUGS & SOCKETS
UHF PL259 types
Low loss, superior quality
50Ω
Line plug 45p
Reducer 15p
Round skt 40p
Sqr skt 40p

BNC 50Ω
Plug 1.10
Socket 1.00
Line skt 1.15

'KEYNECTOR'
Bare Wire Mains Safety Block
£7.95

RELAY (MINI)
4 pole 2 way
7512 6 12V
3 amp contacts
£2.80

CANNON TYPE AUDIO PLUGS (3 PIN XLR)
Male 1.70
Female 1.65
Sockets (Chassis)
Male 1.50
Female 2.35

JACK PLUGS
Huge Discount for quantity please phone
¼" Mono 20p
¼" Stereo 30p
¼" Metal
Mono 30p
⅛ mm Mono 12p
⅛ mm Metal
Mono 20p
⅛ mm Mono 12p
⅛ mm Stereo 35p
⅛ mm Metal
Mono 20p

JACK SOCKETS
Chassis
¼" Mono 20p
¼" Stereo 25p
2½ mm Mono 15p
3½ mm Mono 15p
Line
¼" Mono 20p
¼" Metal 30p
¼" Stereo 30p
⅛" Stereo
Metal 40p
3½ mm Mono 15p
3½ mm Mono
Line 20p

Texas Books in stock. Send for Free Leaflet
BOOKS (no VAT) (Post inc prices)
Towers
Transistor Manual (Bible) 10.50
TTL Data 3.95
Data conversion 4.50
Volt Reg Data 3.95
Interface 3.95
Memory aplic 4.95
Audio/Radio Hbk 4.50
Special function handbook 3.95

COAX (TV)
All Metal
Plug 25p
Socket 25p
Line Skt 40p

3½ DIGIT LCD MULTIMETER
2 amps AC DC
1KV (DC)
750V (AC)
Incredible at £34.50
(SAE brings specs)

Rapid Electronics

MAIL ORDERS:
Unit 2, Hill Farm Industrial Estate,
Boxted, Colchester, Essex CO4 5RD.
TELEPHONE ORDERS:
Colchester (0206) 36412.

ACCESS AND BARCLAYCARD WELCOME

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; 2u2, 50p.
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

POTENTIOMETERS

Rotary, Carbon track Log or Lin 1K - 2M2. Single 32p. Stereo 85p. Single switched 80p. Slide 60mm travel single Log or Lin 5K - 500K 63p each.
Preset submin. hor. 100 ohms -1M 7p each.
Cermet precision multiturn, 0.75W ¼" 100 ohms to 100K - 88p each.

REGULATORS

78L05	30	79L05	65
78L12	30	79L12	65
78L15	30	79L15	65
7805	35	7905	40
7812	35	7912	40
7815	35	7915	40
LM309K	130	LM723	38
LM317K	270	LM338K	475
LM317T	120	78H05 5A	
LM323K	350	▶5V	550

SOLDERING IRONS

Antex CS 17W Soldering iron	460
2.3 and 4.7mm bits to suit	65
CS 17W iron: 450, element	210
Antex XS 25W	480
3.3 and 4.7mm bits to suit	65
Solder pump desoldering tool	480
Spare nozzle for above	70
10 metres 22swg solder	100

TOOLS

Small trimming tool	22
Small pocket screwdriver	16
Large pocket scrawdriver	13
6 piece precision screwdriver set in plastic case	170
Low cost side cutters	160
High quality side cutters	650
Low cost pliers	160
High quality pliers	650
Wire strippers	120
Expo reliant drill	695
Expo Titan drill	1025
Drill stand	1200
Reduced shank drill bits for above 0.8mm, 1mm, 1.4mm	60

OPTO

▶3mm red	7	▶5mm red	7
▶3mm green	10	▶5mm green	10
▶3mm yellow	10	▶5mm yellow	10

Clips to suit - 3p each.

Rectangular		TIL32	40
▶red	12	TIL78	40
green	17	▶TIL111	60
yellow	17	ORP12	85
▶TIL38	40	TIL100	90
2N5777	45	Dual colour	60

Seven segment displays:

Com cathode		Com anode	
DL704 0.3"	95	DL707 0.3"	95
▶FND500 0.5"	100	FND507 0.5"	100
TIL312 0.3"	115	TIL312 0.3"	115
TIL322 0.5"	115	TIL321 0.5"	115

LCD: 3½ digit 580p. 4 digit 620p.

SWITCHES

Submin toggle: SPST 55p. SPDT 60p. DPDT 65p.
Miniature toggle: SPDT 80p. SPDT centre off 90p. DPDT 90p. DPDT centre off 100p.
Standard toggle: SPST 35p. DPDT 48p
Miniature DPDT slide 12p.
Push to make 12p.
Push to break 22p.
Rotary type adjustable stop. 1P12W, 2P6W, 3P4W all 55p each.
DIL switches: 4SPST 80p 6 SPST 80p. 8SPST 100p.

TRANSFORMERS

Please add carriage charges to our normal post charges.

Miniature mains: 606V, 909V, 12012V all @ 100mA 100p each.
PCB mounting. Miniature:
3VA 0-6, 0-6 @ 0.25A; 0-9, 0-9 @ 0.15A; 0-12, 0-12 @ 0.12A 200p each.
6VA 0-6, 0-6 @ 0.5A; 0 9, 0-9 @ 0.3A; 0-12, 0.12 @ 0.25A 270p each.
High quality. Split bobbin construction
6VA 0-6, 0 6 @ 0.5A; 0-9, 0-9 @ 0.4A; 0-12, 0-12V @ 0.3A 220p each.
12VA 0-6, 0-6 @ 1A. 0-9, 0-9 @ 0.8A, 0-12, 0-12 @ 0.5A; 0-15, 0-15 @ 0.4A 295p (plus 40p carriage).
25VA 0-6, 0-6 @ 1.5A; 0-9, 0-9 @ 1.2A; 0-12, 0-12 @ 1A; 0 15, 0-15 @ 0.8A 330p each (plus 60p carriage)
50VA 0-12, 0-12 @ 2A, 0-15, 0-15 @ 1.5A. 440p each (plus 75p carriage)

VERO

VEROBLOC◀	350
Size 0.1 matrix:	
2.5 x 1	22
2.5 x 3.75	75
2.5 x 5	85
3.75 x 5	95
VQ board	160
Veropins per 100:	
Single sided	50
Double sided	60
Spot face cutter	105
Pin insertion tool	162
Wiring pen and spool	310
Spare spool 75p Combs	6

HARDWARE

PP3 battery clips	6
Red or black crocodile clips	6
Black pointer control knob	15
Pr Ultrasonic transducers	350
▶6V Electronic buzzer	60
▶12V Electronic buzzer	65
▶PB2720 Piezo transducer	75
▶64mm 64 ohm speaker	70
▶64mm 8 ohm speaker	70
20mm panel fuseholder	25

CONNECTORS

DIN	Plug	Skt	Jack	Plug	Skt
2 pin	9p	9p	2.5mm	10p	10p
3 pin	12p	10p	3.5mm	9p	9p
5 pin	13p	11p	Standard	16p	20p
Phono	10p	12p	Stereo	24p	25p
1mm	12p	13p	4mm	18p	17p

UHF (CB) Connectors:
PL259 Plug 40p. Reducer 14p.
SO239 square chassis skt 38p.
SO239S round chassis skt 40p.
IEC 3 pin 250V/6A.

Plug chassis mounting	38p
Socket free hanging	60p
Socket with 2m lead	120p

BOXES

Plastic with lid + screws		Aluminium	
		3x2x1"	70
		4x3x1½"	85
3x2x1"	55	4x3x2"	100
4½x3x1½"	88	6x4x2"	120
7x4x2	160	6x4x3"	150

MULTIMETERS

HT-120 4,000 opv
A smart looking 11 range pocket sized multimeter with an impressive spec. Complete with battery, etc. 650p each.
HT-320 20,000 opv.
Highly sensitive 19 range multimeter including transistor tester. Overload protection. DC volts – 1000, AC volts – 1000; DC current 0.25A. 4 resistance ranges. Complete with batteries, leads, etc. 1395p

DIODES

BY127	12	▶1N4001	3
OA47	10	1N4002	5
DA90	8	1N4006	7
OA91	7	1N4007	7
OA200	8	1N5401	12
OA202	8	1N5404	16
1N914	4	1N5406	17
▶1N4148	2	400mWzen	6

SCRs

▶C106D	30
400V 8A	70
400V 12A	95

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

RESISTORS

¼W 5% Carbon film E12 series 4.7 ohm - 1M. 1p each.
½W 5% Carbon film E12 series 4.7 ohm to 4M7 2p each.
¼W 1% metal film E24 series 10 ohm - 1M 6p each.

PCB MATERIALS

Alfac transfer sheets — please state type (e.g. DIL pads etc.)	45
Dalo etch resist pen	100
Fibre glass board 3.75"x8"	80
Ferric chloride 250ml bottle.	100

TRIACS

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

SOCKETS

	Low profile	Wire wrap
8 pin	6p	25p
14 pin	8p	35p
16 pin	9p	42p
18 pin	12p	52p
20 pin	13p	60p
22 pin	16p	70p
24 pin	18p	70p
28 pin	23p	80p
40 pin	25p	98p

Soldercon pins 60P/100

COMPONENT KITS

An ideal opportunity for the beginner or the experienced constructor to obtain a wide range of components at greatly reduced prices. ¼W 5% Resistor kit. Contains 10 of each value from 4.7 ohms to 1M (total of 650 resistors) 480
Ceramic Cap. kit. 5 of each value - 22p to 0.01u (135 caps) 370
Polyester Cap. kit. 5 of each value from 0.01 to 1uF (65 caps) 515
Preset kit. Contains 5 of each value from 100 ohms to 1M (total 65 presets 425
Nut and Bolt kit (total 300 items): 180p

25 6BA ¼" bolts	50 6BA washers	50 6BA nuts
25 6BA ½" bolts	25 4BA ¼" bolts	50 6BA washers
50 6BA nuts	25 6BA ½" bolts	

CABLES

20 metre pack single core connecting cable ten different colours. 65p

Speaker cable	10p/m
Standard screened	16p/m
Twin screened	24p/m
2.5A 3 core mains	23p/m
10 way rainbow ribbon	65p/m
20 way rainbow ribbon	120p/m

NEW CATALOGUE * NEW CATALOGUE!!!!!!!

Our latest catalogue has just been released containing over 2000 stock lines all at extremely competitive prices backed by Rapid's return of post service. Stocks include Denco coils, tools, Verocases, data sheets etc. etc. Send 45p for your copy now (sent free of charge with all orders over £10).

MICRO

BEST PRICES ANYWHERE!

2114L-2	75	Z80A CPU	290	81LS96	85
2716	205	Z80A P10	260	81LS97	85
2532	340	Z80A CTC	260	1488	55
2732	340	Z80A S10	900	1489	55
4116 P20	70	Z80A DMA	1150	Epson Printers and D	
6116-P3 150nS	365	Z80A DART	500	Connectors now avail-	
4164	440	81LS95	85	able at low low prices.	

CRYSTALS

100KHz	235	4.43M	100
1MHz	275	6.0M	140
1.8432M	200	7.0M	150
2.0M	225	8.0M	140
2.4576M	200	10.0M	170
3.579M	95	12M	170
4.0M	140	16M	200

LINEAR

				LM339	45	LM3911	120	NE566	140	TL064	96
				LM348	60	LM3914	175	▶NE567	100	TL071	30
				LM358	50	LM3915	195	▶NE570	370	TL072	50
555CMOS	90	ICL7106	790	LM377	170	LM13600	105	NE571	370	TL074	95
556CMOS	150	ICL7611	95	▶LM380	65	MC1496	68	▶RC4136	55	▶TL081	25
709	25	ICL7621	180	▶LM381	120	MC3340	135	▶RC4558	60	TL082	45
▶741	14	ICL7622	180	LM382	120	▶MF10CN	350	SL480	170	TL084	95
748	35	ICL8038	295	LM384	130	ML922	400	SL490	250	TL170	50
9400CJ	350	ICL8211A	200	LM386	65	ML924	195	SL76018	150	UA2240	120
AY-3-1270	720	ICM7224	785	LM387	120	ML925	210	▶SN76477	380	ULN2003	85
AY-3-8910	370	ICM7555	80	LM393	100	ML926	140	SP8629	250	ULN2004	90
AY-3-8912	540	▶LF351	45	LM709	25	ML927	140	TBA120S	70	XR2206	290
CA3046	60	LF353	85	LM711	60	ML928	140	TBA800	75	ZN414	100
▶CA3080	65	LF356	90	LM725	350	ML929	140	TBA810	96	ZN423	135
CA3089	190	LM10	360	LM733	75	MM5387A	465	TBA820	70	ZN424	135
CA3090AQ	375	LM301A	25	LM741	14	NE529	225	TBA950	220	ZN425E	350
CA3130E	85	LM311	70	LM747	60	NE531	150	TDA1008	320	ZN426E	330
▶CA3140E	36	LM318	120	LM1458	40	NE544	205	▶TDA1022	490	ZN427E	650
CA3161E	100	LM324	40	LM2917	200	▶NE555	16	TDA1024	125	ZN428E	480
CA3189	290	LM334Z	100	LM3900	45	▶NE556	45	TL061	40	ZN459	285
▶CA3240E	110	LM335Z	125	▶LM3909	70	NE565	110	TL062	60	ZN1034E	200

CMOS

		4016	20	4034	140	4054	78	4081	12	40193	65	4528	45
		4017	30	4036	249	4055	80	4082	12	4502	60	4529	150
		4018	45	4039	280	4059	430	4085	48	4503	32	4532	60
4000	10	4019	25	4040	40	4060	42	4086	50	4507	35	4534	400
4001	10	4020	42	4041	40	4063	80	4089	125	4508	110	4538	60
4002	12	4021	40	4042	38	4066	22	4093	18	4510	45	4543	50
4006	50	4022	45	4043	40	4067	225	4094	68	4511	40	4549	360
4007	14	4023	16	4044	40	4068	14	4095	65	4512	40	4553	215
4008	36	4024	33	4046	40	4069	13	4097	290	4514	115	4555	35
4009	24	4025	12	4047	35	4070	13	4098	70	4515	115	4556	35
4010	24	4026	75	4048	38	4071	13	4099	70	4516	55	4559	390
4011	10	4027	20	4049	21	4072	13	40106	40	4518	40	4560	140
4012	15	4028	40	4050	21	4073	13	40109	110	4520	50	4584	35
4013	20	4029	45	4051	42	4075	13	40163	60	4521	130	4585	60
4014	45	4030	14	4052	48	4076	45	40173	100	4526	60	4724	140
4015	40	4031	125	4053	48	4077	14	40175	75	4527	50		

LS TTL

		LS20	12	LS75	20	LS123	34	LS160	35	LS197	45	LS353	60
		LS21	12	LS76	17	LS125	24	LS161	35	LS221	50	LS365	28
		LS22	12	LS78	17	LS126	25	LS162	35	LS240	60	LS366	28
LS00	11	LS26	14	LS83	35	LS132	35	LS163	35	LS241	55	LS367	28
LS01	11	LS27	12	LS85	48	LS136	26	LS164	40	LS242	55	LS368	29
LS02	11	LS30	12	LS86	16	LS138	30	LS165	55	LS243	55	LS373	58
LS03	12	LS32	13	LS90	24	LS139	30	LS166	60	LS244	55	LS374	60
LS04	12	LS37	14	LS92	25	LS145	70	LS170	75	LS245	70	LS375	43
LS05	12	LS38	15	LS93	24	LS147	150	LS173	60	LS247	48	LS377	60
LS08	12	LS40	13	LS95	38	LS148	75	LS174	45	LS251	28	LS378	57
LS09	12	LS42	28	LS96	95	LS151	38	LS175	45	LS257	32	LS390	45
LS10	12	LS47	35	LS107	40	LS153	38	LS190	35	LS258	32	LS393	40
LS11	12	LS48	45	LS109	21	LS154	75	LS191	35	LS259	55	LS399	156
LS12	12	LS51	14	LS112	21	LS155	33	LS192	35	LS266	20	LS541	78
LS13	19	LS55	14	LS113	21	LS156	36	LS193	36	LS273	58	LS670	135
LS14	30	LS73	18	LS114	22	LS157	26	LS195	32	LS279	30		
LS15	12	LS74	17	LS122	35	LS158	29	LS196	45	LS283	38		

TTL

		7413	17	7444	85	7483	30	74122	38	74161	46	74190	40
		7414	23	7446	58	7485	60	74123	38	74162	46	74191	40
		7416	19	7447	36	7486	19	74125	33	74163	46	74192	40
7400	11	7417	19	7448	43	7489	180	74126	33	74164	46	74193	40
7401	11	7420	14	7450	14	7490	19	74132	30	74165	46	74194	40
7402	11	7421	19	7451	14	7491	34	74141	54	74167	150	74195	40
7403	12	7422	19	7453	14	7492	24	74145	48	74170	115	74196	40
7404	12	7427	18	7454	14	7493	24	74147	75	74173	58	74197	40
7405	14	7428	25	7460	14	7494	33	74148	60	74174	53	74198	80
7406	19	7430	13	7472	22	7495	33	74150	48	74175	45	74199	80
7407	19	7432	20	7473	24	7496	38	74153	38	74176	35		
7408	13	7433	20	7474	19	7497	86	74154	47	74177	42		
7409	13	7437	23	7475	26	74100	78	74155	36	74179	75		
7410	13	7438	24	7476	25	74107	22	74156	36	74180	38		
7411	15	7440	14	7480	45	74109	24	74157	28	74181	100		
7412	17	7442	30	7482	65	74121	24	74160	55	74182	55		

TRANSISTORS

				BC517	40	BF337	40	MPSU56	60	ZTX108	8	2N3055	50
				BC547	7	BFR40	23	TIP29A	30	ZTX109	12	2N3442	120
				BC548	10	BFR80	23	TIP29B	55	ZTX300	14	▶2N3702	6
AC125	35	BC149	9	BC549	10	▶BFR81	20	TIP29C	37	ZTX301	16	2N3703	9
AC126	25	BC157	8	BC558	10	BFX29	25	TIP30A	35	ZTX302	15	▶2N3704	6
AC127	25	BC158	10	BCY70	18	BFX84	25	TIP30B	50	ZTX304	17	2N3705	9
▶AC128	20	BC159	8	BCY71	18	BFX85	25	TIP30C	37	ZTX341	30	2N3706	9
AC176	25	BC160	45	BCY72	15	BFX86	28	TIP31A	35	ZTX500	15	2N3707	10
AC187	22	BC168C	10	BD115	55	BFX87	25	TIP31C	37	ZTX501	15	2N3708	10
AC188	22	BC169C	10	BD131	35	BFX88	25	TIP32A	35	ZTX502	15	2N3709	10
AD142	120	BC170	8	BD132	35	BFY50	23	TIP32C	37	ZTX503	18	2N3772	170
AD149	80	BC171	10	BD133	50	BFY51	20	TIP33A	50	ZTX504	25	▶2N3773	195
AD161	40	BC172	8	BD135	40	BFY52	23	TIP33C	75	2N697	20	▶2N3819	18
AD162	40	BC177	18	BD136	30	BFY53	32	TIP34A	60	2N698	40	2N3820	40
AF124	60	BC178	18	BD137	30	BFY55	32	TIP34C	85	2N706A	20	2N3823	65
AF126	50	BC179	18	BD138	30	BFY56	32	TIP35A	105	2N708	20	2N3866	90
AF139	40	BC182	10	▶BD139	35	BRY39	40	TIP35C	125	2N918	35	2N3903	10
AF186	70	▶BC182L	8	▶BD140	35	BSX20	20	TIP36A	125	2N1132	22	2N3904	10
AF239	75	BC183	10	BD204	110	BSX29	35	TIP36C	135	2N1613	30	2N3905	6
BC107	10	BC183L	10	BD206	110	BSY95A	25	TIP41A	45	2N2218A	45	2N3906	10
BC107B	12	BC184	10	BD222	85	BU205	160	TIP42A	45	2N2219A	25	2N4037	45
▶BC108	9	BC184L	7	BF180	35	BU206	180	TIP120	90	2N2221A	25	2N4058	10
BC108B	12	BC212	10	BF182	35	BU208	170	TIP121	90	2N2222A	20	2N4060	10
BC108C	12	BC212L	10	BF184	25	MJ2955	99	TIP122	90	2N2368	25	2N4061	10
▶BC109	9	BC213	10	BF185	25	MJE340	50	TIP141	98	2N2369	16	2N4062	10
BC109C	12	BC213L	10	BF194	12	MJE520	60	TIP142	98	2N2484	25	2N5457	36
BC114	18	BC214	10	BF195	12	MJE521	95	TIP147	110	2N2646	45	2N5458	36
BC115	22	▶BC214L	8	BF196	12	MJE3055	70	TIP2955	60	2N2904	20	2N5459	30
BC117	18	BC237	8	BF197	12	MPF102	40	TIP3055	55	2N2904A	20	2N5485	36
BC119	35	BC238	14	BF198	10	MPF104	40	TIS43	40	2N2905	22	2N5777	45
BC137	40	BC308	12	BF199	18	MPSA05	22	TIS44	45	2N2905A	22	2N6027	30
BC139	40	BC327	14	BF200	30	MPSA06	25	TIS90	30	2N2906	25	40360	40
BC140	28	BC328	14	▶BF244B	22	MPSA12	30	TIS91	30	2N2906A	25	40361	50
BC141	30	BC337	14	BF245	30	MPSA55	30	VN10KM	45	2N2907	25	40362	50
BC142	25	BC338	14	BF256B	45	MPSA56	30	VN46AF	75	2N2907A	25	40408	70
BC143	25	BC477	30	BF257	32	MPSU05	55	VN66AF	85	2N2926	9		
BC147	8	BC478	30	BF258	25	MPSU06	55	VN88AF	95	▶2N3053	23		
BC148	8	BC479	30	BF259	35	MPSU55	60	ZTX107	8	2N3054	55		

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DIGEST

£1000 Reward

Well, that's got your attention — now here's the problem. It would seem that some light-fingered gentlemen have been at work in deepest Surrey. Aura Sounds Ltd, sole importer of Wersi organs, pianos and accessories in the UK, suffered a burglary three days ago (that's Saturday 5th February as I write this) and several expensive items were stolen. Amongst the lost instruments was a computer-controlled rhythm unit, known in the trade as a Wersimatic CX 1. The director of Aura, Mr. Arthur Griffiths says "The thief couldn't have stolen a more easily traceable item! This CX 1 is the only model of its type in the UK at the moment. Indeed, it is virtually a prototype and there are only 10 in existence world-wide. It is absolutely essential that we retrieve this instrument, and we are offering a reward for its recovery. Information leading to the return of the CX 1 and apprehension of the thief (thieves) concerned will carry with it a £1000 reward". Anyone who thinks they have information should contact Mr. Griffiths at Aura Sounds Ltd, Royal Oak Centre, Brighton Road, Purley, Surrey (telephone 01-668 9733).

A Safe Bet

Here's another attention-getter for this page—can you stand the excitement? Nike Clark (for it is she) is unique, with a lot to offer, says the British Safety Council, and that's why they've chosen her to help promote their Action Days. These will be staged to assist industry avoid the disruption of accidents and unnecessary losses by bringing all the latest relevant information, products, expertise and techniques within easy, cost-effective reach of companies all over the country.

The dates are Leeds (13/14 April), Cardiff (22/23 June), Plymouth (14/15 September), Middlesborough (12/13 October) and London (20 May). Anyone wishing some Action should contact Faye Rothwell, British Safety Council, 62/64 Chancellor's Road, London W6 9RS (telephone 01-741 1231 ext. 293).

Disc-continued

We continue the mini-floppy disc saga; Sony announced today (January 20th) that 13 leading floppy industry companies, composed of the following disc drive and media manufacturers, have agreed to support a mutually compatible 3.5" floppy disc format: Atari, Athana, BASF Systems Corporation, Fuji Photo Film Co. Ltd, Memorex Corporation, Media System Technology, Inc, Shugart Associates, Sony Corporation, TDK, 3M, Verbatim Corporation, Wabash Datatech, Inc and Xidex. "The major technological issues relating to compatibility have been settled," Sony said. "The compatibility will strengthen the position of the 3.5" disk with a hard covering as the leading format for a microfloppy industry, as well as reduce costs and expand the potential market through greater second sourcing opportunities." The media itself holds up to 1 megabyte in a double-sided, 135 track per inch version. The media's hard covering protects the user's data, while the precise centring and proven 135 tracks per inch technology contribute to greater reliability by reducing the potential for positioning errors. Once the remaining specifications have been settled, Sony will grant non-exclusive manufacturing licenses to any qualified media manufacturer in order to promote widespread adoption of the standard by manufacturers.

MegaMania Mania

Having reviewed a fair number of games for the January ETI, your intrepid Star Warrior/Deputy Editor had come to the conclusion that high-resolution machines like the Intellivision and Atari 400 rather left the Atari VCS out in the cold. A new game from ActiVision has changed all that, however, because it's so good it's almost worth buying a VCS just for this one cartridge. ActiVision have proved that it's the game design that counts, not the screen resolution. Using only the simplest of shapes they've produced a challenging and absorbing 'space shootout', one which led to the extraordinary sight of eight ASP employees crowded into the ETI workshop one night queueing to play. This is unprecedented, because said employees would normally be quaffing draughts of ale in the local tavern after work.

What does MegaMania involve? Each attack cycle consists of eight waves of Invader-type aliens with loony shapes — these are hamburgers, cookies, bugs, radial tyres, diamonds, steam irons, bow ties (!) and dice (personally I think they look more like lumps of cheese). There are no bases to hide under, which is tricky because some of the baddies move from left to right, others move down the screen, and some do both. The screen wraps round from top to bottom and left to right so if you miss any they come back for another shot, but it's very easy to get trapped unless you can figure out the patterns and the best tactics for each wave. The patterns of movement are, naturally, different for every cycle. Chris 'Fingers' Palmer of Personal Computing Today holds the office record at present with 216, 530 on option 1, difficulty b, a pretty stiff target to beat. MegaMania costs £29.95 and, even though it's only February, gets our vote as game of the year. Go out and buy one. Now.

Microtutor

We have received a letter from Tangerine Computer Systems Ltd, designers of the Microtutor project that was featured in the August, September and October issues of ETI last year. In it they state that they have had many problems with it, paramount being their inability to obtain the necessary components. As a result of this they have taken the decision to withdraw the project from the market. Both we and Tangerine would like to offer our apologies to any readers who may have been inconvenienced by the situation.

Cross Words

Oops! we forgot to give the winners of Crossword No. 5. They were John R. Baldwin of Dorset, A. R. Moss of Hampshire and Stuart McWilliam of West Yorks. Answers:

ACROSS: 1 Chassis. 4 All Pass. 10 Ambient. 11 Dry Cell. 12 PNP. 16 Mid Range. 17 Nanovolt. 18 SME. 19 Monitors. 21 Low Power. 23 Function. 26 Anodised. 29 Owl. 30 Resonant. 32 Betatron. 34 Hum. 36 Asable. 38 Voltaic. 39 P C Board. 40 Housing. DOWN: 2 Hybrid. 3 ITT. 5 LCD. 6 Stereo. 7 Maximum. 8 Pan. 9 Flutter. 12 Press. 13 Panel. 14 Watt. 15 Loop. 20 NPN. 22 WPS. 23 Faraday. 24 Tone. 25 Notch. 26 Album. 27 Dial. 28 DIN Jack. 31 Static. 33 RF Gain. 35 USB. 37 EOR. 38 VCO.

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74LS11	12
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74LS20	13
74LS30	12
74LS32	13
74LS37	14
74LS38	14
74LS42	28
74LS47	36
74LS51	14
74LS73	18
74LS74	16
74LS75	16
74LS76	15
74LS85	40
74LS86	16
74LS90	22
74LS92	30
74LS93	22
74LS107	20
74LS112	20
74LS123	34
74LS125	24
74LS126	25
74LS132	34
74LS136	23
74LS137	90
74LS138	25
74LS139	27
74LS145	70
74LS148	75
74LS151	40
74LS153	40
74LS155	30
74LS156	36
74LS157	27
74LS161	36
74LS163	36
74LS164	30
74LS165	60
74LS166	60
74LS173	55
74LS174	45
74LS175	40
74LS191	36
74LS193	40
74LS195	39
74LS196	48
74LS197	60
74LS221	48
74LS240	55
74LS241	55
74LS242	55
74LS243	55
74LS244	55
74LS245	70
74LS251	30
74LS253	30
74LS257	30
74LS259	55
74LS266	20
74LS273	55
74LS279	30
74LS299	150
74LS367	30
74LS368	26
74LS373	60
74LS374	55
74LS378	60
74LS393	45

7400

7400	11
7401	11
7402	11
7403	12
7404	13
7405	15
7406	20
7407	20
7408	14
7409	14
7410	14
7413	18
7414	20
7420	15
7430	14
7440	14
7442	32
7443	60
7444	60
7447	36
7448	40
7450	14
7451	14
7453	14
7454	14
7460	14
7470	24
7472	24
7473	26
7474	20
7475	25
7476	25
7480	35
7482	65
7483	38
7485	60
7486	18
7489	159
7490	20
7491	35
7492	25
7493	25
7494	35
7495	35
7496	34
74100	80
74104	45
74107	20
74121	24
74123	34
74125	29
74126	33
74141	52
74151	30
74154	50
74155	39
74156	35
74157	30
74190	45
74191	45
74192	45
74193	45
74393	78

CMOS

4000	10
4001	10
4002	12
4006	50
4007	14
4008	32
4009	24
4010	24
4011	11
4012	15
4013	20
4014	48
4015	40
4016	20
4017	32
4018	45
4019	25
4020	42
4021	40
4022	39
4023	14
4024	32
4025	13
4026	80
4027	20
4028	39
4029	45
4030	15
4041	40
4042	40
4043	40
4044	40
4046	48
4049	23
4050	23
4060	45
4069	13
4070	13
4071	13
4072	13
4081	13
4082	13
4093	20
4510	45
4511	45
4514	110
4516	53
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4543	75
4583	90

Many other types in stock — see current price list.

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SAS580	198
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TAA761	104
TAA761A	49
TAA765A	62
TAA861	103
TAA865A	58
TAA2761A	72
TAA4761A	113
TAA4765A	120
TAB1041K	187
TBA120AS	62
TBA120U	72
TBA800	75
TBA10S	75
TBA820	75
TBB1458	62
TBB1458B	40
TCA105	120
TCA105B	108
TCA105G	140
TCA250A	185
TCA205K	200
TCA335A	66
TCA345A	109
TCA345W	177
TCA671	131
TCA780	211
TCA871	114
TCA955	228
TCA965	136
TCA965K	120
TCA971	92
TCA991	80
TCA991K	100
TDA2002	120
TDA2003	126
TDA2030	150
TDA4050B	144
TDA4290	169
TDA4600	184
TDA4700A	546
TDA4718A	435
TFA1001W	252
TL071CP	25N
TL072CP	45N
TL074CN	100N
TL081CP	25N
UAA170	165
UAA170L	152
UAA180	165
UAA190	141
XR2206	300N
ZN414	80N
ZN424P	99
ZN425E	350

CRYSTALS

(in MHz)

0.032768	102	4.433	128
0.100000	453	4.915	157
1.000	453	5.000	157
1.8432	320	5.026	128
2.000	268	6.000	157
2.4576	268	6.144	157
3.2768	188	6.5536	128
3.579	128	8.000	1.88
4.000	102	8.867	128
4.194	128	10.000	157
		18.432	188

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DIN AUDIO

Pins	plug	skt
2	8p	8p
3	17p	8p
4	17p	14p
5 (180°)	17p	11p
5 (240°)	18p	8p
6	20p	20p
7	20p	30p

PARALLEL TYPE

	Plug	Skt
16 way	1.10	1.30
20 way	1.25	1.45
26 way	1.50	1.70
34 way	1.65	1.95
40 way	1.85	2.10

Plugs have retainers. Sockets have strain relief

JACK PLUGS, SKTS

MONO 2.5"			
chrome P1	53p	34p	42p
plastic P2	32p	14p	20p
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chrome P3	81p		52p
plastic P4	60p	16p	20p
Mono 3.5mm	18p		14p
Stereo	23p		42p

IC SOCKETS

pins	each	25 for
8	6	1.20N
14	8	1.80N
16	9	1.80N
18	11	2.20N
20	12	2.40N
22	14	2.80N
24	15	3.00N
28	18	3.60N
40	25	5.00N

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LED yellow or green **70**
(high efficiency)
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6V 60 mA **48**
14V 40 mA **54**

6V filament
3015F 8 mA **255**
3015F 15 mA **255**

LED's
5mm red 10
yellow 19
green 16
Mountings, B65 3

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7-segment
Common anode
MAN72A red 75
MAN82A yellow 110
MAN52A green 110
Common cathode
MAN74A red 85
MAN84A yellow 110
MAN54A green 110

KNOBS

Black plastic
K1 skirted with spot 16
K2 as K1, 35mm 21
K3 pointer 15
K7 19mm knurled 23
K8 as K7 + skirt 23

THERMISTORS

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Disk type, 5mm dia. Resistance at 20°C; 6R8, 10, 22, 47, 100, 220, 470, 1K, 2K2, 4K7, 10K, 22K, 47K, 100K each 18p

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Min. 10mm dia. Hrix. or Vert. 100ohms — 1M **13p**
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Ceramic Very small 1.8, 2.2, 2.7 etc, up to 1n **5p each.** 1n5, 2n2, 3n3, 4n7, 6n8, **5p**; 10n, 22n, **6p**; 33n, 47, **7p**; 100n, **6p**
Polyester, Siemens Layer Type 7.5mm lead spacing 100V
1n, 1n5, 2n2, 3n3m **6p**; 4n7, 6n8, 8n2, 10n 12n, 15n, 18n, 22n, 33n, 47n, **7p** 56n, 68n, **7p**; 82n, 100n, **9p** 120n, 150n, **15p**; 180n, 220n, **12p**; 270n, 330n, 330n, 390n, 470n, **15p**; 560n, 680n, **24p**; 10mm spacing 1uF **25p**; 15mm spacing 2u2 **35p**; 22.5mm, spacing 1uF 400V **50p**; 3.33uF 100V **69p**; In depth stocks.

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2.2/25	13	1000/16	26
2.2/63	9	1000/25	36
4.7/63	9	1000/40	44
4.7/100	14	1000/63	76
6.8/40	9	2200/6	09
10/6	13	2200/16	44
10/25	9	2200/25	
10/40	11	2200/40	73
10/63	12	4700/16	72
10/100	15	4700/25	90
22/10	9		
22/25	11		
22/40	12		
22/63	15		
22/100	16		
47/3	3		
47/10	11		
47/25	12		
47/40	15		
47/63	15		
47/100	18		
100/3	3		
100/10	12		
100/16	12		
100/25	12		
100/40	15		
100/63	20		
100/100	27		
220/10	16		
220/16	16		
220/25	16		
220/40	20		
220/28	28		
220/100	42		
470/10	19		
470/16	19		
470/25	19		
470/40	27		
470/63	45		
470/100	73		

TANTALUM BEADS

0.1/35	13
0.22/35	13
0.47/35	13
1.0/35	13
2.2/16	13
2.2/35	16
4.7/16	16
4.7/35	18
6.8/16	16
6.8/25	24
10/6.3	16
10/16	18
10/25	18
22/6.3	18
22/16	30
22/25	30
33/6.3	24
33/10	30
47/6.3	30
100/10	66

For full ranges of very many other types please see Cat 82 and/or current price list.

BOXES

High quality Black ABS plastic or die-cast plain or stove grey.

L	W	D	ABS		Plain		Stove Gr	
50	50	25	–		5001P	90p	5001	123p
100	60	25	2002	96p	5002P	117p	5002	154p
113	63	31	2003	109p	5003P	143p	5003	184p
121	66	40	2004	115p	5004P	162p	5004	210p
152	82	50	2005	134p	5005P	216p	5005	268p
192	113	61	2006	235p	5006P	314p	5006	401p

VERO RANGE plastic boxes

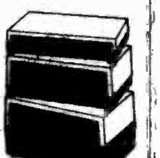
L	W	D		
72	47	25	21024	64p
120	50	35	21390	87p
180	110	55	21391	160p

G RANGE professional Instrument Cases

134	90	44	21089	£7.68
224	140	64	21090	£11.62
302	170	84	21091	£15.78

VEROBOX CASES

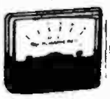
to give a completely professional finish to a much valued project.
ABS, light grey top; dark grey bottom + 2 anodised panels



L	O	H	TYPE	PRICE
205	140	40	21034	£4.62
205	140	75	21035	£5.02
205	140	110	21036	£6.54
180	120	39	21037	£4.11
180	120	65	21038	£4.40
180	120	90	21039	£4.69
155	85	39	21040	£3.31
155	85	60	21041	£3.31
155	85	80	21042	£4.30
125	65	30	21047	£2.48
125	65	39	21048	£3.16
125	65	50	21049	£3.56

METERS

Large range of types in stock; also probes, leads, accessories, etc.
PANEL MOUNTING in 50, 100, 500μA; 1, 5, 10, 50, 100, 500mA; 1A either model.

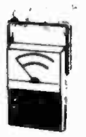


MU Range 50 × 45mm **£2.68**

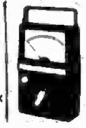
T Range 60 × 45mm **£5.95**

MULTIMETERS

NH56A NEW — 20KΩ/V AC/DC/-RES/dB in 23 ranges: 130 × 88 × 37mm **£11.20N**



YN360TR 20KΩ/V: AC/DC/R/dB/Transistor Test: in 21 ranges: 145 × 96 × 45mm **£16.45N**



SEMICONDUCTORS

1N914	03
1N914B	10
1N916	02N
1N4007	06
1N4148	03
1N5402	14
1N5407	18
2N697	23
2N706	18
2N930	20
2N1132	23
2N1302	110
2N1303	58
2N1304	62
2N1305	62
2N1306	80
2N1307	67
2N1308	147
2N1309	99
2N1599	100
2N1613	25
2N1711	25
2N1893	32
2N2218A	31
2N2219A	25
2N2222A	25
2N2369A	21
2N2484	25
2N2646	45
2N2904	26
2N2904A	25
2N2905A	25
2N3053	23
2N3054	55
2N3055	48
2N3405	64
2N3663	15
2N3702-11	08
2N3771	180
2N3794	21
2N3819	22
2N3820	40
3823	60
2N3904	15
2N3906	15
2N4036	46
2N4058-62	09
2N4124	25
2N4126	25
2N4284	30
2N4286	18
2N4289	23
2N4291	24
2N4292	21
2N4991	62
2N5062	32
2N5192	110
2N5195	106
2N5457	32
2N5458	32
2N5459	36
2N6050	380
2N6057	375
6F40	152
16F40	165
40HF40	225
40361	DIS
40362	65
40406	71
40408	95
40412	108
40430	100
40594	123
40595	123
40636	147
40673	145
A9903	16
AA113	13
AA116	9
AA117	13
AA118	9
AA119	9
AC126	25
AC127	25
AC128	25
AC151R	55
AC153K	20
AC176	25
ACY17	155
ACY18	120
ACY19	99
ACY20	90
ACY21	86
ACY39	170
ACY41	10
AD136	150
AD142	90
AD149	88
AD161	35
AD162	35
AF114	37
AF115	37
AF116	57
AF117	64
AF124 AF125	37
AF126	37
AF127	37
AF200	10
AF239	114
AF279	30
AFY12	204N
AFY16	327N
AFY180	310N
AFY18E	615N
AFY42	481N
AU106	240
AU111 (use AU116)	
AUY22	10.95
BO140	25N
BO146	30N
BO226	45N
B1906	38
BA379	25
BAS40-03	36
BAS70-03	41
BAT14-036	11.75
BB409	33
BC107A,B	16
BC108A,B,C	16
BC109B,C	18
BC121W	30N
BC122Y	100
BC126	20
BC125	20
BC140	25
BC141	30
BC147A	10
BC149	10
BC154	25
BC160	25
BC161	30
BC167A	09
BC167B	08
BC168A	09
BC168B	09
BC169B	09
BC169C	09
BC177B	16
BC178B	16
BC179B	18
BC182	09
BC182L	09
BC183	09
BC183L	09
BC184	09
BC184L	09
BC202Y	120
BC212	09
BC212L	09
BC213	09
BC213L	09
BC214	08
BC214L	09
BC238C	09
BC239C	09
BC258B	08
BC267B	16
BC300	32
BC301	24
BC303	30
BC327	16
BC328	11
BC337	14
BC338	11
BC413	09
BC414	09
BC477	24
BC546	10
BC547	09
BC548	09
BC549	09
BC550	10
BC556	10
BC557	09
BC558	09
BC559	09
BC560	10
BC879	38
BC880	43
BCY31A	157
BCY58	18
BCY70	18
BCY71	18
BCY72	18
BD130	45N
BD131	48
BD132	48
BD135	27
BD136	27
BD139	30
BD140	32
BD644	42N
BD679	62
BD680	64
BF115	35
BF167	25
BF173	25
BF177	25
BF178	25
BF244B	40
BF254	14
BF255	14
BF420	31
BF421	34
BF457	35
BF458	35
BF459	35
BF597	12N
BFR34A	84
BFR39-41	23
BFR79-81	23
BFT65	119
BFT66	192
BFX29	24
BFX84	24
BFX85	24
BFX87	28
BFX88	26
BFY50	24
BFY51	24
BFY52	24
BFY90	143
BR34	70
BR64	110
BRY39	45
BSX20	22
BSX26	22
BSX63	769N
BT106	147
BT108	136
BU105	170
BU124	85
BU208	180
BUX26	360N
BUX28	545
BUX81	744
BUX85	249
BUZ10A	478
BUZ15	12.27
BUZ20	523
BUZ23	787
BUZ24	12.50
BUZ32	625
BUZ33	844
BUZ41A	637
BUZ44A	9.67
BUZ45	12.76
BUZ48	18.94
BUZ50A	783
BUZ54A	21.43
BUZ80	739
BUZ83	11.29
BUZ83A	11.86
BUZ84A	12.75
BY164	48
C106D1	45
C0326	480N4
C0340	490N4
C407	17
C0546	126N1
C762	40
C1406	77
D4 clip for C1406 and E2506	10
D1046	88
E1110	76
E1210	76
E2506	154
EB383	20
MJ2955	90
MJE340	55
MJE2955	95
MJE3055	70
MPF102	40
MPS6531	40
MPS6534	42
MPSA12	36
MPSA63	38
NAS206S5	81
OA47	12
OA90	10
OA91	10
OA95	DIS
OA202	14
OC28	75
OC29	75
OC35	75
OC36	90
OC84	25
PM7A2	373
PN70	10
PN72	05
Q4006LT	104
Q4010LT	115
Q4025H	450
T2700D	189
T2800D	104
TAG3-400	100
TAG209-400	85
TAG209-600	130
TIC106D	48
TIC106M	55
TIC126D	64
TIC206D	54
TIC226D	61
TIC236D	98
TIC246D	105
TIP31A	36
TIP32A	36
TIP41A	45
TIP41C	60
TIP42A	45
TIP42C	60
TIP150	75
TIP2955	55
TIP3055	55
TIS43	50
U763	50
VN10KM	55
VN46AF	93
VN66AF	105
VN88AF	123
W02	25

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Type CK—1P/12 way, 2P/6 way, 3P/4 way, 4P/3 way **48p**; Min Toggles — S7101 SPDT **57p**; S7201 DPDT **80p**; S7301 3PDT **£1.64**; S7203 DPDT **96p**; Push Button min. 8531 make/8533 break **62p**; 8225 DPDT **£1.34.**
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2% Mullard metal film 5.1 ohms — 300K **5p each**, 10 of one value **40p**
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Quartz Into Pint Pot?

The world's first analogue quartz chronograph wristwatch has been introduced by Seiko. The biggest and most experienced watch house worldwide, Seiko is renowned for its innovative achievements having many world firsts to its credit, including the recent introduction of the first television watch (see ETI Digest, September 82). Until now quartz chronographs with digital readouts have been commonplace but the introduction of the Seiko Analogue Quartz Chronograph is the result of many years of research and development. It is an achievement which is thought to be far in advance of any other watch house. Four independent micro-step motors have been successfully miniaturized into a small wristwatch module and it is this fact that has made possible the development of this new analogue quartz chronograph. Micro technlogy has also played an important factor in terms of design; the watch itself is much thinner than conventional chronographs with mechanical movements.

Other impressive technical features of this new Seiko model include a chronograph with a 5/100th second capability, a split time measurement facility, the ability to record two consecutive finishes, a tachymeter, and a remaining time indicator as well as a tally counter. All three chronograph hands go round once for demonstration purposes, by simply depressing the buttons. Four different models, one of which is a Sports 100 watch (water resistant to 100 metres), will be available in the shops in May. Each model has a stainless steel case and bracelet and the range of watches offers a choice of different colour dials and prices vary between £110.00 and £140.00 each retail.

Shorts

● Anyone who fancies going back to school this summer is invited to attend the 1983 Electronic Systems Summer School at the University of Essex. Two courses are offered, 'Feedback and Communication Systems' and 'Digital and Computer Systems'. The school will run from Sunday evening, 10th July to Friday afternon, 15th July, and teachers wishing to obtain further detials of the courses should contact Mrs J. Mead, Dept. of Electrical Engineering Science, University of Essex, Colchester (telephone 0206 862286 ext. 2358).

● Or perhaps you want to find out more about computer based training, in which case you should contact Sue Punch of Mills and Allen Communications Ltd, 1-4 Langley Court, Long Acre, London WC2E 9JY (telephone 01-240 1307). They're holding a one-day course on CBT techniques and uses, followed by a two-day workshop on CBT and practical design. Dates are 23rd, 24th and 25th of March and the venue is in Central London.

● Can't imagine what's come over Motorola's PR people: their new development system based on the MC6809 processor, XDOS operating system and BASIC-M compiler has been named the EXORset 100. Nought out of 10 for good taste, gentlemen . . .

● As usual, we've received word of a number of catalogues this month: first off is one from Wavetek Electronics, the test and measurement equipment manufacturers. New products include a VHF frequency synthesiser, a 3.7-7.6 GHz microwave signal generator, and a cross channel spectrum analyser. Free copies of the 210-page catalogue are available from Wavetek's new sales and service office at Tag Lane, Hare Hatch, Reading, Berks. RG10 9LT (telephone 073522 2124).

● OK Industries UK Ltd have produced the second one; it's a new 16-page full colour brochure describing the range of Elrack terminal enclosures, lab racks and computer desks. Lots of the stuff is 19" rack-sized and, although constructed to industrial standards, most products in the range are suitable for the electronics amateur. OK Industries are at Dutton Lane, Eastleigh, Hants SO5 4AA (telephone 0703 610944).

● Finally the F.C. Lane Group have their 1982/83 catalogue out, which contains pots, fuses, resistors, ferrites, and a wide range of connectors and accessories, plus flat cable. Contact F.C. Lane Electronics Ltd, Slinfold Lodge, Horsham, West Sussex, RH13 7RN (telephone 0403 790661).

● The Blacksburg Group, Inc want to encourage as many radio amateurs and shortwave listeners as possible to use the newly-assigned 10 MHz (30 metre) band. Their Slinky Dipole (good grief!) can do the job but requires new tuning information, which Blacksburg are giving away free to any Slinky Dipole owner. Simply send your name, address, and two International Reply Coupons for your Tuning Chart. The address is PO Box 242, Blacksburg, Virginia 24060, USA.

● Got nothing booked for May 16-17th this year? Logical Solutions, Inc and Network Conferences are holding a seminar on the design for testability (what an awful word) of LSI/VLSI circuits, including components, subassemblies and systems. Full details from Network Conferences Ltd, Printers Mews, Market Hill, Buckingham, MK18 1JX (telephone 02802 5226).

● Had any wizard wheezes lately? A new book called "The Practical Guide for Pepple with a New Idea" will help you through the jungle that comprises the modern patent process. It also contains information about marketing your idea effectively, choosing trademarks etc etc. The book is available for £5.95 post paid from Laurence Shaw, George House, George Road, Edgbaston, Birmingham B15 1PG.

● Dragon 32 and Tandy TRS-80 colour computer owners will be pleased to hear that a new monthly magazine of USA origins and dealing exclusively with these computers is now available. A sample copy of "Rainbow" can be obtained by sending £1.95 plus a large 56p SAE to Elkan Electronics, Freepost, 11 Bury New Road, Prestwich, Manchester M25 6LZ (or ring 061-798 7613 — 24 hour service).

● A new company with an 80% British shareholding reckons that more than £400 million will be spent on constructing new cable TV networks in Britain by next year. Cable TV Construction Ltd will act as consultants and expects to create jobs for several hundred people.

● If you fancy interfacing your Commodore 64 or VIC 20 to a Centronics printer, Wego Computers of 22a High Street, Caterham, Surrey can sell you the necessary interface for your serial port. The device is completely compatible with the other port devices such as disc drives and draws its power from the printer. The cost is £79 plus VAT and the phone number is 0883 49235 if you want more information.

ETI

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5 precision wrenches in hinged plastic case. Sizes – 4, 4.5, 5, 5.5 and 6mm **£1.75**

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HEX KEY SET ON RING. Sizes 1.5, 2, 2.5, 3, 4, 5, 5.5 and 6mm. Made of hardened steel. HX/1 **£1.25**

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SX14	150	½ watt Resistors 22 ohm-2m2 Mixed	£1
SX15	100	1 and 2 watt Resistors 22 ohm-2m2 Mixed	£1

Paks SX12-15 contain a range of Carbon Film Resistors of assorted values from 22 ohms to 2.2 meg. Save pounds on these resistor paks and have a full range to cover your projects.
*Quantities approximate, count by weight.

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Guaranteed to save you money.

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BARGAINS

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LCD 10 MEGOHM INPUT IMPEDANCE
*3½ digit *16 ranges plus hFE test facility for PNP and NPN transistors *Auto zero, auto polarity *Single-handed, pushbutton operation *Over range indication *12.5mm (½-inch) large LCD readout *Diode check *Fust circuit protection *Test leads, battery and instructions included

Max indication	1999 or – 1999
Polarity indication	Negative only. Positive readings appear without + sign.
Input impedance	10 Megohms
Zero adjust	Automatic
Sampling time	250 milliseconds
Temperature range	– 5°C to 50°C
Power Supply	1 x PP3 or equivalent 9V battery
Consumption	20mW
Size	155 x 88 x 31mm

RANGES
DC Voltage 0-200mV
0-2-20-200-1000V Acc: 0.8%
AC Voltage 0-200-1000V
Acc: 1.2% DC Current 0-200uA
0-2-20-200mA 0-10 A Acc: 1.2%
Resistance 0-2-20-200K ohms
0-2 Megohms Acc: 1%
BI-PAK VERY LOWEST POSS PRICE
£35.00 each
LEATHER CASE FOR RE188m £2.50 each

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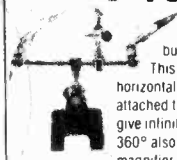
American Police type screamer powered from any 12-volt supply into 4 or 8 ohm speaker. Ideal for car burglar alarm, freezer breakdown and other security purposes. BP124 5 watt 12v max – Siren Alarm Module
£3.85
Order No BP124

The Third and Fourth Hand...



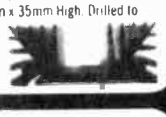
.... you always need but have never got 'until now. This helpful unit with Rod mounted horizontally on Heavy Base. Crocodile clips attached to rod ends. Six ball & socket joints give infinite variation and positions through 360° also available attached to Rod a 2½ diam magnifier giving 2.5 x magnification. Helping hand unit available with or without magnifier. Our Price with magnifier as illustrated ORDER NO. T402 **£5.50**
Without magnifier ORDER NO. T400 **£4.75**

SX52 6 Black Heatsink will fit TO-3 and TO-220. Ready drilled. Half price value £1

SX53 1 Power finned Heatsink. This heatsink gives the greatest possible heat dissipation in the smallest space owing to its unique staggered fin design, pre drilled TO-3 Size 45mm square x 20mm high 40p

SX54 TO-66 size 35mm x 30mm x 12mm 35p

SX55 1 Heat Efficiency Power Finned Heatsink 90mm x 80mm x 35mm High. Drilled to take up to 4 x TO-3 devices £1.50 each



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FB4	2	14 x 4"	110	£2.00

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NPN like 2N3055 – but not full spec
100 watts 50V min.
10 for £1.50 – Very Good Value
100s of uses – no duds
Order No. SX90

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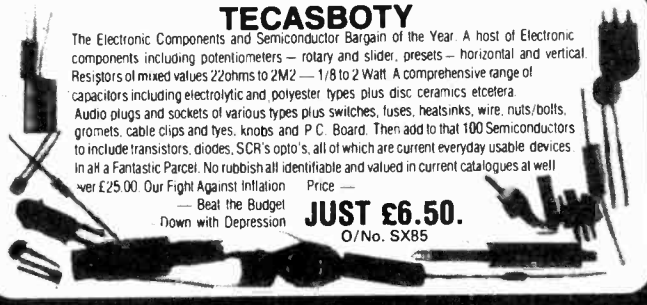

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ZX81 MUSIC BOARD

There have been a great many commercial and hobbyist designs for ZX81 peripherals, but we feel this one is something special. Full software listings will be given to help you use the board and the price is low. Design and development by M. P. Moore.

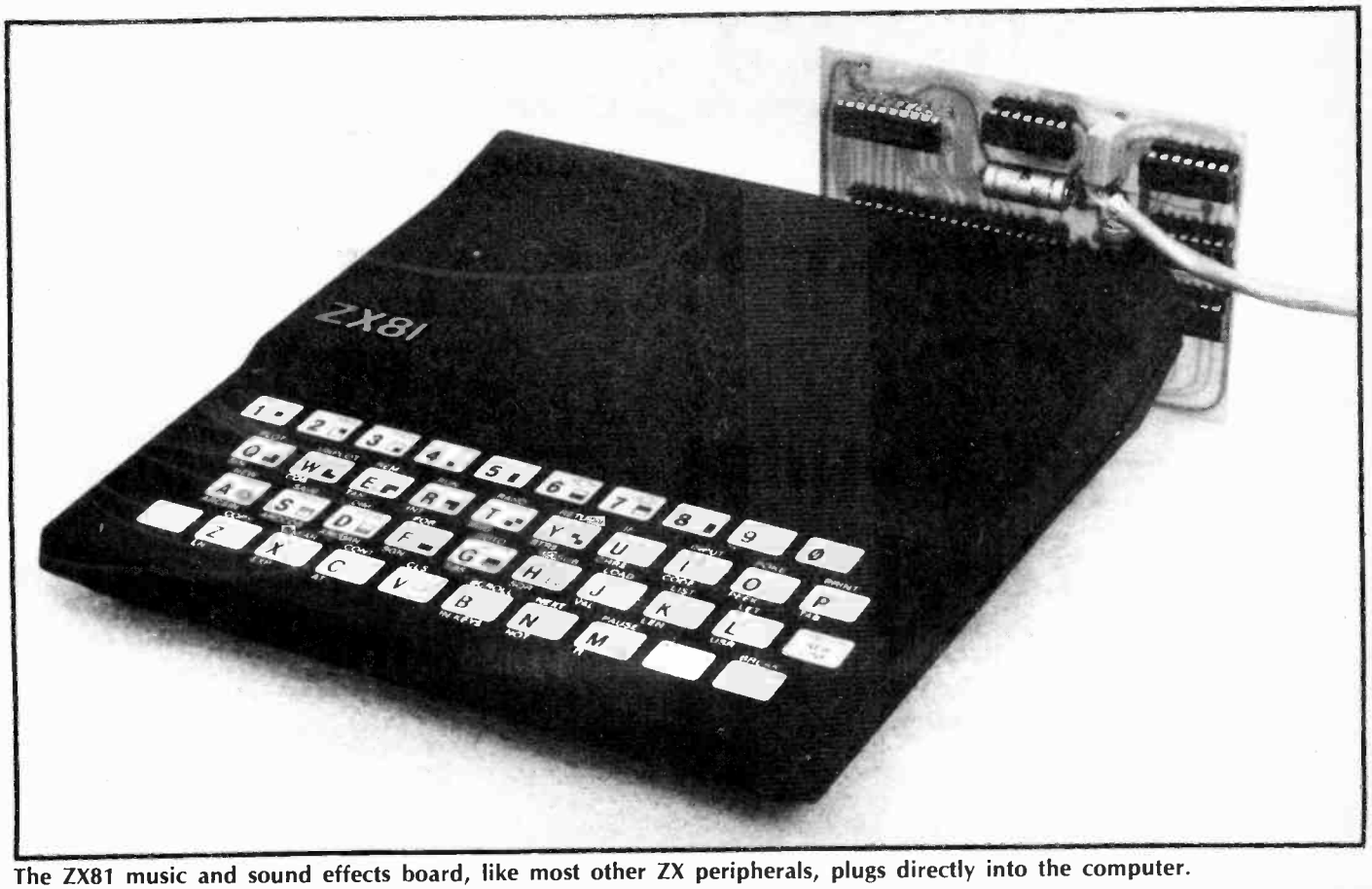
Give your space invaders program real 'zapp' — this add-on board enables you to hear those little green monsters being blasted away. Plug in the board, load the software cassette, and with two instructions you have a wide range of on-board sounds for your computer games; or you can copy music for your ZX81 to play, or devise your own sound effects for use in your own programs. You can also mix your own sound effects with the on-board sounds if you wish.

The unit is a sound generator with a fusible-link memory programmed with sounds varying from gunshots to spaceships, and with a basic octave of notes from which a range of seven or more octaves of music is obtained. When used with the software supplied it will bring ZX81 games to life with startling realism. The board will produce sounds with the basic 1K ZX81 but its full potential is realised with a 16K expansion, when the music program can provide a completely new use for those who are wondering what to do with their ZX81 now they have it.

A complete kit of parts is available (see Buylines), which also includes a comprehensive user's manual and software cassette. A demonstration cassette containing on-board sounds and music generated by the add-on sound board is available at an all-inclusive price of 95p. Petron Electronics have been good enough to grant us permission to publish both their PCB design and the complete software listings, including the PROM hex dump, to satisfy those diehard readers who insist on doing everything themselves. However, given the low price of Petron's kit, which contains all the hardware required plus documentation, we think that this is the best way to go for cost-effectiveness, ease of construction and convenience.

Construction

All components in the circuit are mounted on a single-sided PCB (see overlay): IC sockets are supplied for all ICs. Two screened leads provide the connection from the PCB to your amplifier; all other connections to the board are made via an edge connector which plugs straight into the back of the ZX81



The ZX81 music and sound effects board, like most other ZX peripherals, plugs directly into the computer.

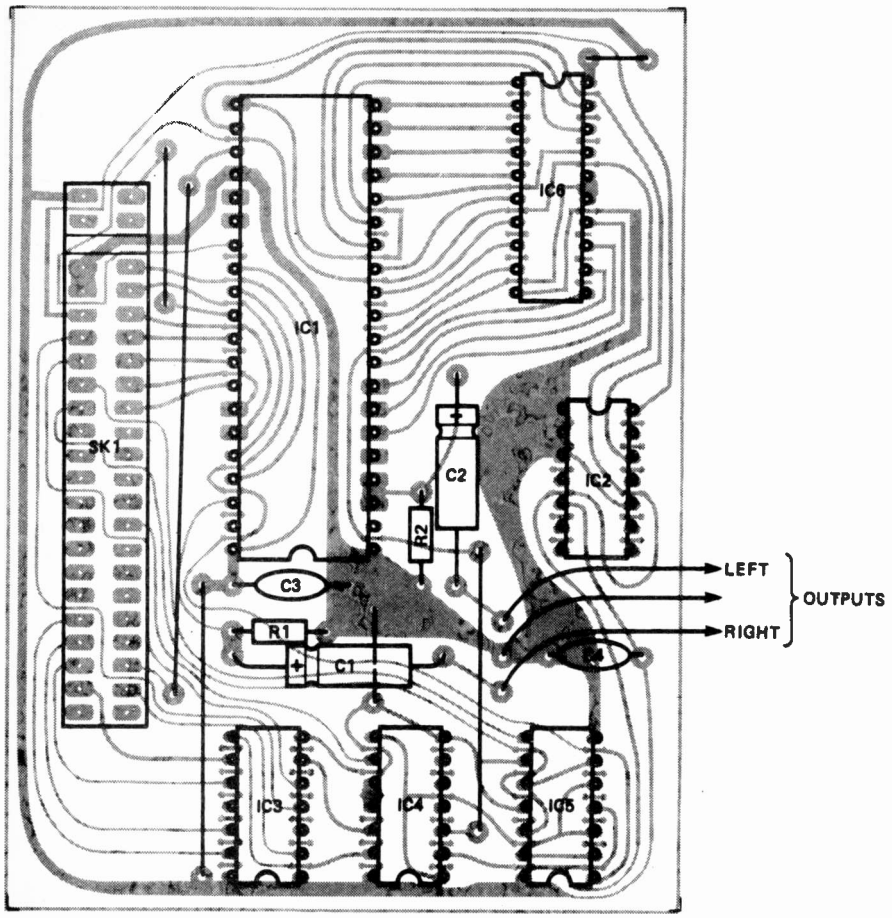


Fig. 1 Component overlay for the ZX81 sound board.

PARTS LIST

Resistors (all ¼W, 5%)	
R1, 2	1k2
Capacitors	
C1, 2	100u 16 V axial electrolytic
C3, 4	100n polyester
Semiconductors	
IC1	AY-3-8910
IC2	74LS93
IC3	74C20
IC4	74C32
IC5	74C02
IC6	TBP28L22N

Miscellaneous
PCB; edge connector; IC sockets; two off phono plugs; 2 m of screened cable.

BUYLINES

Petron Electronics supply a full kit of parts for the project. The kit includes the PCB and all components, and comes complete with a comprehensive user's manual and software cassette. The kit price is £24.05 all inclusive. The board is also available ready-built, together with manual and cassette, for £29.95. A demonstration cassette is available for 95p all inclusive. The manual may be purchased separately for £1.25, refunded upon subsequent purchase of a kit. Petron Electronics may be found at 1 Courtlands Road, Newton Abbot, Devon.

(or 16K RAM pack if used).

First of all solder the six IC sockets and then the six links: some of these are close to each other or to other components and the use of insulated wire is recommended. Now solder resistors R1 and R2 — these resistors can be of any value between 1k0 and 1k8. Solder the electrolytic capacitors C1 and C2, taking care to mount them the right way round (see overlay), and then capacitors C3 and C4. Finally, carefully insert and solder the edge connector leaving a gap of approximately 7 mm between the connector and the PCB. The pin corresponding to 9 V on the connector is not required and, for safety purposes, has been cut. Now carefully check all your soldered joints, preferably with a magnifying glass, and make sure that there are no bridges across any of the tracks.

If the board is to be used with a stereo amplifier, cut the length of screened cable supplied in half and solder the inner cores to one end to the left and right outputs, and connect the outer cores (screen) to the point marked GND. Take care to insulate these wires so that they will not short across other component leads. If you wish to use the board with a mono amplifier, connect a wire link between the two outputs and to this link connect the inner core of one of end of the screened cable, taking the screen to 0 V and insulating the cable as before. Connect the phono plugs (or one of them if you are using a mono amplifier) to the other end of the screened cable.

Now, carefully checking the orientation of the ICs, insert them into the IC sockets. Note that IC2 and IC6 are mounted in the opposite direction to the other ICs. With your ZX81 switched *off*, carefully plug the board into the back of the ZX81. If you have a 16K RAM pack, plug this on *first:* the sound board will plug onto the back of your RAM pack. Switch on your ZX81 and wait for the inverse K prompt to appear on your screen.

On-Board Sound Program

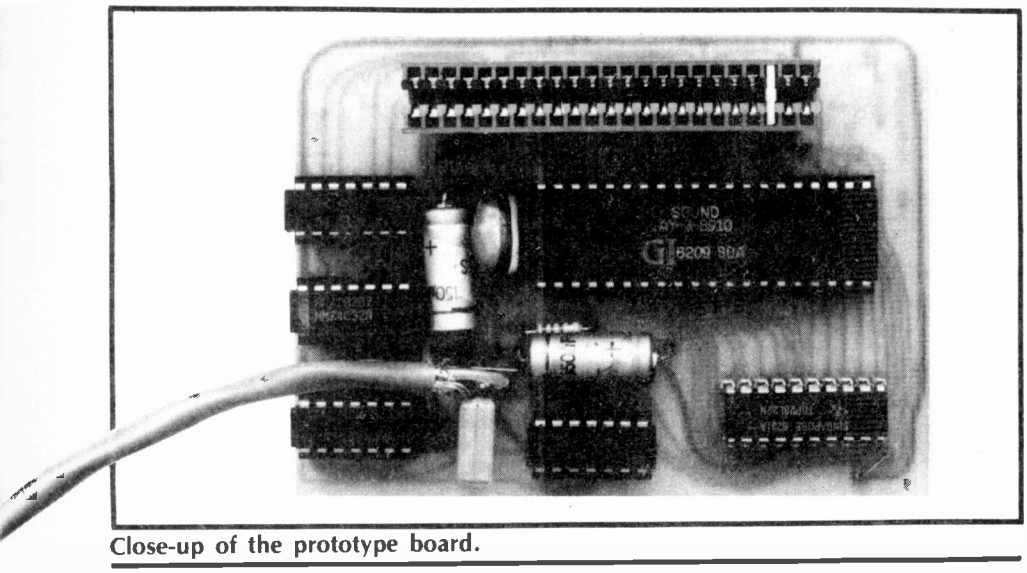
This program enables you to include the on-board sounds listed in Table 2 in your own programs. To use these sounds all you have to do is to load the first short program from the software cassette and connect up your amplifier, keeping the volume fairly low. The following program will allow you to review the range of principal on-board sounds available before incorporating them in your own programs.

```
10  PRINT "SOUND NO.?"
20  INPUT S
30  POKE 16531,S
40  RAND USR 16514
50  CLS
60  GOTO 10
```

In order to run this program type **GOTO 10.**

The computer will now ask you the number of the sound you wish to hear: **SOUND NO. ?** As an example, type **153 NEWLINE.** The computer will repeat this question after each sound. A continous sound (eg helicopter) must be silenced by typing 0 or another sound number.

In order to use these sounds in your own programs, enter your program without altering line 1 of program "S". At each point in your program where you require a sound to be generated, you simply include the following program lines:-



Close-up of the prototype board.

TABLE 1

BC1	BDIR	FUNCTION
o	o	INACTIVE
0	1	WRITE TO PSG
1	0	READ FROM PSG
1	1	LATCH ADDRESS

EPROM DATA

00	00	00	00	00	00	00	00
00	00	00	00	00	00	1F	07
10	10	10	FF	28	09	69	00
00	3B	00	00	10	FF	32	08
96	02	C8	02	64	02	0F	00
10	10	10	3C	00	08	00	32
03	0F	00	10	10	10	3C	00
08	07	10	10	10	FF	05	09
07	08	10	10	96	03	08	07
10	00	10	FF	0C	0F	BE	00
BE	00	BE	00	00	38	10	10
10	00	01	09	5F	00	5F	00
5F	00	00	38	10	10	10	00
01	09	2F	00	2F	00	2F	00
00	38	10	10	10	00	01	09
17	00	17	00	17	00	00	00
10	10	10	00	03	09	19	00
32	00	41	00	1E	00	0A	0A
0A	6E	00	6E	00	00	00	09
10	0C	0F	10	96	03	08	1F
07	10	10	10	FF	64	09	5A
01	5A	01	5A	01	00	38	0F
0F	0F	05	01	05	01	05	01
00	38	10	10	10	00	19	09
FA	03	00	00	03	05	10	0A
10	FF	01	0C	A0	01	64	01
96	00	0F	30	10	10	10	32
02	09	FF	3F	10	10	10	FF
32	08	5C	0F	70	0E	A0	0D
DC	0C	28	0C	28	0C	68	0B
D2	0A	46	0A	9A	09	22	09
22	09	A0	08	28	08	AE	07

PROGRAM 'S'

```
1       REM (Our machine code).

Machine code at line 1:
3E 07 D3 FF 3E 78 D3 F7
21 B4 40 E5 01 FB 0E C5
16 xx 3E 0E D3 FF 7A D3
F7 14 3E 0F D3 FF ED A2
20 F0 C1 E1 16 00 7A D3
FF 5E 7B D3 F7 14 10 F5
C9 xx xx xx xx xx xx xx
xx xx xx xx xx xx xx
```

POKE 16531, x
RAND USR 16514

where x is the number of the sound required from table 2.

The sound POKEd to 16531 remains the same until changed. Therefore, if you wish to repeat the same sound, there is no need to repeat **POKE 16531,x** — all you need to do is repeat the line **RAND USR 16514.**

Fast repetition of single sounds can be used to give a different effect. For example, the following program uses the rifle shot (sound 50) to generate a machine gun sound:

```
70   POKE 16531,50
75   FOR D=1 TO 40
80   RAND USR 16514
85   PAUSE 1
90   NEXT D
```

Now type **GOTO 70** and the computer will generate a burst of machine gun fire.

Table 2 gives the principal sounds that may be obtained, but there are many other interesting sounds which you can find by experimenting with other numbers not listed in this table.

HOW IT WORKS

IC6 is a fusible-link read-only memory (PROM) programmed with the data for all the on-board sounds and a basic octave of notes for music. This memory is accessed through the ports on IC1.

IC1 is a programmable sound generator (PSG), an AY-3-8910 which can be programmed to generate a wide range of sounds. Once data is written to this chip it produces and maintains the sound without continuous CPU maintenance, thus making it ideal for use with computer programs.

The PSG has three analogue outputs: outputs A and B are connected directly together and, via C1, connect to one channel of your amplifier; output C is connected via C2 to the other amplifier channel. The board will, therefore, give a dual image effect when used with a stereo amplifier. If you wish to use a mono amplifier, the analogue output C is connected directly to A and B.

IC3 and IC4a are used as an address decoder: the output of IC4a will be logic 0 when address lines A0, A1 and A4 - A7 are 1; $\overline{M1}$ must also be logic 1. IC4b is used to provide a chip select signal for the PSG only when the Input/Output request ($\overline{IORQ}$) is at logic 0. Thus the output of IC4b will be 0 only when a read or write operation on the PSG is to be performed. Whenever the output of IC4b is logic 1, the outputs of IC5c and IC5d will be 0, BC1 aand and BDIR will both be 0, and the PSG will be in the inactive state: see Table 2. (Since whenever it is deselected the 'inact' signal is sent, it is not necessary for the ZX81 program to send 'inact' to the PSG.)

IC5a and IC5b are used, together with IC5c and IC5d, to provide the necessary combinations of 0 and 1 for BC1 and BDIR. The output of IC4c drives the fusible-link PROM chip select input: this is to minimise the possibility of data bus contention between the PSG and the PROM should PSG port D accidentally be programmed as an output port, since IC4c output will only be 0 during a PSG read cycle.

The maximum clock frequency to the PSG is 2 MHz. IC2 is a low power Schottky version of the 7493 counter and is used here to divide the ZX81 clock frequency by 2.

Next month we will conclude this project by giving full listings and explanations of software to play up to 833 chords of music; to devise your own sound effects; and to mix your effects with the on-board sounds.

TABLE 2

Sound N	Description	Continuous?	Sound N	Description	Continuous?
0	Silence	—	92	Mid blip	No
8	Cannon fire	No	106	High blip	No
9	Pistol shot	No	204	Musical blip	No
50	Rifle shot	No	57	Steam engine	Yes
64	Missile	No	145	Steam engine with whistle	Yes
18	Sonar	Yes	167	Train horn lower note	Yes
153	Explosion	No	178	Train horn upper note	No
190	Helicopter	Yes	32	Propellor aeroplane	Yes
28	Fog horn	Yes	39	Jet plane on the ground	Yes
29	Fog horn	Yes	134	Jet plane flying	Yes
21	Compressor	Yes	52	Mechanical hammer	Yes
99	Waterfall	Yes	49	UFO	Yes
101	Waterfall	Yes	131	UFO	Yes
121	Low bong	No	213	UFO	Yes
33	Mid bong	No	214	UFO	No
45	High bong	No	231	UFO	Yes
78	Low blip	No			

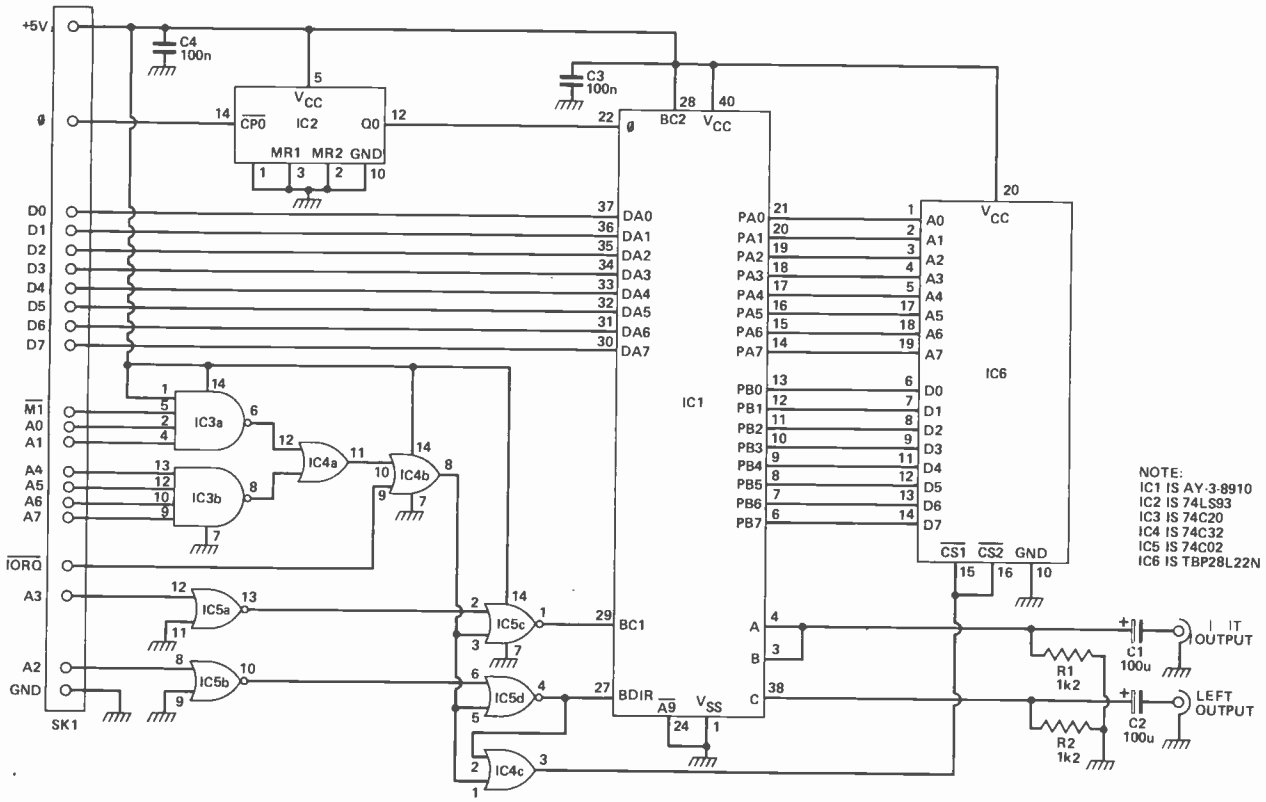
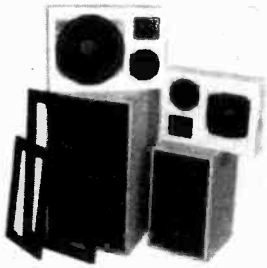


Fig. 2 Complete circuit diagram for the ZX81 sound board.

ETI

MULLARD SPEAKER KITS



Purposefully designed 40 watt R.M.S. and 30 watt R.M.S. 8 ohm speaker systems recently developed by MULLARD'S specialist team in Belgium. Kits comprise **Mullard** woofer (8" or 5") with foam surround and aluminium voice coil. **Mullard** 3" high power domed tweeter. **B.K.E.** built and tested crossover based on Mullard circuit, combining low loss components, glass fibre board and recessed loudspeaker terminals. SUPERB SOUNDS AT LOW COST. Kits supplied in polystyrene packs complete with instructions.

8" 40W system — recommended cabinet size 240 x 216 x 445mm
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OMP 80 LOUDSPEAKER

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Supplementary parts for 18V D.C. power supply (transformer, bridge rectifier and smoothing capacitor) **£3.50.**

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- Controls loads up to 1KW
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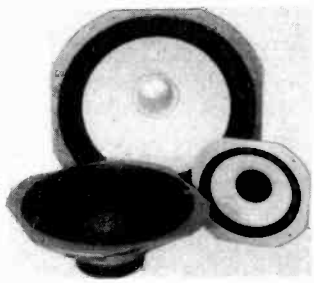
16 way numeric keyboard Standard keyboard providing 0-9 and A-F functions.
Size: 100mm x 100mm x 2mm. Price: **£5.36 + 36p p&p**

Alpha Numeric Keyboard Full size 55 key non encoded keyboard with the commonly required functions in a Qwerty array. Matrix output via a 16 pin DIL socket.
Size: 350mm x 100mm x 2mm. Price: **£13.99 + 50p p&p**

LOUDSPEAKERS



15" 100 watt R.M.S. (HI-FI, P.A., DISCO, BASS GUITAR) Die cast chassis, 2" aluminim voice coil, white cone with aluminium centre dome. 8 ohm imp., Res. Freq. 20Hz., Freq. Resp. to 2.5KHz., Sens. 97dB (As photograph). **Price: £32.00** + £3 carriage.
12" 100 watt R.M.S. (HI-FI) Die cast chassis. 2" aluminium voice coil. Black cone. 8 ohm imp., Res. Freq. 20Hz., Freq. Resp. to 4.5KHz. Sens. 95dB. (As photograph). **Price: £23.50** + £3 carriage.
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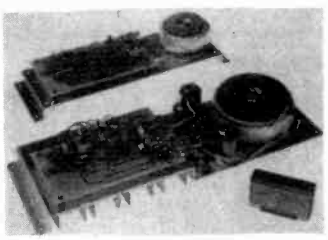

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T.H.D.: Less than 0.1%
Supply: 240V 50Hz
Sizes: OMP 100 360 x 115 x 72mm
OMP 300 460 x 153 x 66mm
Prices: OMP 100 **£31.50 each + £2.00 P&P**
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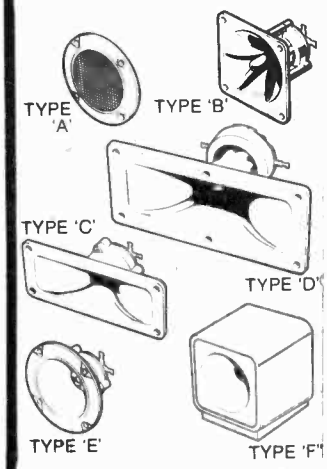
Join the Piezo revolution. The low dynamic mass (no voice coil) of a Piezo tweeter produces an improved transient response with a lower distortion level than ordinary dynamic tweeters. As a crossover is **not** required these units can be added to existing speaker systems of up to 100 watts (more if 2 put in series). **FREE EXPLANATORY LEAFLETS SUPPLIED WITH EACH TWEETER.**



TYPE 'A' (KSN2036A) 3" round with protective wire mesh, ideal for bookshelf and medium sized Hi-fi speakers. **Price £3.45 each.**

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Build a quality 60watt RMS system 8ohms

Build a quality 60 watt R.M.S. system.

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★ **3-way crossover 6dB/oct 1.3 and 6KHz**
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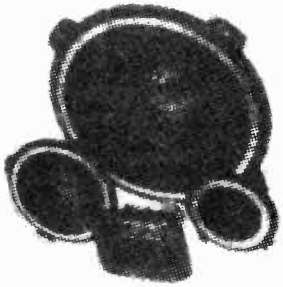

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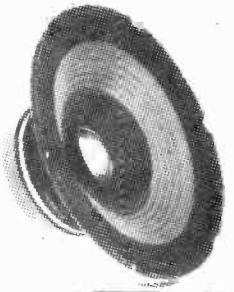

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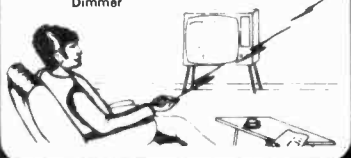

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Based on the ZN1034E Timer IC this kit will switch a mains load on (or off) for a preset time from 20 mins. to 35 hrs. Longer or shorter periods may be realised by minor component changes. Max. load 1KW. **£5.00**

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Based on the SAB0600 IC the kit is supplied with all components, including loudspeaker, printed circuit board, a pre-drilled box (95 × 71 × 35mm) and full instructions. Requires only a PP3 9V battery and push-switch to complete. AN IDEAL PROJECT FOR BEGINNERS. Order as XK102
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Based on ZN414 IC, kit includes PCB, wound aerial and crystal earpiece and all components to make a sensitive miniature radio. Size: 5.5 × 2.7 × 2cms. Requires PP3 9V battery. IDEAL FOR BEGINNERS **£5.00**

COMPONENT PACKS

PACK 1	650 Resistors 47 ohm to 10 Mohm — 10 per value £4.00
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PACK 3	60 Polyester Capacitors 0.01 to 1μF/250V — 5 per value £5.55
PACK 4	45 Sub-miniature Presets 100 ohm to 1 Mohm — 5 per value £2.90
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This new design is based on the ICL7126 (a lower power version of the ICL7106 chip) and a 3½ digit liquid crystal display. This kit will form the basis of a digital multimeter (only a few additional resistors and switches are required—details supplied), or a sensitive digital thermometer (−50°C to +150°C) reading to 0.1°C. The basic kit has a sensitivity of 200mV for a full scale reading, automatic polarity indication and an ultra low power requirement—giving a 2 year typical battery life from a standard 9V PP3 when used 8 hours a day, 7 days a week.
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This value-for-money kit features a bi-directional sequence, speed of sequence and frequency of direction change, being variable by means of potentiometers and incorporates a master dimming control **£14.60**

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A lower cost version of the above featuring unidirectional channel sequence with speed variable by means of a pre set pot. Outputs switched only at mains zero crossing points to reduce radio interference to a minimum.
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REMOTE CONTROL KITS

MK6 SIMPLE INFRA RED TRANSMITTER
Pulsed infra red source complete with hand-held plastic box. Requires a 9V battery. **£4.20**

MK7 INFRA RED RECEIVER
Single channel, range approx. 20ft. Mains powered with a triac output to switch loads up to 500W at 240V ac. **£9.00** (RC500K –Special Price for MK6 and MK7 together **£12.50**

MK8 CODED INFRA RED TRANSMITTER
Based on the SL490, the kit includes all components to make a coded transmitter and only requires a 9V (PP3) battery and keyboard. 8 x 2 x 1.3cms **£5.90**

MK10 16-WAY KEYBOARD
For use with MK8 and MK18 to generate 16 different codes for decoding by the ML928 or ML926 receiver (MK12) kit. **£5.40**

MK11 10-Channel + 3 Analogue o/p IR Receiver
Based on ML922 decoder IC. Functions include on/standby output, toggle, control of volume, tone and lamp brightness. Includes its own mains supply. **£12.00**

MK12 16-CHANNEL IR RECEIVER
For use with MK8 kit with 16 on/off outputs, which with further interface circuitry, such as relays or triacs, will switch up to 16 items of equipment on or off remotely. Latched or momentary outputs – please specify when ordering. Includes its own mains supply. **£11.95**

MK13 11-WAY KEYBOARD For use with MK8, MK18 and MK11 kits. **£4.35**

MK16 Mains Powered IR Transmitter
Mains powered for continuous operation – single channel, for applications such as burglar alarms, automatic door openers, etc. Range approx. 6 ft. **£2.50**

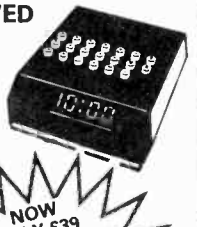
MK17 12V d.c. IR RECEIVER
For use with MK6 or MK16. Relay output with DP 3 Amp change-over contacts, may be used as latched, momentary or "break beam" receiver. Operates from 6-13V d.c. **£9.50**

MK18 HIGH POWER IR TRANSMITTER
Similar to MK8 but with range of approx. 60ft. **£6.20**

Ancillary Kits : MK2 Solid State Relay
Opto-isolated with zero voltage switching. No. triac supplied. **£2.60**

MK15 DUAL LATCHED SOLID STATE RELAY
Comprises 2 x solid state relays and latch for use with momentary version of the MK12. 2 output triacs required (not supplied). **£4.50**

THE MULTI-PURPOSE TIMER HAS ARRIVED



Now you can run your central heating, lighting, hi-fi system and lots more with just one programmable timer. At your selection it is designed to control four mains outputs independently, switching on and off at pre-set times over a 7 day cycle, e.g. to control your central heating (including different switching times for weekends), just connect it to your system programme and set it and forget it—the clock will do the rest.

FEATURES INCLUDE:-
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DESIGNER'S NOTEBOOK

Who needs to bother winding miles of wire onto a bobbin when high voltages can be generated with some inverters and a handful of diodes and capacitors? Rory Holmes shows how it's done.

In this month's first Designer's Notebook we shall be looking at a variety of interesting voltage multiplier circuits that can be built using ordinary CMOS gates and common-or-garden 1N4148 signal diodes. DC-to-DC converters for a number of applications became possible by simply driving voltage multiplier chains with an AC clock signal, again implemented with CMOS gates. The initial supply voltage can be multiplied both positively and negatively, to give for example a split rail op-amp supply from a standard 5 V TTI supply. Negative and positive voltage references used in analogue-to-digital conversion and other signal conditioning circuits can also be generated, as can general purpose high voltage bias rails.

By using a novel 'chain' of inverter gates to independently drive each node of a diode-capacitor ladder, some rather unique circuits result.

Chain Reaction

First, let's look at the usual multiplier circuits shown in Fig. 1a. These are normally used with rectifier-type diodes, low frequency AC inputs (sine waves) from transformers, and electrolytic smoothing capacitors. At first glance there seems to be no common pattern between them, and little similarity to the multiplier chains used in TVs and other EHT power supplies.

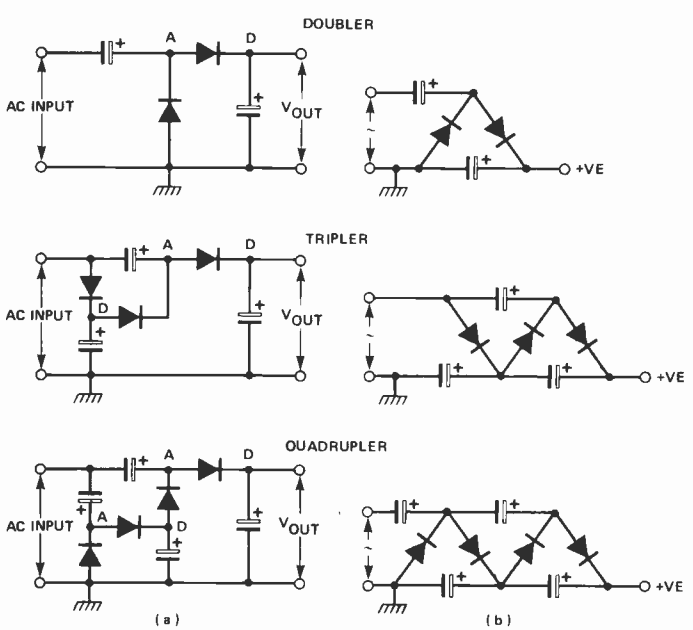

Fig. 1 Standard voltage multiplier circuits.

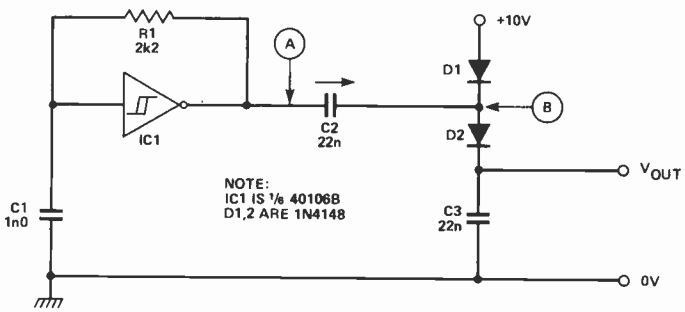

Fig. 2 A CMOS doubler circuit.

However, in all cases the AC input waveform is fed via capacitors to appear at those circuit junctions marked 'A' in Fig. 1a, while those junctions marked 'D' will maintain a steady DC potential relative to the earth point. We can thus redraw the circuits by connecting up the capacitors in two series chains (assuming their values are altered accordingly) and still preserve the same circuit action. One chain carries the AC signal, while the other accumulates the DC voltage shifts. Figure 1b shows these redrawn circuits, which now appear as extensions of the standard ladder network. The doubler, of course, remains in its original form since it only has one set of capacitors.

Starting with the doubler, we can build a very simple DC-to-DC converter using one CMOS gate as shown in Fig. 2. The Schmitt inverter gate is configured as a square wave oscillator running at about 100 kHz — the multiplier capacitors C2 and C3 will therefore have a low impedance at this frequency, which is also within the switching speed capability of the 1N4148s. For this reason, rectifier diodes such as the 1N4001, which have much slower switching speeds, cannot be used in these circuits.

The oscillator output at point 'A' will therefore be switching between the 0 V and 10 V supply levels. When the output is at logic low, capacitor C2 will charge up positively (in the direction of the arrow) via D1. D2 is reverse biased and so effectively out of circuit. When point 'A' goes high to +10 V the positive end of C2 at 'B' will be raised to +20 V. This reverse biases D1 and allows C3 to charge up through D2. The voltage on C3 is thus maintained at about +20 V less two diode drops (ie at 18V6) as the cycle repeats itself. This is known as a diode charge pump.

Building An Extension

This principle can be extended using exactly the same chainlike structure as illustrated in the positive and negative multipliers of Fig. 3. In both cases the inverter gates are cascaded and driven from a square wave

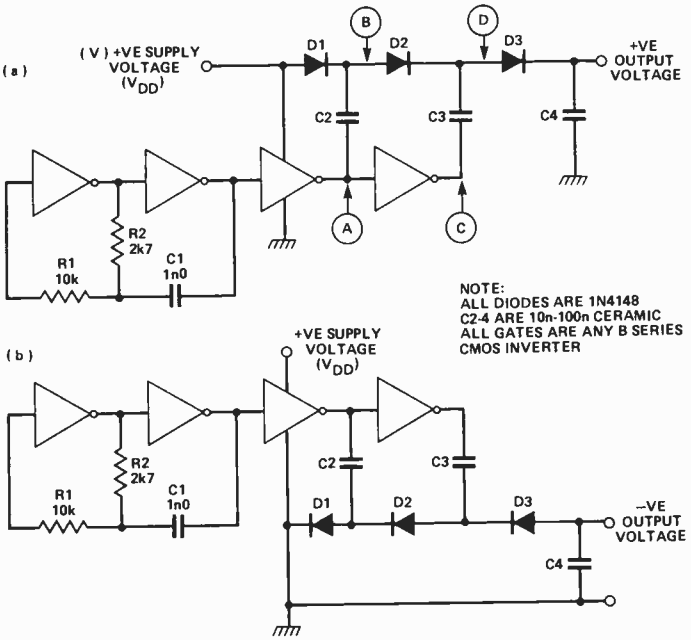

Fig. 3a A two-stage positive voltage multiplier (multiples by +3). b. A two-stage negative voltage multiplier (multiplies by −2).

oscillator at around 100 kHz. Each inverter gate contributes its own output current (a maximum of around 2 mA) via the capacitors into the multiplier chain: because of this, the available output current will always be the same no matter how many times the voltage is multiplied (two times in this case).

The positive multiplier output of Fig. 3a includes the initial positive supply potential, and so generates three times this voltage less the three diode drops of 0V7 each. The negative multiplier of Fig. 3b, on the other hand, is referenced to the ground rail, giving −2 times the voltage (again less the diode drops).

As mentioned before, all the diodes are 1N4148s: the multiplier capacitors C2-4 are all non-critical and may be anything from 10nF to 100nF. C4 may be a polarised tantalum capacitor of a few microfarads to provide further smoothing. Any type of CMOS gate which can be connected as an inverter could be used, as well as all the standard inverters, though the 4049B hex inverter offers slightly more output current. It's also possible to use the 74C series types such as the 74C04 or 74C14. Pin-outs for these chips are given in Fig. 4 and not on any of the circuit diagrams, since they differ from type to type.

The oscillator implementation and its frequency are also non-critical; you could experiment with anything

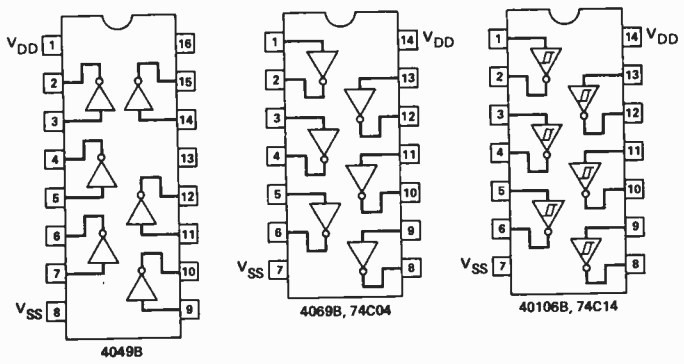

Fig. 4 Pin-outs for the standard hex inverter packages which may be used in the circuits given in this article.

from several kilohertz to several hundred kilohertz. Remember, though, that as the frequency decreases, the impedance for a given capacitor value will increase, so increasing the impedance of the multiplier output.

Table 1 lists out the different voltages you can expect from different chain lengths and supply voltages, based on the circuits of Fig. 3. The number of stages refers to the number of capacitors that are actively driven from inverter outputs. Using this table it becomes very easy to design a generator for any voltage requirement; the output voltage could be clamped to the exact level required using an ordinary zener diode regulator. But remember there isn't much current available, and as the output is loaded the voltage will decrease due to the supply impedance. The higher supply voltages will generally provide more output current.

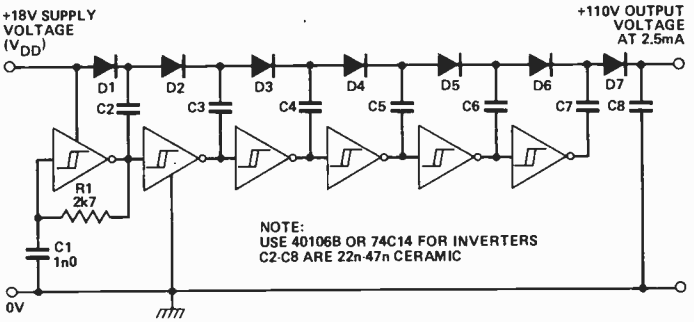

Fig. 5 A 110 V supply using one hex inverter IC.

As an example, Fig. 5 shows a longer multiplier designed to give 110 V and built using only one hex inverter IC, of the Schmitt trigger type (40106B). Using ceramic capacitors, this circuit could be built to a very small size.

Operating Principles

How do these multipliers actually work — the doubler circuit of Fig. 2 is straightforward, but what about the longer types? Voltage multiplier explanations are usually notoriously difficult to follow, let alone understand, and

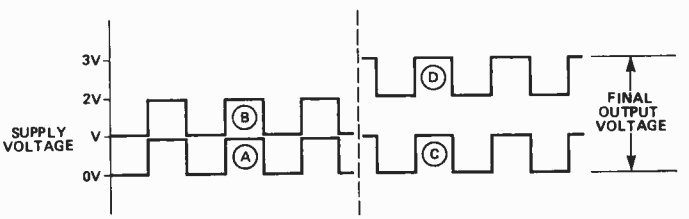

Fig. 6 Waveforms for a two-stage positive multiplier (idealised for clarity with diode drops ignored).

we shall therefore adopt a more graphic approach. If we measure the voltages at the lettered points in Fig. 3a and plot them against time, we get the waveforms shown in Fig. 6. These waveforms have been idealised for clarity — no account has been taken of the voltage drops due to the diodes in the circuit. From these it can be seen that the voltage across C2 (the difference between the waveforms A and B) is a constant 1V, where V is the supply voltage, while that across capacitor C3 (between points C and D) is 2V. We also know that the final output voltage across C4 is 3V. Moving down the chain towards the final output, then, we find that each capacitor maintains a DC charge which increases in integer multiples of the supply voltage. How so?

Consider capacitor C2 in Fig. 3a. At power-on it is discharged but when point A switches low, it charges up

TABLE 1

OUTPUT POLARITY / NO. OF STAGES	CMOS SUPPLY VOLTAGE 5V +	5V −	10V +	10V −	18V +	18V −
1	8.6	3.6	18.6	8.6	34.6	16.6
2	12.9	7.9	27.9	17.9	51.9	33.9
3	17.2	12.2	37.2	27.2	69.2	51.2
4	21.5	16.5	46.5	36.5	86.5	68.5
5	25.8	20.8	55.8	45.8	103.8	85.8
6	30.1	25.1	65.1	55.1	121.1	103.1
7	34.4	29.4	74.4	64.4	138.4	120.4

Table relating supply voltage and number of stages to the (unloaded) output voltage, for positive and negative output multipliers based on the circuits of Figs. 3a and 3b and allowing 0V7 for each diode drop.

to the supply voltage via D1 (neglecting diode drops). Point B is therefore at supply voltage. When point A switches high, then, point B is raised to twice the supply voltage. Point C must be at zero volts since it is the inverse of point A, so current flows via D2 (which is now forward biased) from point B into C3 until C3 is charged up to the voltage at B (ie twice supply). The next clock pulse takes point A low, so point B is at supply less the voltage that has leaked into C3, and C2 is topped up via D1 again. Meanwhile point C has switched to supply voltage, so point D is now at three times supply and D2 is reverse biased, preventing C3 from discharging back into C2. C3 can discharge into C4 via D3, however, so the voltage across C4 is maintained at three times supply.

It should now be clear that no matter what the length of the multiplier, each capacitor in the chain maintains a steady DC charge which equals that on the previous one plus the supply voltage, and each capacitor tops up the next one in the chain on each alternate half-cycle. Figure 7a, for example, shows five stages of a multiplier chain driven by a square wave signal, while Figs. 7b and 7c use a waveform to represent the voltage levels at each capacitor node for each half of the cycle. The direction and voltage of the DC charges on each capacitor is also shown — remember these are constant as shown by the graph of Fig. 6.

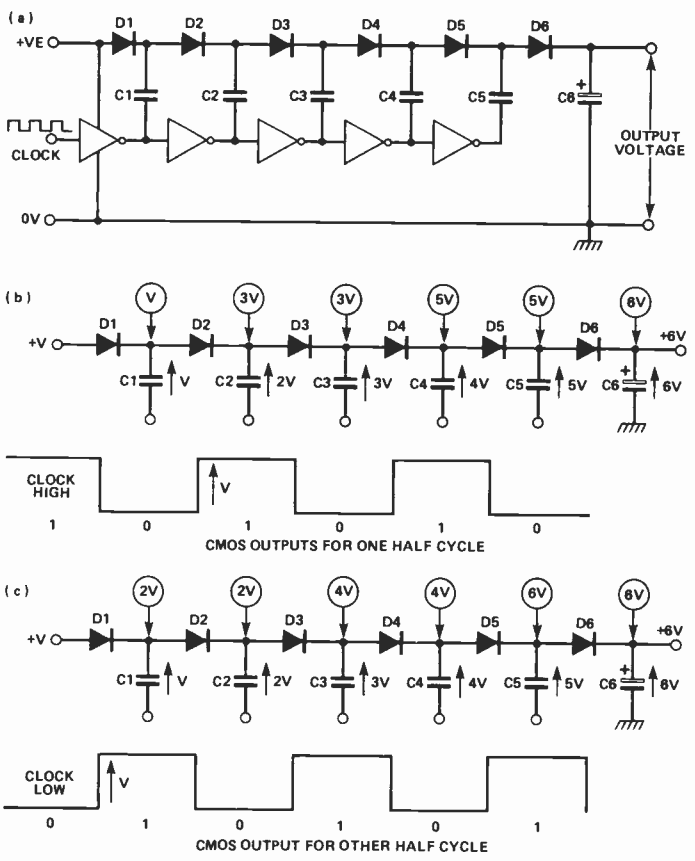

Fig. 7 How multiplier voltages accumulate down the chain.

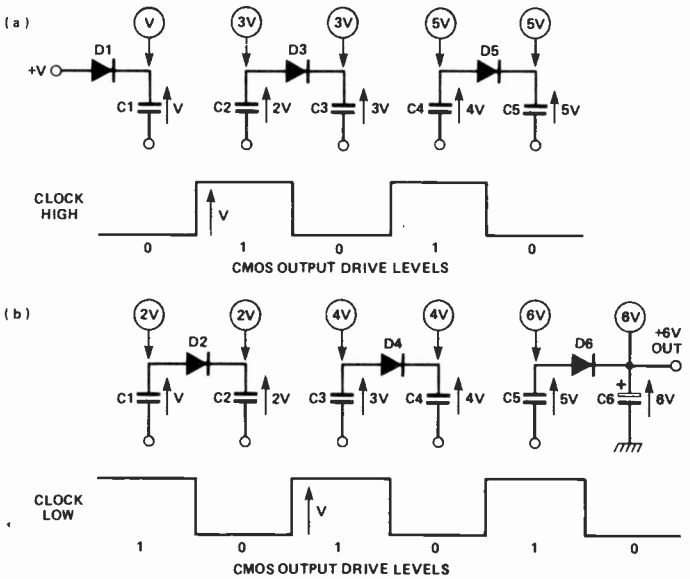

Fig. 8 Charging paths for an extended multiplier chain. The diagrams only show those diodes which are forward biased (conducting) during alternate half cycles of the drive waveform.

Looking at C1 and C2 in Fig. 7b we can see that the positive (top) end of C1 will be at V volts (V is the supply voltage) while the positive end of C2 is at 3V volts (2V of its own, raised up a further V volts at the CMOS output). Diode D2 will therefore be reversed biased and effectively out of circuit. For similar reasons C3 will be at 3V volts (less that which has leaked away) and can therefore be charged up via D3 from C2. On the other half cycle in Fig. 7c, however, C3 will be raised up to 4V volts by the CMOS output, while C2 returns to 2V. So this time D3 is reverse biased and will not conduct. C1 is now raised to 2V and can thus charge C2 via D2. The conducting and non-conducting parts of the circuit for each half cycle are shown in Fig. 8, which gives a much clearer illustration of the diode charge pump action.

The Appliance Of Science

Figure 9 shows the circuit of a split-rail power supply that generates ±10 V from a 5 V supply input. It could be

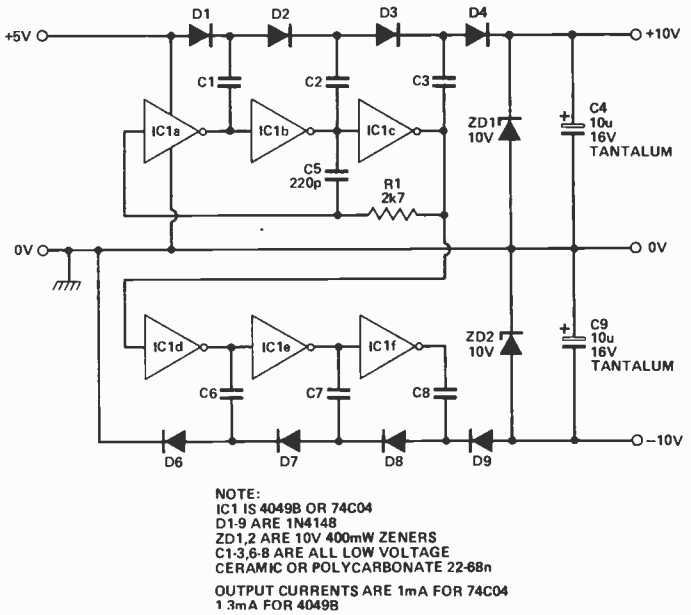

Fig. 9 A split-rail supply using one hex inverter package.

used to power low current op-amp circuitry and other CMOS circuits from a standard TTL power supply. Again, only one hex inverter pack is required and we recommend that the 4049B is used with its slightly higher output current capability. The circuit takes advantage of the three cascaded inverters that drive the positive multiplier chain, by also using them to form a 'ring-of-three' oscillator. The multiplier chain is therefore self-oscillating!

The positive side in turn drives the negative chain of IC1d, e and f. From Table 1 we would expect the available output voltages to be +17V2 and −12V2, which are then clamped to the ±10 V levels by zeners ZD1 and ZD2. Series limiting resistors for the zener diodes are unnecessary due to the current-limited output of the multiplier.

Figure 10 shows a variation on the previous circuit's positive multiplier section, using all six inverters to provide more output current at ±10 V. To achieve higher output currents, simply parallel the CMOS gates that drive the capacitor chain: the available currents will add together due to the nature of the CMOS output FETs. This technique is useful for CMOS operating at low supply voltages.

Figure 11 gives the circuit for a 24-stage positive multiplier to generate a high-voltage, low-current supply. This could be used for a solid state 'megger' (high resistance meter and insulation tester). The 24 stages can be achieved using only four hex inverter packs, and will provide 433 V from an 18 V supply. This circuit illustrates the fact that the inverters may be wired up in any fashion so long as alternate capacitors receive opposite phases of the square wave.

The circuit will deliver at least 2 mA at 430 V! — not lethal but pretty painful, so be careful. We suggest the addition of a 1M0 series resistor in the positive supply lead to limit the available current to about 400 uA. A 100 uA meter would provide suitable megohm readings.

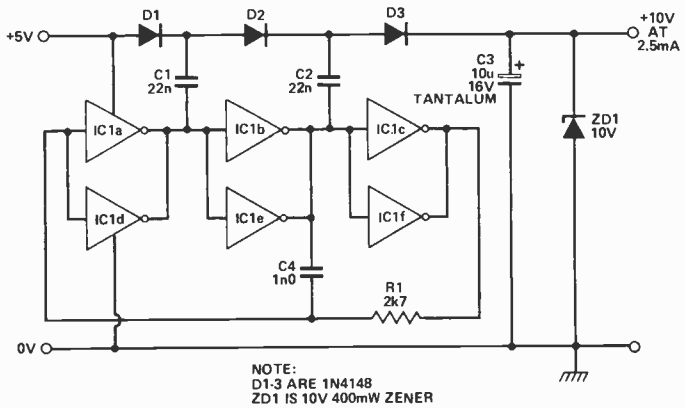

Fig. 10 Paralleling inverter stages to give a higher current supply.

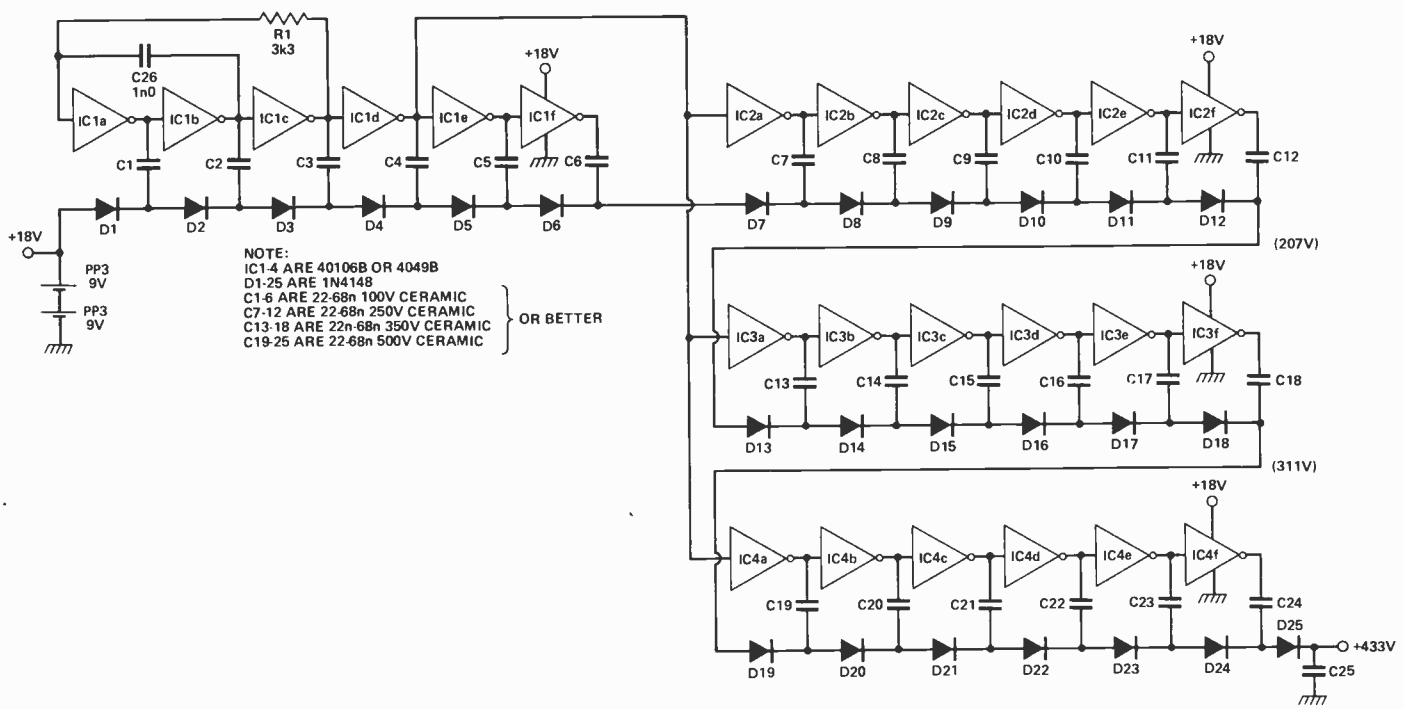

Fig. 11 A 433 V generator using a 24-stage positive multiplier and an 18 V supply.

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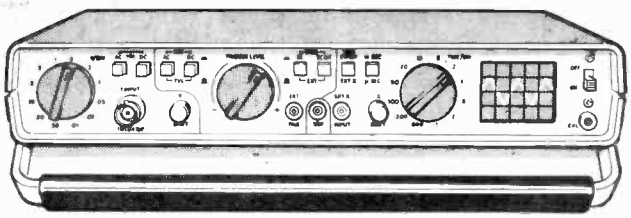

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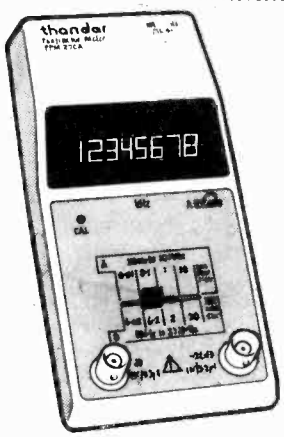

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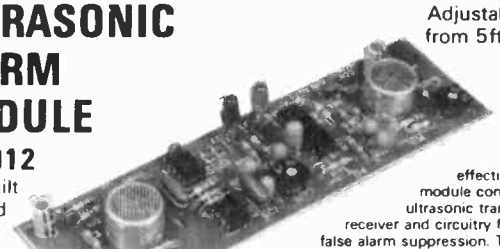

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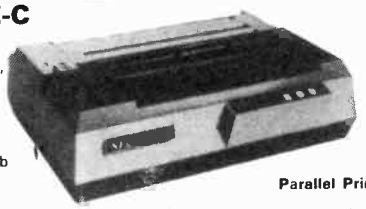
SANYO 12" Hi Res Green Monitor	**£99** + £6 carr.

ACORN ATOM
Basic Built £135 Expanded £175
(carr £3 per unit)
Atom Disc Pack **£299** + £6 carr
3A 5V Regulated PSU **£26** + £2 carr.
Phone or send for our BBC Atom list.

NEC PC 8023 BE-C
Features include:
80 cols 100CPS,
Bi-Directional, Logic seeking, Proportional Spacing, Forward & Reverse Line Feed, Hi-Res and Block Graphics, International and Greek characters, Auto-Underline, Super & Sub Scripts, Friction & Tractor, 2K Buffer, Cartridge Ribbon.



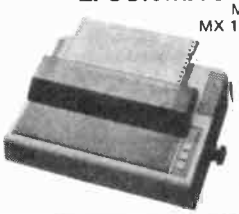
£320 + £8 carr.

PRINTERS

SEIKOSHA GP 100A
80 Cols 30 CPS
Full ASCII e GRAPHICS
10" Wide paper
Now only **£190** + £6 carr.
Ask for details on GP 250A

Parallel Printer lead for BBC/Atom to most printers £13.50
Variety of interfaces, ribbons in stock
2,000 fan fold sheets 9½" × 11" £13.50 + £3 p & p

EPSON MX 80 and 100F/T3
MX 80 80CPS 80 cols
MX 100 100CPS 136 cols
Logic Seeking, Bi-directional, Bit Image Printing, 9 x 9 Matrix
Logic Seeking, Bi-directional, Bit Image Printing, 9 × 9 Matrix, Auto Underline, Tractor and Friction Feed, Centronix & Bit Parellel Interface as standard



MX 80 F/T3 £325
MX 100 F/T3 £430
(£8 Carr/Printer)

RUGBY ATOMIC CLOCK
This Z80 micro controlled clock/calender receives coded time data from NPL Rugby. The clock never needs to be reset. The facilities include 8 independent alarms and for each alarm there is a choice of melody or alternatively these can be used for electrical switching. A separate timer allows recording of up to 240 lap times without interrupting the count. Expansion facilities provided. See July/August ETI for details. Complete Kit **£120** + **£2.00** p&p

MICROTIMER
6502 Based Programmeable clock timer with
- ★ 224 switching times/week cycle
- ★ 24 hour 7 day timer
- ★ 4 independent switch outputs directly interfacing to thyristor/triacs
- ★ 6 digit 7 seg. displays to indicate real time, ON/OFF and Reset times
- ★ Output to drive day of week switch and status LEDS.

Full details on request. Price for kit £57.00

CONNECTOR SYSTEMS

I.D. CONNECTORS
(Speedblock Type)

No of ways	Header Plug	Recep-tacle	Edge Conn
10	90p	90p	200p
20	145p	125p	240p
26	175p	150p	300p
34	200p	160p	380p
49	220p	190p	550p
50	235p	200p	600p

JUMP LEADS
4in Ribbon Cable with headers

	14 pin	16 pin	24 pin	40 pin
1 end	145p	165p	240p	380p
2 ends	210p	230p	345p	540p

24in Ribbon Cable with sockets

	20 pin	26 pin	34 pin	40 pin
1 end	160p	210p	270p	300p
2 ends	290p	385p	490p	540p

24in Ribbon Cable with D. Conn
25 way Male 500p Female 550p

AMPHENOL CONNECTORS

36 way Solder Type Plug (centronix type)	550p
36 way Solder Socket (centronix type)	550p
36 way IDC Plug (centronix type)	500p
24 way Solder Plug (IEEE type)	500p
24 way Solder Socket	500p
24 way IDC Plug	485p

RIBBON CABLE (Grey)

10 way	60p
14 way	80p
16 way	90p
20 way	105p
26 way	140p
34 way	220p
40 way	265p
50 way	330p
64 way	370p

D-CONNECTORS

	9 way	15 way	25 way	37 way
MALE				
Solder	90p	130p	180p	250p
Angled	160p	230p	285p	425p
FEMALE				
Solder	110p	160p	210p	350p
Angled	175p	240p	310p	500p
Hood	95p	95p	95p	125p

RS232 CONNS (25 way D)

24" Single end Male	£5.50
24" Single end Female	£6.00
24" Female-Female	£11.00
24" Male-Male	£10.00
24" Male-Female	£11.50

DIL HEADERS

	older type	IDC type
14 pin	40p	100p
16 pin	50p	110p
24 pin	100p	150p
40 pin	200p	225p

EURO CONNECTORS
(Indirect Edge Conn)

DIN STD	Plug	Skt
41617 21 way	170p	170p
41617 31 way	180p	180p
41612 2 x 32 way	250p	320p
Angled 2x32 way	325p	375p
41612 3x32 way	275p	380p
Angled 3x32 way	-	400p
2x32 way zidc a+c	-	525p
(for 2x32 way specify a+b or a+c)		

EDGE CONNECTORS

	0.1in	0.156in
2x18 way	–	140p
2x22 way	200p	170p
2x23 way	210p	–
2x25 way	225p	220p
1x43 way	260p	–
2x43 way	395p	–
2x50 way	–	–
1x77 way	700p	–
S100 Conn	–	600p

MICRODOCTOR
This is not a logic analyser or an oscilliscope. It tests a microsystem and gives a printed reprint on RAM, ROM and 1/0 – it will print memory map, search for code, check dataline shorts and operates peripherals

Microdoctor complete with PSU, Printer, probe cable and two configuration boards. **£295.**

PLEASE SEND SAE FOR PRICE LIST

SOFTY II INTELLIGENT PROGRAMMER
The complete micro processor development system for Engineers and Hobbyists. You can develop programs, debug, verify and commit to EPROMS or use in host computer by using softy as a romulator. Powerful editing facilities permit bytes, blocks of bytes changed, deleted or inserted and memory contents can be observed on ordinary TV. Accepts most + 5v Eproms.
Softy II complete with PSU, TV Lead and Romulator lead **£169**

SPECIAL OFFER

2114L	80p
2716 (+5v)	250p
2532	350p
4116-2	80p
4164-2	450p
6116P-3	350p

UV ERASERS

UV1B up to 6 Eproms	£47.50
UV1T with Timer	£60.00
UV140 up to 14 Eproms	£61.50
UV141 with Timer	£78.00

(Carr £2/eraser)
All erasers are fitted with mains switches and safety interlocks

TRAINER KITS

6502 Junior Computer	£85.00
6802 Nancomp I	£80.00
6809 Nancomp II	£80.00
1802 Micro Trainer	£64
E80 Manta	£115
Z80 Menta	£115

(fully built and documented)
Full details on request

BOOKS (No VAT p&p £1)

CMOS Cook Book	£7.75
CRT Controller H/Book	£7.95
Programming the Z80	£11.50
Z80 Microcomp. handbook	£6.95
Programming the 6502	£10.25
6502 Assy. Lang.	£12.10
6502 Applications	£10.20
6502 Software Design	£9.05
6502 Games	£10.52

Large selection of databooks, interfacing books, books on BBC, etc in stock. As for our list.

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VOLTAGE REGULATORS FIXED PLASTIC

1A	+ve		−ve	
5V	7805	40p	7905	45p
6V	7806	40p	7906	45p
8V	7808	40p	7908	45p
12V	7812	40p	7912	45p
15V	7815	40p	7915	45p
18V	7818	40p	7918	45p
24V	7824	40p	7924	45p
5V 100mA	78L05	30p	79L05	60p
6V 100mA	78L06	30p		
8V 100mA	78L08	30p		
12V 100mA	78L12	30p	79L12	60p
15V 100mA	78L15	30p	79L15	60p

OTHER REGULATORS
- LM309K 1A 5V 140p
- 78HGKC 600p
- LM317K TO3 325p
- 78HO5KC 550p
- LM317T 200p
- 78GUIC 200p
- LM337T 225p
- 79GUIC 225p
- LM323K 3A 5V 450p
- 79HGKC 700p
- LM723 150mA Adj 30p
- ICL 7660 200p
- LM305AH 250p
- TL494 300p
- 78H12 600p
- 78S40 225p
- SG3524 300p
- 78P05 900p

OPTO ELECTRONICS
- 2N5777 40p
- OCP71 180p
- ORP12 120p
- ORP60 120p
- ORP61 120p
- TIL78 55p
- TIL31A 120p
- TIL32 55p
- TIL81 90p
- TIL100 75p

OPTO ISOLATORS
- ILD74 130p
- MCT26 100p
- MCS2400 190p
- ILQ74 240p
- MOC3020 150p
- TIL111 70p
- TIL112 70p
- TIL113 70p
- TIL116 70p

LEDS
0.125"
- TIL209 Red 10p
- TIL211 Gr 12p
- TIL212 Yel 15p

0.2"
- TIL220 Red 10p
- TIL222 Gr 12p
- TIL228 Ye 15p
- Rectangular LEDs (R,G,Y) 30p

DISPLAYS
- DL704 140p
- DL707 Red 140p
- [illegible] 120p
- FND500 90p
- FND507 90p
- MAN3640 200p
- MAN4640 200p
- NSB5881 570p
- TIL311 600p
- TIL312/3 110p
- TIL321/3 130p
- TIL330 140p
- 7750/60 200p
- Bargraph 225p

DRIVERS
- 9368 250p
- 9370 300p

COMPUTER COMPONENTS

CPUs
- 1802CE 650p
- 2650A £12
- 6502 350p
- 6502A 500p
- 6800 225p
- 6802 250p
- 6809 650p
- 68B09 £12
- 6809E £12
- 8035 350p
- 8039 300p
- 8080A 280p
- 8085A 350p
- INS8060 £11
- TMS9980 £20
- TMS9995 £12
- Z8 £24
- Z80 290p
- Z80A 320p
- Z80B £12
- 8088 £18
- 8748 £18

SUPPORT DEVICES
- 3242 800p
- 3245 450p
- 6520 280p
- 6522 550p
- 6522A 550p
- 6532 550p
- 6551 650p
- 6821 100p
- 68B21 220p
- 6829 £12.50
- 6840 375p
- 68B40 600p
- 6850 110p
- 68B50 220p
- 6852 250p
- 6854 700p
- 68B54 800p
- 6875 570p
- 8154 950p
- 8155 350p
- 8156 350p
- 8205 225p
- 8212 110p
- 8216 100p
- 8224 110p
- 8226 250p
- 8228 220p
- 8243 280p
- 8250 850p
- 8251 250p
- 8253 390p
- 8255 250p
- 8256 £36
- 8257 400p
- 8259 400p
- 8271 £36
- 8279 440p
- 8284 350p
- 8288 £11
- 8755 £16
- 9902 £3
- TMS4500 £14
- TMS9928 £30
- Z80P10 250p
- Z80AP10 280p
- Z80CTC 250p
- Z80ACTC 280p
- Z80ADART 700p
- Z80ADMA £10
- Z80S10/1/2 £9

RAMs
- 2101 4A 400p
- 2102-3L 120p
- 2107B 500p
- 2111A 300p
- 2112-A 300p
- 2114-2L 100p
- 2147 450p
- 4027-3 300p
- 4044-45 450p
- 4116-15 120p
- 4116-20 80p
- 4118-3 450p
- 4164-2 400p
- 4816APZ-3 270p
- 5101 300p
- 5516 950p
- 6116-3 420p
- 6116LP-3 750p
- 6514-45 200p
- 6810 120p
- 7489 210p
- 74S189 225p
- 74S201 350p
- 74S289 175p
- 93415 600p
- 93425 600p

ROMs/PROMs
- 74S188 325p
- 74S287 350p
- 74S288 225p
- 74S387 325p
- 74S471 650p
- 74S473 650p
- 74S474 650p
- 74S570 650p
- 74S571 650p
- 74S573 950p

EPROMs
- 2516(+5v) 250p
- 2532 370p
- 2532-30 £7
- 2564 £12
- 2708 250p
- 2716(+5v) 250p
- 2732 (350ns) £6
- 2716 (350 ns) £5
- 2764 £11
- 2732(350ns) 750p
- TMS2716 750p

CRT CONTROLLER
- CRT6545 900p
- CRT5027 £18
- CRT5037 £18
- EF9365/6 £45
- MC6845 650p
- MC6847 650p
- SFF96364 £8
- TMS9918 £60
- TMS9927 £18
- TMS9928 £20
- TMS9929 £20

INTERFACE ICs
- AD558CJ 775p
- AD561J £14
- AD7581 160p
- AM25S10 350p
- AM25LS2521 £2
- AM26LS31 125p
- AM26LS32 125p
- D7002 480p
- DAC80 £28
- DM8131 375p
- DP8304 460p
- DS3691 400p
- DS8830 140p
- DS8831 140p
- DS8832 250p
- DS8833 225p
- DS8836 150p
- DS8838 225p
- LF13201 450p
- MC1488 55p
- MC1489 55p
- MC3418 950p
- MC3446 300p
- MC3480 850p
- MC3486 500p
- MC3487 300p
- MC4024 325p
- MC4044 325p
- MC14411 675p
- MC14412 750p
- 75107 90p
- 75110/12 160p
- 75114/15 160p
- 75121/22 140p
- 75150P 120p
- 75154 140p
- 75182 90p
- 75361 150p
- 75363 150p
- 75365 150p
- 75451/2 65p
- 75453/4 72p
- 75491/2 70p
- 8T26 120p
- 8T28 120p
- 8T95/96 90p
- 8T97/98 90p
- 81LS95/96 90p
- 81LS97/98 90p
- 9602 220p
- 9637AP 160p
- ZN425E-8 350p
- ZN426E-8 350p
- ZN427E-8 600p
- ZN428E-8 500p

DISC CONTROL ICs
- FD1771 £20
- FD1791 £22
- FD1793 £23
- FD1795 £28
- FD1797 £28
- 8271 £36
- WD1691 £15
- WD2143 550p

CHARACTER GENERATORS
- RO-3-2513UC 750p
- RO-3-2513LC 700p
- SN74S262AN £10
- MC66760 750p
- DM86564 £12

KEYBOARD ENCODER
- AY5-2376 700p
- 74C922 420p
- 74C923N 500p

BAUD RATE GENERATORS
- MC14411 675p
- COM8116 700p
- 4702B 750p

[illegible]
- AY-3-1015P 300p
- AY-5-1013P 300p
- COM8017 300p
- IM6402 450p
- TR1602 300p

ZIF SKTs
(TEXT TOOL)
- 24 pin 600p
- 28 pin 800p
- 40 pin £10

MODULATORS
- 6MHz UHF 375p
- 8MHz UHF 450p

CRYSTALS
- 32.768KHz 100p
- 100HKz 250p
- 200HKz 280p

Freq in MHz
- 1.0 290p
- 1.008 275p
- 1.5 450p
- 1.8432 210p
- 2.00 225p
- 2.45760 210p
- 2.5 250p
- 2.662 250p
- 3.276 150p
- 3.5795 100p
- 3.686 300p
- 4.00 150p
- 4.194 200p
- 4.43 110p
- 4.608 250p
- 4.915 250p
- 5.0 175p
- 6.0 150p
- 6.144 150p
- 7.0 150p
- 7.168 175p
- 8.00 175p
- 8.86 175p
- 10.00 175p
- 10.5 250p
- 10.7 150p
- 12.00 150p
- 14.318 175p
- 14.756 250p
- 15.00 200p
- 16.00 200p
- 17.7 200p
- 18.00 200p
- 18.432 150p
- 19.968 150p
- 20.00 200p
- 26.690 150p
- 27.145 200p
- 38.6667 175p
- 48.0 175p
- 55.5 400p
- 116 300p
- 145.80 250p
- 15.068 £2
- 24.00 £2

DIL SWITCHES
- 4 way 70p
- 6 way 85p
- 8 way 90p
- 10 way 145p

REAL TIME CLOCK
- MM58174 700p
- MSM5832 700p
- MK3805 £ TBA

LOW PROFILE SOCKETS BY TI

8 pin	9p	18 pin	16p	24 pin	24p
14 pin	10p	20 pin	18p	28 pin	26p
16 pin	11p	22 pin	22p	40 pin	30p

WIRE WRAP SOCKETS BY TI

8 pin	25p	18 pin	50p	24 pin	80p
14 pin	35p	20 pin	60p	28 pin	80p
16 pin	40p	22 pin	65p	40 pin	100p

TRANSISTORS
- AD161/2 45p
- BC107/8 13p
- BC109C 14p
- BC117 20p
- BC147/8 9p
- BC149 10p
- BC157/8 10p
- BC159 11p
- BC169C 12p
- BC172 12p
- BC177/8 17p
- BC179 18p
- BC182/3 10p
- BC184 11p
- BC187 30p
- BC212/3 11p
- BC214 12p
- BC237 15p
- BC327 16p
- BC337 16p
- BC338 16p
- BC461 25p
- BC477/8 30p
- BC516/7 40p
- BC547B 14p
- BC548C 12p
- BC549C 16p
- BC557B 14p
- BC559C 16p
- BCY70 18p
- BCY71 22p
- BD131 75p
- BD132 50p
- BD135/6 40p
- BD139 40p
- BD140 40p
- BD189 60p
- BD232 60p
- BD233 75p
- BD235 85p
- BD241 60p
- BD242 60p
- BD379 60p
- BD380 60p
- BD677 40p
- BF244B 35p
- BF256B 50p
- BF257/8 32p
- BF337 30p
- BFR39 25p
- BFR40/1 25p
- BFR79 25p
- BFR80/1 25p
- BFR96 180p
- BFX29 40p
- BFX30 27p
- BFX84/5 40p
- BFX86/7 27p
- BFX88 27p
- BFX89 108p
- BFY51/2 24p
- BFY56 33p
- BFY90 80p
- BRY39 45p
- BSX19/20 24p
- BU104 225p
- BU105 190p
- BU108 250p
- BU109 225p
- BU126 150p
- BU180A 120p
- BU205 200p
- BU208 200p
- BU406 145p
- BUX80 600p
- BUY69C 350p
- E310 50p
- MJ802 400p
- MJ2501 225p
- MJ2955 90p
- MJ3001 225p
- MJ4502 400p
- MJE340 60p
- MJE2955 100p
- MJE3305 70p
- MPF102 40p
- MPF103/4 30p
- MPF105 30p
- MPSA06 30p
- MPSA12 50p
- MPSA13 50p
- MPSA20 50p
- MPSA42 50p
- MPSA43 50p
- MPSA56 32p
- MPSA70 50p
- MPSA93 40p
- MPSU06 63p
- MPSU07 60p
- MPSU45 90p
- MPSU65 78p
- TIP29A 35p
- TIP29C 40p
- TIP30A 35p
- TIP30C 40p
- TIP31A 40p
- TIP31C 45p
- TIP32A 40p
- TIP32C 40p
- TIP33A 70p
- TIP33C 80p
- TIP34A 90p
- TIP34C 120p
- TIP35A 120p
- TIP35C 140p
- TIP36A 140p
- TIP36C 150p
- TIP41A 50p
- TIP41C 55p
- TIP42A 60p
- TIP42C 65p
- TIP54 160p
- TIP120 75p
- TIP121 75p
- TIP122 80p
- TIP142 120p
- TIP147 120p
- TIP2955 78p
- TIP4055 70p
- TIS93 30p
- ZTX108 12p
- ZTX300 13p
- ZTX452 45p
- ZTX500 15p
- ZTX502 16p
- ZTX504 18p
- ZTX552 55p
- ZTX652 60p
- ZTX752 70p
- VN66AF 72p
- VN10KM 60p
- VN66 80p
- 2N697 25p
- 2N698 45p
- 2N706A 30p
- 2N708 30p
- 2N918 45p
- 2N930 18p
- 2N1131/2 36p
- 2N1613 25p
- 2N1711 25p
- 2N2102 70p
- 2N2160 350p
- 2N2219A 25p
- 2N2222A 25p
- 2N2369A 17p
- 2N2484 25p
- 2N2646 40p
- 2N2904/5 25p
- 2N2906A 25p
- 2N2907A 25p
- 2N2926 9p
- 2N3053 25p
- 2N3054 55p
- 2N3055 35p
- 2N3442 140p
- 2N3553 240p
- 2N3584 250p
- 2N3643/4 48p
- 2N3702/3 10p
- 2N3704/5 10p
- 2N3706/7 10p
- 2N3708/9 10p
- 2N3773 200p
- 2N3819 20p
- 2N3820 40p
- 2N3823 30p
- 2N3866 90p
- 2N3902 700p
- 2N3904 15p
- 2N3906 16p
- 2N4037 65p
- 2N4123/4 27p
- 2N4125/6 27p
- 2N4401/3 25p
- 2N4427 90p
- 2N4871 50p
- 2N5087 27p
- 2N5089 27p
- 2N5172 27p
- 2N5191 90p
- 2N5245 40p
- 2N5401 60p
- 2N5459 30p
- 2N5460 60p
- 2N5485 36p
- 2N5875 250p
- 2N6027 30p
- 2N6052 300p
- 2N6059 325p
- 2N6107 65p
- 2N6247 190p
- 2N6254 130p
- 2N6290 65p
- 2SC1306 100p
- 2SC1307 150p
- 2SC1957 90p
- 2SC1969 150p
- 2SC2028 80p
- 2SC2029 200p
- 2SC2078 160p
- 2SC2335 200p
- 2SC2612 200p
- 3N128 120p
- 3N140 120p
- 3N141 110p
- 3N201 110p
- 3N204 200p
- 40290 250p
- 40361/2 75p
- 40408 90p
- 40409 100p
- 40410 100p
- 40594 120p
- 40595 120p
- 40673 75p
- 40871/2 100p

DIODES
- BY127 12p
- BYX36300 20p
- OA47 8p
- OA90/91 9p
- OA95 9p
- OA200 9p
- OA202 10p
- 1N941 4p
- 1N916 7p
- 1N4148 4p
- 1N4001/2 5p
- 1N4003/4 6p
- 1N4005 6p
- 1N4006/7 7p
- 1N5404/5 14p
- 1N5404/7 19p
- IS920 9p

BRIDGE RECTIFIERS
- 1A 50V 19p
- 1A 100V 20p
- 1A 400V 25p
- 1A 600V 30p
- 2A 50V 30p
- 2A 100V 35p
- 2A 400V 45p
- 3A 200V 60p
- 3A 600V 72p
- 4A 100V 95p
- 4A 400V 100p
- 6A 50V 80p
- 6A 100V 100p
- 6A 400V 120p

- 0A 400V 200p
- 25A 400V 400p

[illegible]
2.7V-33V
- 400mW 9p
- 1W 15p

TRIACS PLASTIC
- 3A 400V 60p
- 6A 400V 70p
- 6A 500V 88p
- 8A 400V 75p
- 8A 500V 95p
- 12A 400V 85p
- 12A 500V 105p
- 16A 400V 110p
- 16A 500V 130p
- T2800D 130p

THYRISTORS
- A 400V 100p
- 8A 600V 140p
- 12A 400V 160p
- 16A 100V 180p
- 16A 400V 180p
- C106D 45p
- MCR10136 38p
- TIC44 27p
- 2N3525 130p
- 2N4444 180p
- 2N5060 30p
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MOTOROLA 9" open chassis monitor. Standard 240 v AC with composite 75 ohm video input, bandwidth in excess of 18 mhz. Monitors are ex equipment and although unguaranteed they are all tested prior to despatch, and have no visible burns on the screens. Dim approx. 9" x 9" x 9". Supplied complete with mains and input lead. Ideal ZX81 etc. or giving the tele back to the family!! Black and white phosphor. **£35.00** + £9.00 Carr.

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REAL TIME CLOCK/CALENDAR

It seems strange that many microcomputers cannot tell the time of day or the date when such a facility can be so useful to the programmer. Never fear, ETI is here, with a simple peripheral for 6502-based machines. Design by M.D. Bedford

Programmers who are familiar with mainframe or minicomputers will probably be aware that it is generally possible to access the actual time and date from within a program. Such a facility is known as a real time clock and is often not available on the more modest microcomputers. It is not difficult to see that a real time clock would enhance any system — applications range from control programs, to the determination of the elapsed time between occurrences, to giving listings that professional touch by using the time and date in the header.

Two approaches are possible for the implementation of a real time clock — software or hardware. Traditionally, a software solution has been used in which a hardware interrupt is generated at regular intervals, probably every 20 milliseconds, these being counted by the interrupt handling routine which then calculates the time and date. Such a system obviously requires initialising and would prompt the user for the time and date each time the computer was switched on *(our own word processor uses this system — Ed)*. Quite apart from the possible inconvenience, this method is probably unsuitable for most microcomputer users as it would require modification of the monitor program in ROM to prompt for the time and date. On the other hand, it is possible to devise a hardware alternative with battery back-up which is transparent to the system when not being accessed and doesn't lose the time and date on power-down of the main system.

For these reasons a hardware approach is presented here. The design is primarily intended for the Tangerine Microtan system, the PCB given here being of such a size that it will plug directly into the system rack. From an electronic point of view, however, there is no reason why the board may not be used with any 6502-based computer.

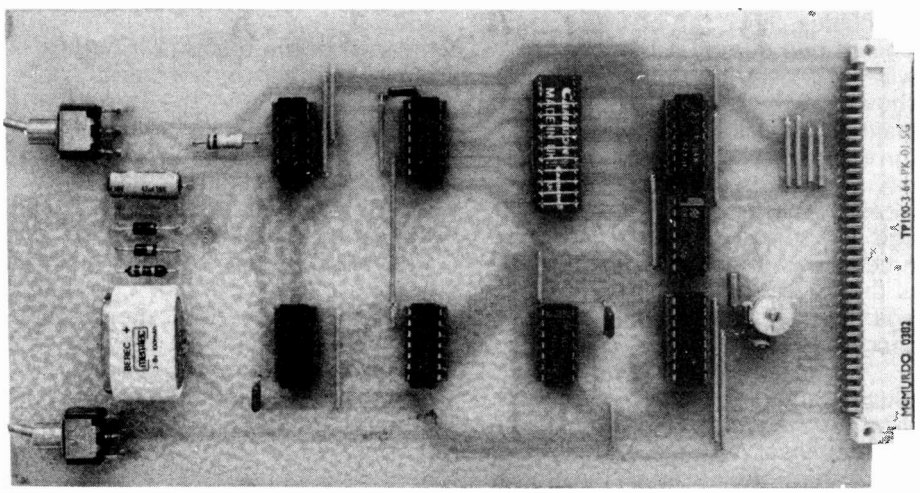
Functional Description

The real time clock, which may be configured to occupy any 16-byte block within the Tangerine I/O area, has 16 registers as specified in Table 1. It will be noticed that 12 of the registers are used to store the time and date, two registers being used to store (in BCD format) any number which may take a value greater than nine. For example, the value of the minutes is calculated as (10*REGISTER 5) + REGISTER 4. Of these 12 registers, registers 1-3 are read-only, these 'seconds' registers being automatically set to zero on starting the clock.

Each time the clock is updated, ie every tenth of a second, a flip-flop is set, writing a value of 15 to all the readable registers to indicate that an update has taken place since the last read. Reading a register under these conditions resets the flip-flop so that a further read will produce a valid result.

This board may also be used to generate interrupts at regular intervals, this function being controlled by register 15 as described in Table 2. Switch SW2 may be used to disable interrupts, a facility which is especially useful in view of the fact that this board does not reset at switch-on.

The remaining registers are write-only and have various control functions. Register 0 should have a value of 0 written to it to select non-test mode for normal operation. A value of 1, 2, 4 or 8 should be written into register 13 to indicate leap year, leap year + 1, leap year + 2, or leap year + 3 respectively. A value of 1 written to register 14 will start the clock, whereas a value of 0 will stop it. Switch SW1 gives the board write-proteciton, hence obviating the accidental overwriting of the time and date once initialised. This facility does not affect register 15 so that interrupts may still be selected when the



A bird's eye view of the completed project.

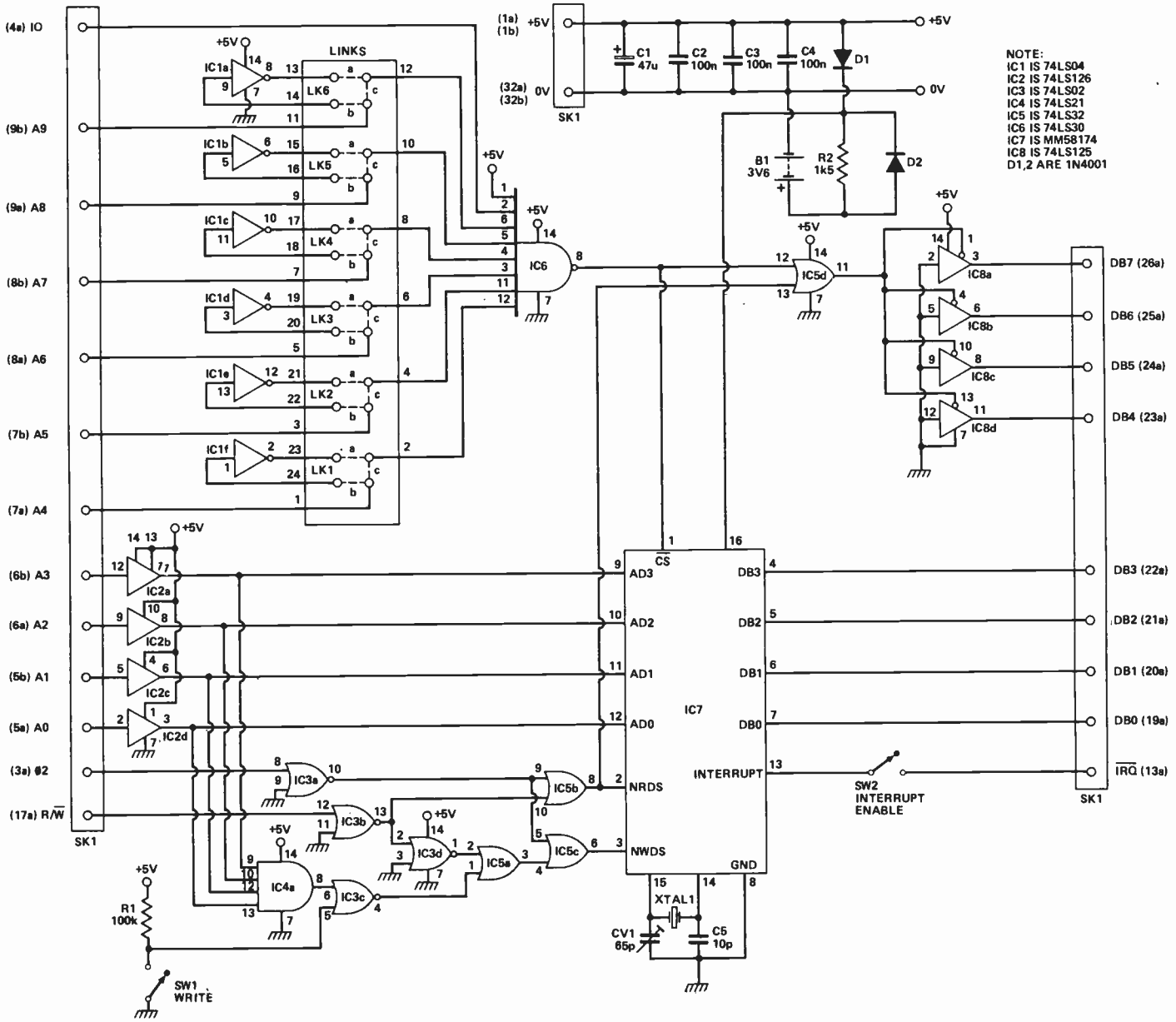


Fig. 1 Circuit diagram of the real time clock/calendar. Non-Microtan owners will find a circuit to generate the IO signal in last month's ETI.

board is write-protected. Both switches are mounted so that 'down' selects the enabling of the appropriate function.

The battery back-up facility allows data to be retained when the computer is not switched on, hence avoiding the need to initialise the clock at power-on. The time and date will be retained for about three months with a fully charged battery and a minimum of one hours use every nine days will ensure that the battery remains in a state of full charge.

Construction

If the printed circuit board layout presented here is adhered to, construction should present no difficulties. Since the board is of a single-sided design, a number of wire links need to be fitted as shown on the component layout diagram. Sockets should be used throughout for the integrated circuits. It should be noted that the MM58174 IC is fabricated in CMOS and accordingly the usual precautions of not touching the pins of the IC and not soldering the board while the IC is in its socket should be adhered to.

We suggest that DIL headers plugged into DIL sockets should be used for the wiring of the selectable address links. A 16-pin and an 8-pin socket should be used to make up the 24-pin by 0.3" socket used for these links. The required start address should be set up as follows: the start of the board is 16* (the binary number represented by links 1-6) from the start of the Tangerine I/O area, where link 1 is the least significant bit. Making links a and b gives a 0, making link c gives a 1. So, for example, the following links will set up the board to start at 48 bytes from the start of the I/O area: link 6 ab, link 5 ab, link 4 ab, link 3 ab, link 2 c, link 1 c. If the board is to be constructed to a different layout to suit non-Tangerine systems, the only points to be borne in mind are that C2, C3 and C4 should be well distributed around the board and that XTAL1, CV1 and C5 should be mounted close to IC7.

HOW IT WORKS

The heart of the circuit, IC7, is the MM58174 real time clock which reads and writes four bits of data onto DB0-DB3. ALthough not absolutely necessary (since the top four bits could be masked out by programming), a neat hardware solution is provided by the use of IC8 to zero DB4-DB7 during read operations. The circuitry comprising IC1, IC6 and the DIL links gives a chip select for IC7 and IC8 when an address in the range selected by the links is accessed.

Since the MM58174 is specifically intended to interface with microprocessors such as the 8080 or Z80, the circuitry comprising IC3 and most of IC5 is required to generate the NRDS and NWDS signals from the 6502 R/$\overline{W}$ and $\phi 2$. Hence write protection may be provided by blocking NWDS when SW1 is in the closed position. IC4 is used to detect when register 15 is being addressed (A0-A3 all high) and under these circumstances overrides the write protection.

IC2 is to buffer A0-A3 — in fact, the whole circuit is designed to present no more than one TTL load to any bussed signal.

D1 is used to pass the + 5 V supply to IC7 when it is present, the battery being trickle-charged through R2 under these conditions. When the + 5 V supply is not present, D1 prevents the battery from discharging through the power supply and IC7 is supplied with sufficient voltage to operate in standby mode via D2.

PARTS LIST

Resistors (all ¼W, 5%)	
R1	100k
R2	1k5
Capacitors	
C1	47u 16 V axial electrolytic
C2-4	100n disc ceramic
C5	10p ceramic plate
CV1	5-65p trimmer
Semiconductors	
IC1	74LS04
IC2	74LS126
IC3	74LS02
IC4	74LS21
IC5	74LS32
IC6	74LS30
IC7	MM58174 (see Buylines)
IC8	74LS125
D1,2	1N4001
Miscellaneous	
SW1,2	SPCO PCB-mounting toggle switches (see Buylines)
B1	3V6 PCB-mounting Nicad battery (see Buylines)
SK1	2 x 32 way A + B DIN Euro connector (male, angled pins) — see Buylines

PCB (see Buylines); DIL sockets to suit.

TABLE 1

List of Real Time Clock Registers

Reg No	Function	Access Mode
0	test	write
1	tenths of seconds	read
2	units of seconds	read
3	tens of seconds	read
4	units of minutes	read/write
5	tens of minutes	read/write
6	units of hours	read/write
7	tens of hours	read/write
8	units of days	read/write
9	tens of days	read/write
10	day of week	read/write
11	units of months	read/write
12	tens of months	read/write
13	year status	write
14	start/stop	write
15	interrupt	read/write

TABLE 2

DESCRIPTION OF INTERRUPT MODES

Function	Value in Register 15
no interrupts	0 or 8
single interrupt after 60 seconds	4
repeated interrupts at 60 second intervals	12
single interrupt after 5 seconds	2
repeated interrupts at 5 second intervals	10
single interrupt after 0.5 seconds	1
repeated interrupts at 0.5 second intervals	9

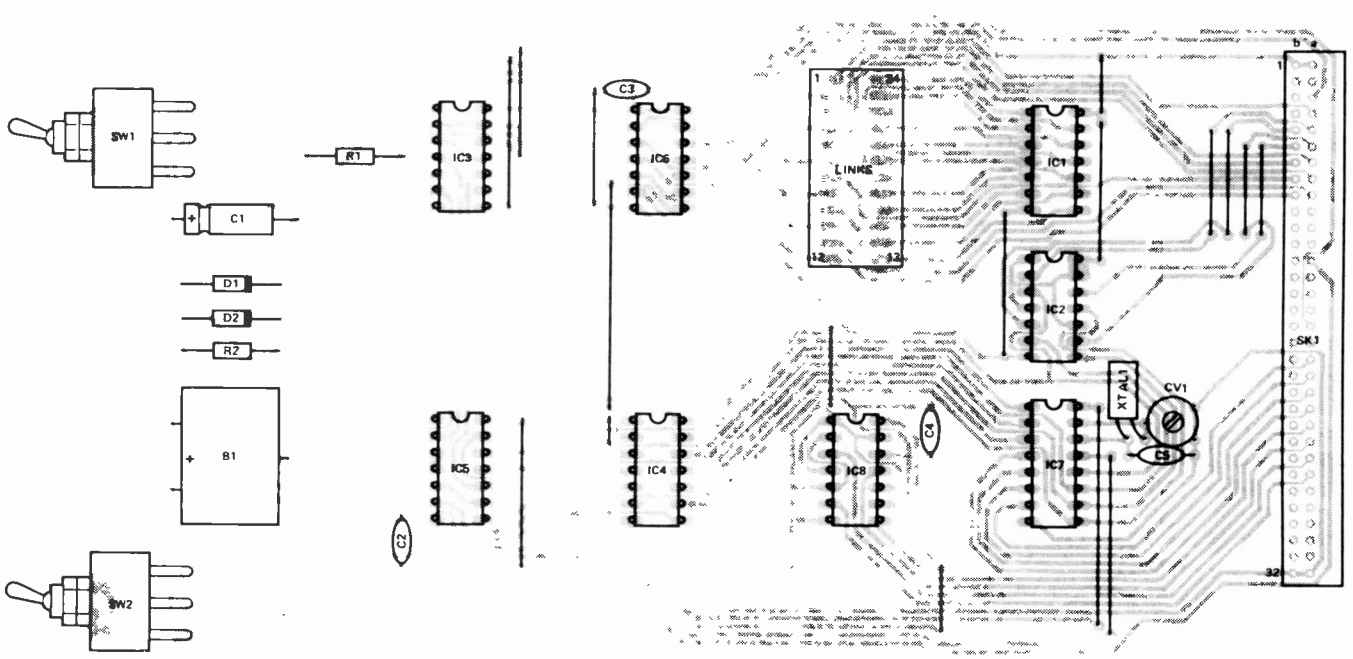
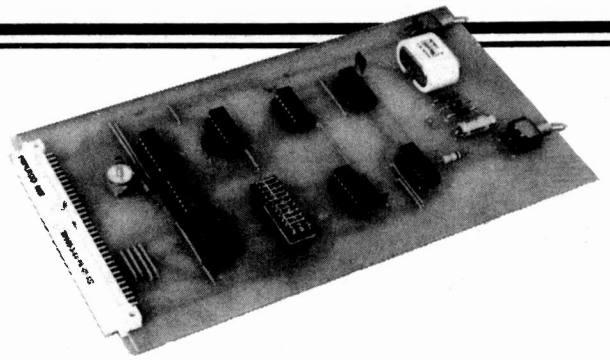


Fig. 2 Component overlay for the real time clock.



Programming

The following BASIC program is used for initialising the real time clock/calendar. The board should be write-enabled before running the program — however, if this is not done the user will be instructed to do so by the program. The program will fully validate the information given before writing it to the clock, to reduce the likelihood of human errors. We suggest that a time and date a few minutes ahead of the actual time is entered, the RETURN following the day of the week request being pressed exactly as this time arrives.

```
10 REM . . .MM58174 REAL TIME
   CLOCK INITIALISATION
   PROGRAM
20 DEF FNC(I) = VAL(MID$(TD$,
   I, 1))
30 DEF FNN(I) = 10 * FNC(I) +
   FNC(I+1)
40 DIM DM(12)
50 DATA 31, 28, 31, 30, 31, 30,
   31, 31, 30, 31, 30, 31
60 FOR I=1 TO 12: READ
   DM(I):NEXT I
70 PRINT "MM58174
   INITIALISATION"
80 INPUT "ENTER START
   ADDRESS OF BOARD"; AD
90 POKE AD, 0:REM . . . NON
   TEST MODE
100 POKE AD+15, 0:REM . . .
   DISABLE INTERRUPTS
110 POKE AD+14, 0:REM . . .
   STOP CLOCK
120 I=PEEK(AD+4):I=PEEK(AD+4)
130 J=15 AND (I+1):POKE AD+4,
   J
140 I=PEEK(AD+4)
150 IF I=J THEN 180
160 PRINT "WRITE ENABLE REAL
   TIME CLOCK — RETURN
   WHEN DONE"; :GET A$
170 GOTO 120
180 INPUT "ENTER TIME AND
   DATE IN THE FORM HH MM
   DD/MM/YY"; TD$
190 HH = FNN(1)
200 IF HH<0 OR HH>23 THEN
   180
210 POKE AD+7, FNC(1): REM . . .
   HOURS * 10
220 POKE AD+6, FNC(2): REM
   . . .HOURS
230 MM = FNN(4)
240 IF MM<0 OR MM>59 THEN
   180
250 POKE AD+5, FNC(4):REM . . .
   MINUTES * 10
260 POKE AD+4, FNC(5):REM
   . . .MINUTES
270 YY = FNN(13)
280 IF YY<0 OR YY>99 THEN 180
290 YR =
   2↑(3-(YY-4*INT(YY/4)))
300 IF YR=8 THEN
   DM(2)=29:GOTO 320
310 DM(2)=28
320 POKE AD+13, YR:REM . . .
   YEAR STATUS
330 MM = FNN(10)
340 IF MM<1 OR MM>12 THEN
   180
350 POKE AD+12, FNC(10):REM
   . . . MONTH * 10
360 POKE AD+11, FNC(11):REM
   . . . MONTH
370 DD = FNN(7)
380 IF DD<1 OR DD>DM(MM)
   THEN 180
390 POKE AD+9, FNC(7):REM . . .
   DAY * 10
400 POKE AD+8, FNC(8):REM . . .
   DAY
410 INPUT "ENTER DAY OF WEEK
   (1-7, 1=MONDAY)"; DW
420 IF DW<1 OR DW>7 THEN
   410
430 POKE AD+10, DW:REM . . .
   DAY OF WEEK
440 POKE AD+14, 15:REM . . .
   START CLOCK
450 PRINT "WRITE DISABLE REAL
   TIME CLOCK"
460 STOP
470 END
```

To access the time and date from within a program, the following BASIC subroutine may be used: a few words of explanation are probably appropriate. Line 1040 clears the update flip-flop by reading the clock once. The following two lines then loop until a value of 15 is read, indicating that an update has just taken place and that a tenth of a second is available to read the registers before the next update. It is the requirement to read 11 registers in this 100 milliseconds time slot (in order to avoid the possiblity of an update occurring between the reading of two registers) which accounts for the strange appearance of much of the rest of the subroutine. The inherent slowness of BASIC on an eight-bit microcomputer dictated the avoidance of FOR-NEXT loops, subscripted variables and numerical constants in the time-critical portion. The routine returns with numeric values of seconds, minutes . . . months in R2-R7 respectively, an ASCII representation of the time in TM$ and an ASCII version of the date in DT$.

```
1000 REM . . .MM58174 READING
   ROUTINE
1010 R2=AD+2:R3=AD+3:R4=
   AD+4:R5=AD+5
1020 R6=AD+6:R7=AD+7:R8=
   AD+8:R9=AD+9
1030 RA=AD+10:RB=AD+11:
   RC=AD+12
1040 Z = PEEK(AD+2)
1050 Z = PEEK(AD+2)
1060 IF Z<>15 THEN 1050
1070 R2=PEEK(R2):R3=PEEK(R3):
   R4=PEEK(R4)
1080 R5=PEEK(R5):R6=PEEK(R6):
   R7=PEEK(R7)
1090 R8=PEEK(R8):R9=PEEK(R9):
   RA=PEEK(RA)
1100 RB=PEEK(RB):RC=PEEK(RC)
1110 TM$=CHR$(48+R7)+CHR$
   (48+R6)+":"+CHR$(48+R5)
   +CHR$(48+R4)
1120 TM$=TM$+":"+CHR$(48+-
   R3)+CHR$(48+R2)
1130 DT$=CHR$(48+R9)+CHR$
   (48+R8)+" "+MM$(RB+
   10*RC)
1140 R2 = R2 + 10*R3
1150 R3 = R4 + 10*R5
1160 R4 = R6 + 10*R7
1170 R5 = R8 + 10*R9
1180 R6 = RA
1190 R7 = RB + 10*RC
1200 RETURN
```

Prior to calling the above subroutine, the following portion of program should be executed to store the names of the months in the array MM$:

```
10 DIM MM$(12)
20 DATA "JANUARY",
   "FEBRUARY", "MARCH",
   "APRIL", "MAY", "JUNE"
30 DATA "JULY", "AUGUST",
   "SEPTEMBER", "OCTOBER",
   "NOVEMBER", "DECEMBER"
40 FOR N=1 TO 12: READ
   MM$(N):NEXT N
```

BUYLINES

The MM58174 real time clock/calendar IC is available from Cricklewood Electronics, Technomatic or Watford Electronics. The PCB-mounting switches and Nicad battery might be a bit tricky to find unless you have industrial contacts, but non-PCB types could be used and wires taken to the PCB pads; there's enough room on the PCB, which is available from our PCB Service as usual. See page 87. The Euro connector is stocked by Watford Electronics.

ETI

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4015	23 04015	0.50
4016	23 04016	0.22
4017	23 04017	0.40
4020	23 04020	0.55
4021	23 04021	0.65
4022	23 04022	0.55
4023	23 04023	0.15
4024	23 04024	0.33
4025	23 04025	0.15
4027	23 04027	0.20
4028	23 04028	0.50
4029	23 04029	0.55
4035	23 04035	0.67
4040	23 04040	0.88
4042	23 04042	0.50
4043	23 04043	0.80
4044	23 04044	0.88
4046	23 04046	0.80
4049UB	22 04049	0.24
4050	23 04050	0.24
4051	23 04051	0.55
4052	23 04052	0.55
4053	23 04053	0.55
4060	23 04060	0.75
4066	23 04066	0.30
4068	23 04068	0.16
4069UB	22 04069	0.14
4070	23 04070	0.16
4071	23 04071	0.16
4072	23 04072	0.16
4073	23 04073	0.16
4075	23 04075	0.16
4076	23 04076	0.55
4077	23 04077	0.18
4078	23 04078	0.18
4081	23 04081	0.18
4082	23 04082	0.16
4093	23 04093	0.30
4099	23 04099	0.80
4175	23 04175	0.80
4502	23 04502	0.60
4503	23 04503	0.50
4506	23 04506	0.70
4507	23 04507	0.37
4508	23 04508	1.50
4510	23 04510	0.55
4511	23 04511	0.45
4512	23 04512	0.55
4514	23 04514	1.25
4515	23 04515	1.25
4516	23 04516	0.60
4518	23 04518	0.35
4520	23 04520	0.60
4521	23 04521	1.30
4522	23 04522	0.89
4526	23 04526	0.60
4527	23 04527	0.80
4528	23 04528	0.65
4529	23 04529	0.70
4531	23 04531	0.65
4532	23 04532	0.80
4534	23 04534	4.00
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4538	23 04538	0.85
4539	23 04539	0.80
4543	23 04543	0.80
4549	23 04549	3.50
4553	23 04553	2.70
4554	23 04554	1.20
4555	23 04555	0.35
4556	23 04556	0.40
4557	23 04557	2.30
4558	23 04558	0.80
4559	23 04559	3.50
4560	23 04560	2.50
4561	23 04561	1.00
4562	23 04562	2.50
4566	23 04566	1.20
4568	23 04568	1.45
4569	23 04569	1.70
45672UB	23 04572	0.32
4580	23 04580	3.25
4581	23 04581	1.40
4582	23 04582	0.70
4583	23 04583	0.80
4584	23 04584	0.27
4585	23 04585	0.45
4702	23 04702	4.50
4703	23 04703	4.40
4704	23 04704	4.24
4705	23 04705	4.24
4706	23 04706	4.50
4720	23 04720	4.00
4723	23 04723	0.85
4724	23 04724	0.85
4725	23 04725	2.24
40014	23 40014	0.54
40085	23 40085	0.88
40098	23 40098	0.54
40106	23 40106	0.80
40160	23 40160	1.05
40161	23 40161	1.05
40162	23 40162	1.05
40163	23 40163	1.05
40174	23 40174	1.05
40175	23 40175	1.05
40192	23 40192	1.08
40193	23 40193	1.08
40195	23 40195	1.08

74LSXX

Type	Stock No.	Price
74LS00	31 07400	0.11
74LS01	31 07401	0.11
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74LS10	31 07410	0.14
74LS11	31 07411	0.14
74LS12	31 07412	0.14
74LS13	31 07413	0.32
74LS14	31 07414	0.32
74LS15	31 07415	0.14
74LS20	31 07420	0.14
74LS21	31 07421	0.14
74LS22	31 07422	0.14
74LS26	31 07426	0.14
74LS27	31 07427	0.30
74LS28	31 07428	0.18
74LS30	31 07430	0.14
74LS32	31 07432	0.14
74LS33	31 07433	0.14
74LS37	31 07437	0.18
74LS38	31 07438	0.14
74LS40	31 07440	0.18
74LS42	31 07427	0.30
74LS47	31 07447	0.75
74LS48	31 07448	0.40
74LS49	31 07449	0.80
74LS51	31 07451	0.14
74LS54	31 07454	0.14
74LS55	31 07455	0.14
74LS74	31 07474	0.21
74LS75	31 07475	0.21
74LS76	31 07476	0.25
74LS78	31 07478	0.18
74LS83	31 07483	0.33
74LS85	31 07485	0.44
74LS86	31 07486	0.15
74LS90	31 07490	0.24
74LS91	31 07491	0.38
74LS92	31 07492	0.32
74LS93	31 07493	0.24
74LS95	31 07495	0.38
74LS107	31 74107	0.31
74LS109	31 74109	0.25
74LS112	31 74112	0.21
74LS113	31 74113	0.21
74LS114	31 74114	0.21
74LS122	31 74122	0.27
74LS123	31 74123	0.38
74LS125	31 74125	0.27
74LS126	31 74126	0.27
74LS132	31 74132	0.27
74LS133	31 74133	0.24
74LS136	31 74136	0.20
74LS138	31 74138	0.30
74LS139	31 74139	0.30
74LS151	31 74151	0.30
74LS153	31 74153	0.34
74LS155	31 74155	0.30
74LS156	31 74156	0.33
74LS157	31 74157	0.27
74LS158	31 74158	0.27
74LS160	31 74160	0.34
74LS161	31 74161	0.38
74LS162	31 74162	0.38
74LS163	31 74163	0.38
74LS164	31 74164	0.40
74LS165	31 74165	0.80
74LS166	31 74166	0.58
74LS168	31 74168	0.89
74LS170	31 74170	0.83
74LS173	31 74173	0.47
74LS174	31 74174	0.37
74LS175	31 74175	0.40
74LS181	31 74181	0.87
74LS183	31 74183	1.05
74LS190	31 74190	0.38
74LS191	31 74191	0.38
74LS192	31 74192	0.39
74LS193	31 74193	0.38
74LS194	31 74194	0.38
74LS195	31 74196	0.38
74LS196	31 74196	0.38
74LS197	31 74197	0.47
74LS221	31 74221	0.50
74LS240	31 74240	0.60
74LS241	31 74241	0.60
74LS242	31 74242	0.55
74LS243	31 74243	0.55
74LS244	31 74244	0.60
74LS245	31 74245	1.00
74LS251	31 74251	0.38
74LS253	31 74253	0.38
74LS257	31 74257	0.38
74LS258	31 74258	0.38
74LS259	31 74259	0.61
74LS260	31 74260	0.20
74LS266	31 74266	0.20
74LS273	31 74273	0.70
74LS279	31 74279	0.35
74LS283	31 74283	0.40
74LS290	31 74290	0.40
74LS293	31 74293	0.40
74LS298	31 74298	0.54
74LS365	31 74365	0.34
74LS366	31 74366	0.40
74LS367	31 74367	0.30
74LS368	31 74368	0.30
74LS373	31 74373	0.72
74LS374	31 74374	0.72
74LS375	31 74375	0.31
74LS377	31 74377	0.80
74LS378	31 74378	0.44
74LS379	31 74379	0.44
74LS385	31 74385	1.38
74LS386	31 74386	0.27
74LS390	31 74390	0.51
74LS393	31 74393	0.48
74LS398	31 74398	0.80
74LS399	31 74399	0.65
74LS490	31 74490	0.60
74LS670	31 74670	1.15

74CXX

Type	Stock No.	Price
74C00	29 07400	0.35
74C02	29 07402	0.35
74C04	4069C	
74C08	29 07408	0.35
74C10	29 07410	0.35
74C14	4584C	
74C20	29 07420	0.35
74C30	29 07430	0.35
74C32	29 07432	0.35
74C42	29 07442	1.05
74C48	29 07448	1.50
74C73	29 07473	0.75
74C74	29 07474	0.75
74C76	29 07476	0.60
74C83	29 07483	1.30
74C85	29 07485	1.30
74C86	29 07485	1.30
74C89	29 07489	3.60
74C90	29 07490	1.05
74C93	29 07493	1.05
74C95	29 07495	1.25
74C107	29 74107	0.80
74C151	29 74151	2.10
74C154	29 74154	3.05
74C157	29 74157	2.18
74C160	40160	
74C1610	40161CM	
74C1620	40162CM	
74C1630	40163CM	
74C164	29 74164	1.05
74C165	29 74165	1.10
74C173	4076C	
74C1740	40174CM	
74C1750	40175CM	
74C1920	40192CM	
74C1930	40193CM	
74C1950	40195CM	
74C200	29 74200	0.60
74C221	29 74221	1.55
74C901	29 74901	0.55
74C902	29 74902	0.55
74C903	29 74903	0.55
74C904	29 74904	0.56
74C905	29 74905	0.50
74C906	29 74906	0.55
74C907	29 74907	0.55
74C908	29 74908	1.10
74C909	29 74909	2.10
74C910	29 74910	5.00
74C914	29 74914	1.10
74C918	29 74918	1.30
74C925	29 74925	6.00
74C926	29 74926	6.00
74C927	29 74927	6.00

74HCXX

Type	Stock No.	Price
74HC00	30 07400	0.60
74HC02	30 07402	0.50
74HC04	30 07404	0.60
74HC10	30 07410	0.56
74HC20	30 07420	0.50
74HC86	30 07486	0.74
74HC132	30 74132	1.20
74HC266	30 74266	0.81
74HC4002	30 04002	0.50
74HC4075	30 04075	0.50
74HC242	30 74242	2.00
74HC243	30 74243	2.00
74HC74	30 07474	0.74
74HC109	30 74109	0.68
74HC175	30 74175	1.08
74HC373	30 74373	2.40
74HC374	30 74374	2.40
74HC533	30 74533	2.48
74HC534	30 74534	2.40
74HC165	30 74165	1.88
74HC173	30 74173	1.20
74HC160	30 74160	1.33
74HC161	30 74161	1.33
74HC162	30 74162	1.33
74HC163	30 74163	1.33
74HC4538	30 74538	2.18
74HC85	30 74280	2.85
74HC280	30 74280	2.85
74HC42	30 07442	1.00
74HC138	30 74138	1.08
74HC139	30 74139	1.08
74HC4514	30 04514	3.40
74HC4543	30 04543	2.75
74HC157	30 74157	0.92
74HC158	30 74158	0.80
74HC257	30 74257	0.80

LINEAR ICs

Type	Stock No.	Price
LM10CN	61 00010	3.80
MF10	61 00011	5.05
L149	61 00149	1.88
ZNA234	61 02340	0.50
U237B	61 00237	1.20
U247B	61 00247	1.20
U257B	61 00257	1.20
U267B	61 00267	1.20
LM301AH	61 03010	0.67
LM301AN	61 03011	0.27
LM308H	61 03080	0.70
LM308CN	61 03081	0.65
LM324	61 03240	0.45
LM339N	61 03390	0.66
LF347	61 00347	1.60
LM348	61 03480	0.90
LF351	61 03510	0.49
LF353	61 03530	0.70
LM380N	61 00380	1.00
LM381	61 00381	1.81
LM382	61 00382	1.81
ZN419CE	61 00419	1.90
ZNA423	61 04230	1.00
ZN425E/8	61 04250	3.50
ZN426E/8	61 04260	3.00
ZN427E/8	61 04270	6.20
ZN428E/8	61 04280	4.78
ZN429E/8	61 04290	2.18
ZN432CJ10	61 04320	20.08
ZN433CJ10	61 04330	22.50
ZN440J	61 04400	8.88
ZN450E	61 04500	7.81
NE542	61 05420	1.28
NE544	61 00544	1.80
NE555N	61 05550	0.20
NE556N	61 05560	0.50
SL560C	61 05600	1.88
NE562	61 00562	4.05
NE564	61 00564	4.29
NE565	61 00565	1.00
NE566	61 00566	1.30
NE567	61 00567	1.30
NE570N	61 00570	3.85
SL624	61 00624	3.20
uA709HC	61 07090	0.64
uA709PC	61 07091	0.38
uA710HC	61 07100	0.64
uA710PC	61 07101	0.58
uA711CN	61 07110	0.85
uA733CN	61 07330	0.88
uA741CH	61 07410	0.66
uA741CN	61 07411	0.20
uA747CN	61 07470	0.70
uA748CN	61 04780	0.30
uA758	61 00758	2.35
TBA820M	61 00820	0.78
TDA1028	61 01028	2.11
TDA1029	61 01029	2.11
ZNA1034	61 01034	2.18
LM1035	61 01034	2.18
TDA1054M	61 01054	1.45
TDA1062	61 01062	1.95
TDA1072	61 01072	2.88
TDA1074A	61 01074	5.04
TDA1083	61 01083	1.95
TDA1090	61 01090	3.05
HA1137	61 12411	1.20
HA1196	61 01196	2.00
HA1197	61 01197	1.08
TDA1220	61 01220	1.40
LM1303	61 01303	0.88
LM1307	61 01307	1.55
MC1310P	61 01310	1.80
MC1330	61 01330	1.20
MC1350	61 01350	1.20
HA1370	61 11370	1.90
HA1388	61 01388	2.76
LM1458N	61 14580	0.45
MC1496P	61 01496	1.25
SL1610	61 01610	1.82
SL1611	61 01611	1.80
SL1612	61 01612	1.80
SL1613	61 01613	2.08
SL1620	61 01620	2.50
SL1621	61 01621	2.50
SL1623	61 01623	2.44
SL1625	61 01625	2.50
SL1626	(SL6270)	
SL1630	61 01630	1.82
SL1640	61 01640	2.25
SL1641	61 01641	2.25
MC1648	61 01648	3.25
TDA2002	61 02002	1.25
ULN2240	61 02240	3.25
ULN2242	61 01090	3.05
ULN2283	61 02283	1.00
CA3080	61 03080	0.70
CA3089	61 03089	1.84
CA3123	61 03123	1.40
CA3130E	61 31300	0.80
CA3130T	61 31301	0.90
CA3140E	61 31400	0.46
CA3189E	61 03189	2.20
CA3240E	61 32400	1.27
MC3357	61 03357	2.05
MC3359 (see ULN3859)		
ULN3859	61 03859	2.95
KM3701	61 03701	65.53
KM3702	61 03702	74.84
LM3900	61 39000	0.60
LM3909N	61 39090	0.68
LM3914N	61 03914	2.80
LM3915N	61 03915	2.80
KB4400	61 04400	0.80
KB4412	61 04412	1.95
KB4413	61 04413	1.95
KB4417	61 04417	1.80
KB4420B	61 04420	1.09
TDA4420	61 14420	2.05
TDA4421	61 14421	2.05
KB4423	61 04423	2.30
KB4424	61 04424	1.05
KB4430	61 04430	2.30
KB4431	61 04431	1.95
KB4432	61 04432	1.95
KB4433	61 04433	1.52
KB4436	61 04436	2.63
KB4437	61 04437	1.75
KB4438	61 04438	2.22
KB4441	61 04441	1.38
KB4445	61 04445	1.29
KB4446	61 04446	2.75
KB4448	61 04448	1.65
NE5044	61 05044	2.28
MC5229	61 05229	0.60
NE5532	61 55320	1.85
KM5624	61 05624	4.35
SD6000	61 06000	3.75
SL6270	61 06270	2.03
SL6310	61 06310	2.46
SL6440	61 06440	3.38
SL6600	61 06600	3.75
SAS6810	61 06610	1.48
SL6640	61 06640	2.76
SL6690	61 06690	3.75
SL6700	61 06700	2.75
SAS6710	61 06710	1.48
LS7225	61 07225	3.65
ICM7555	61 75550	0.80
CL8038CC	61 08038	4.50
MSL9362	61 09362	1.75
MSL9363	61 09363	1.75
K10170	61 10170	1.87
TK10321	61 10321	2.75
HA11223	61 11223	2.16
HA11225	61 11225	1.45
HA12002	61 12002	1.22
HA12017	61 12017	0.80
HA12402	61 12402	1.95
HA12411	61 12411	1.20
HA12412	61 12412	1.55
LF13741	61 13741	0.33
MK50366	61 50366	3.35
MK50375	61 50375	3.85
MM53200	61 53200	3.90

PRESCALER

Type	Stock No.	Price
U264	61 02640	2.27
U265	61 02650	3.18
U266	61 02660	2.43
11C90DC	61 01190	12.95
MSL2312R	61 02312	3.84
MSL2318	61 02318	3.84
MSM5523	61 05523	11.30
MSM5524	61 05524	11.30
MSM5525	61 05525	7.85
MSM5526	61 05526	7.85
MSM55271	61 55271	9.75
ICM7106CP	61 07106	9.55
ICM7107CP	61 07107	9.56
LC7137	61 07137	7.50
ICM7216B	61 72161	18.50
ICM7216C	61 72162	19.95
ICM7217A	61 07217	9.50
SP8629	61 08629	3.85
SP8647	61 08647	6.00
SP8793	61 08793	7.70
95H90	61 09590	7.80
HD10551	61 10551	2.45
HA12009	61 12009	6.00
HD44015	61 44015	4.45
HD44752	61 44752	8.00
MC145151P	61 14151	8.00
MC145152P	61 14151	6.00
MC145156P	61 14156	4.60

SMALL SIGNAL AUDIO

Type	Stock No.	Price
BC182	58 00182	0.10
BC212	58 00212	0.10
BC237	58 00237	0.08
BC238	58 00238	0.08
BC239	58 00239	0.08
BC307	58 00307	0.08
BC308	58 00308	0.08
BC309	58 00309	0.08
BC327	58 00327	0.13
BC337	58 00337	0.13
BC413	58 00413	0.10
BC414	58 00414	0.11
BC415	58 00415	0.10
BC416	58 00416	0.11
BC548	58 00546	0.12
BC550	58 00550	0.12
BC556	58 00556	0.12
BC560	58 00560	0.12
BC639	58 00639	0.22
BC640	58 00640	0.22
MPSA13	58 04013	0.30
MPSA63	58 04063	0.30
ZTX108	58 01108	0.10
ZTX212	58 01212	0.10
ZTX653	58 01653	0.20
ZTX753	58 01753	0.20
2N2904	58 02904	0.25
2N2905	58 02905	0.25
2N3905	58 03905	0.10
2SB646A	58 03646	0.30
2SB648A	58 03648	0.40
2SD666A	58 03666	0.30
2SD668A	58 03668	0.40
2SA872A	58 02872	0.19
2SA1084E	58 01084	0.25
2SA1085E	58 01085	0.25
2SC1775A	58 01775	0.10
2SC2546E	58 02546	0.24
2SC2547E	58 02547	0.24

AUDIO POWER

Type	Stock No.	Price
BD139	58 15139	0.28
BD140	58 15140	0.31
BD165	58 15165	0.40
BD166	58 15166	0.40
BD179	58 15179	0.38
BD180	58 15180	0.41
TIP31A	58 15031	0.35
TIP32A	58 15032	0.35
MJ2955	58 12955	0.80
2N3055	58 13099	0.50
2SB720	58 15720	0.60
2SD760	58 17600	0.60
2SJ49	60 01049	3.10
2SJ50	60 01050	4.25
2SJ83	60 01083	3.55
2SK134	60 00134	3.10
2SK135	60 00135	4.25
2SK227	60 00227	3.55
2SD753	58 03753	2.34

SMALL SIGNAL RF

Type	Stock No.	Price
BFY50	58 06500	0.22
BF241	58 06241	0.10
BF273	58 06273	0.10
BF274	58 06274	0.20
BF362	58 06362	0.49
BF440	58 06440	0.21
BF441	58 06441	0.21
BF479	58 06479	0.66
BF679S	58 06679	0.55
BFR91	58 07091	1.33
BFT95	58 10095	0.99
BFW92	58 08092	0.60
BFY90	58 09090	0.90
NE21936	58 21936	5.00
ZTX323	58 06232	0.60
2N2369A	58 02369	0.30

RF POWER

Type	Stock No.	Price
BFW16A	58 08016	0.65
MRF237	58 14237	3.20
MRF238	58 14238	10.50
MRF245	58 14245	40.00
MRF449A	58 14449	18.50
MRF472	58 14472	1.26
MRF475	58 14475	4.00
MRF629	58 14629	4.99
PT8811	58 18811	0.60
TP2320	58 12320	10.24
VN66AF	60 02066	0.95
ZTX3866	58 03866	0.45
2N3866	58 13866	1.20

SMALL SIGNAL FET

Type	Stock No.	Price
BF256	59 00256	0.30
BF960	60 06960	0.88
BF961	60 06961	0.70
BF963	60 06963	0.99
J310	59 02310	0.69
J176	59 02176	0.65
2SK55	59 01055	0.32
2SK168	59 01168	0.37
3SK45	60 04045	0.49
3SK51	60 04051	0.54
3SK60	60 04060	0.58
3SK88	60 04088	0.99
40673 see 3SK51		
40822 see 3SK51		
40823	60 03823	0.85
3SK112	60 04112	4.60

DIODES

Type	Stock No.	Price
AA112	12 01126	0.25
BA244	12 02447	0.17
BA379	12 03797	0.35
ND4981-7E	12 49817	0.51
OA91	12 00916	0.07
OA47	12 00476	0.10
PW02	12 62006	0.75
S04	12 24006	0.45
W005	12 10506	0.20
1N4001	12 40016	0.06
1N4002	12 40026	0.07
1N4004	12 40046	0.07
1N4148	12 41486	0.05
1N5404	12 54046	0.10
1N6263	12 62637	0.82

VARICAPS

Type	Stock No.	Price
BA102	12 01025	0.30
BA121	12 01215	0.30
BB105B	12 01055	0.30
BB109B	12 01095	0.27
BB204B	12 02045	0.36
BB212	12 02125	1.95
ITT210	12 02105	0.30
MVAM115 see KV1236		
MVAM125 see KV1225		
KV1210	12 12105	2.45
KV1211 see KV1236		
KV1225	12 12255	2.75
KV1235	12 12355	2.75
KV1236	12 12365	2.55
KV1310	12 13105	0.40
KV1310	12 13205	0.40

ZENER DIODES

BZY88C 400mW. 5%.

Type	Stock No.	Price
2V7	12 00278	0.10
3V3	12 00338	0.10
3V9	12 00398	0.10
4V7	12 00478	0.10
5V1	12 00518	0.10
5V6	12 00568	0.10
6V8	12 00688	0.10
8V2	12 00828	0.10
9V1	12 00918	0.10
10	12 01008	0.10
11	12 01108	0.10
12	12 01208	0.10
15	12 01508	0.10
18	12 01808	0.10
22	12 02208	0.10
27	12 02708	0.10
33	12 03308	0.10

SCRS TRIACS

Type	Stock No.	Price
BRY55 100	52 55100	0.50
C106D1	52 00106	0.70
C122D1	52 00122	1.46
2N6403	52 06403	2.22
2N6073A	58 06073	0.80

BALANCED MIXERS

Type	Stock No.	Price
SBL1	12 00003	4.60
SBL1 8	12 00013	5.90
SBL1-X	12 00023	6.33
SRA1	12 00033	10.00
SRA1-1	12 00043	12.77
SRA1H	12 00053	18.34
SRA3	12 00063	16.35

LEDs

Type	Stock No.	Price
3mm round types		
CQX25 Red/Clr	15 20250	0.15
V178P Red	15 01780	0.15
CQX26 Gr/Clr	15 20260	0.18
V179P Green	15 01790	0.18
CQX27 Yel/Clr	15 20270	0.18
V180P Yellow	15 01800	0.18
CQX41A Or/Rd	15 20410	0.18
Standard 5mm DIA LEDs		
CQY40L Red	15 10400	0.12
CQY72L Green	15 10720	0.15
CQY74L Yellow	15 10740	0.15
CQX38A Or/rd	15 20380	0.20
CQX39B Or/cl	15 20390	0.20
Rectangular 2.5 x 5mm LEDs		
CQX10 Red	15 20100	0.17
CQX11 Green	15 20110	0.20
CQX12 Yellow	15 20150	0.20
CQX40 Or/Red	15 20400	0.24
Infra-Red LEDs		
CQY99 Emit	15 10990	0.50
BPW41 Det	15 30410	1.51

IR Optocoupler

Type	Stock No.	Price
BNY37	15 40370	1.44

FLAT DIFFUSED

Type	Stock No.	Price
V320	15 03200	0.17
V321	15 03210	0.20
V322	15 03220	0.20
V323	15 03230	0.20
V330	15 03300	0.17
V331	15 03310	0.26
V332	15 03320	0.26
V333	15 03330	0.20
V340	15 03400	0.17
V341	15 03410	0.26
V342	15 03420	0.20
V343	15 03430	0.20
V510	15 05100	0.17
V511	15 05110	0.26
V512	15 05120	0.20
V513	15 05130	0.20
V520	15 05200	0.17
V521	15 05210	0.26
V522	15 05220	0.20
V523	15 05230	0.20
V530	15 05300	0.17
V531	15 05310	0.20
V532	15 05320	0.20
V533	15 05330	0.20
V540	15 05200	0.17
V541	15 05410	0.20
V542	15 05420	0.20
V543	15 05430	0.20
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V551	15 05510	0.26
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FEVAs

Could the end be in sight for semiconductors? Once again ETI gets a world exclusive, as Owen Bishop describes the revolutionary technology which is poised to take us through to the 21st Century.

It seems an age since the Gemini spaceflights of the middle nineteen-sixties, yet then was born an entirely new concept in electronics which has only just been brought to production stage. Almost weekly we hear of spin-offs from space-age technology, but this is one which threatens to render obsolete almost all of today's circuit designs. Opto-technology, surface acoustic wave devices and bubble memories are out of the running before they have hardly begun to crawl.

FEVAs, Field Effect Voltage Amplifiers, were born in the sixties, grew up in the seventies and, in the eighties, are ready to take over all the functions that are performed by semiconductor and related devices today. Their full designation is SCFEVAs, which gives a clue to their origin, for this is an abbreviation of Space-Channel Field Effect Voltage Amplifiers. The space channel will soon replace all the N-channel and P-channel devices we take for granted nowadays.

Serendipity

No, this is not the acronym for yet another complex electronic wonder but a word which means 'making unexpected discoveries by accident'. FEVAs began this way during one of the early space-walks of the Gemini missions. The immense potential of the discovery was realized immediately by astronaut Lee Old, but it is only today that the news is beginning to surface.

It happened like this. During their second space-walk, the astronauts were engaged in a capsule-service practise routine. Their task was to insert a plug of expanded polystyrene into a recess in the rear of the capsule in order to enhance its aerodynamic qualities in readiness for re-entry into Earth's atmosphere. You may think that expanded polystyrene is an unlikely material for this purpose but it has several features in its favour. Its strength-to-mass ratio is one of the highest, a factor of immense importance in space travel. As any handyman knows, another advantage of expanded polystyrene is that it is easily cut, and as any handyman also knows, the best way of cutting it is to use a hot wire. The extremely high thermal insulating properties of expanded polysteyrene mean that a hot-wire cutter functions perfectly, even in the sub-zero temperatures of outer space. So it was to be a neat and well-thought-out manoeuvre, but then the unexpected happened.

Blowing In The Wind

Whenever Lee switched on his hot-wire cutter, his colleague 'Gig' Potter was alarmed by intense activity on the Solar Wind Detector. This was an on-board experiment devised by the Department of Applied Physics of the University of Minniwaukee, the purpose of which was to monitor the streams of electrons being repelled from the Sun's chromosphere. When the wire was hot, the effect was like a solar gale! Lee immediately realized that there must be some kind of interaction between his hot wire and the Solar Wind Detector. Electromagnetic interference was immediately ruled out, for the wire was not coiled and, in any event, was powered by direct current.

It must be that electrons from the atoms of the wire were being energised by the heating, were escaping from the confines of the wire and passing to the Solar Wind Detector. Maybe there was an electric field caused by the friction between Lee's space-gloves and the expanded polystyrene which was accelerating the electrons toward the detector.

Back To Earth

We hear a lot about taking Earth-bound manufacturing technologies to space to gain the advantages of the conditions there, but this is a case of bringing the conditions of space down to Earth. Lee's penetrating insight told him that the key to implementing his discovery was to create space conditions on Earth, and the solution to this problem was blindingly simple. Take a suitable container and suck the air out of it! The space channel is, in fact, known in everyday parlance as a *vacuum*. Lee resigned his commission in order to devote himself full-time to promoting the commercial aspects of his discovery. But Lee was back on Earth in more senses than one! He soon came up against the incredulity and stultifying caution of the financial world, at whose door must be laid the blame for the excessive delay in bringing to the human race the far-reaching benefits of this new technology.

The FEVA Diode

Curiously enough, one of the key devices in this new range does not in fact amplify voltages. It mirrors the original space-walk conditions: enclosed in a sealed glass capsule (Fig. 1) is a hot wire and a metal plate. When the wire is heated by passing a current through it, and a potential difference is applied between the wire and the plate, electrons flow from the wire to the plate across the space channel. We have an *electric current*. As in the original scenario, the plate (corresponding to the solar wind detector) is *unheated,* so electrons do not flow from the plate to the wire. Current flows *in only one direction,* just as at a PN junction in semiconductors. These devices have taken their name from their semiconductor equivalent device and are known as FEVA *diodes*. But whereas we have to use highly purified silicon and rare metals such as antimony to manufacture a semiconductor device, the FEVA needs nothing but sweet nothingness to provide its conducting channel. Apart from the low-cost metals used for making the wire and plate, the FEVA is constructed entirely of re-cycled glass and plastic.

The story of the terminal pin design is an amusing one. Lee was looking for something to hold his prototype FEVA diode when he came across a handy four-pin socket which had resided for years unused in his junkbox (Fig. 2). He had never known the original purpose of this socket, for it had been in the box when it was donated to him by

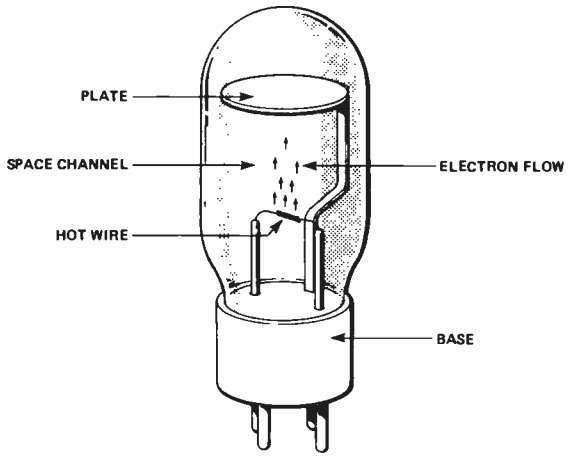


Fig. 1 The prototype FEVA diode. The base is of formaldehyde-phenol plastic (known as Bakelite) and is not to be confused with the base of a transistor.

his grandfather. It suited the present purpose well and, such is the way of things once they have been found to suit, there was no real incentive to re-design the socket for later devices. The novel 'kite' configuration of the pins offers many advantages over the old-fashioned DIL array. As many electronics hobbyists known to their cost, it is so easy to insert the IC the wrong way round, but this is quite impossible with a FEVA.

Field Effect Devices

If the FEVA diode is the counterpart of the semiconductor diode, the basic FEVA device typified by the PM2DX (Fig. 3) is the equivalent of the field effect transistor. The so-called 'grid' is a sheet of wire gauze cunningly introduced by Lee between the wire and plate to modulate the electric field and so regulate the flow of electrons in the space channel. A very small change in the potential of this plate has a significant effect on the current flowing through the device, simulating the effect of gate potential in a conventional FET, though the mechanism is somewhat different and at present less well understood. A resistor placed in series with the plate (or *anode* as it is now called, referring of course to the corresponding anode terminal of the semiconductor diode) develops a useful change of potential running to several tens of volts. Incidentally, these devices work at high voltages, levels that would reduce the ordinary FET to a bead of charred silicon!

Integration

No sooner had the initial designs been proven in extensive laboratory and field trials than the logical follow-up was to put more than one device in the same capsule. An early example is the ECH21 frequency converter (Fig. 4), but already the OEMs, eager for the rapid and profitable returns that this new technology will generate for many decades to come, are pressing ahead with mind-boggling developments.

The first commercial product incorporating the new range of miniaturized FEVAs is to be launched in April 1983. This is a digital time-piece of elegant and sizable proportions. No need for the short-sighted to put on their specs to read this one! It comes with a durable PVC backpack for the battery power supplies, with a choice of embroidered shoulder straps for the ladies. Those of you who have a half-acre building-plot to spare and have planning permission for a five-storey block, will be pleased to know that the first 1-kilobyte FEVA-technology personal computer is due to be launched in April 1984. The installation expenses may readily be recouped, for it incorporates heat-exchangers which may be connected as a thermal source for your local district-heating scheme.

In the meantime, hobbyists can throw away their magnifying glasses and turn to the man-sized technology of the future. Mauldin Electronics Ltd and Armpit International are both marketing a hobbyist familiarization conversion kit which includes an assortment of FEVAs, 3kg of FEVA sockets, four square metres of 14 swg aluminium sheet for mounting the FEVA sockets ('chassis' is the newly coined term), a 50 W soldering iron with 8 mm bit, an oven-glove for use in handling hot FEVAs and a colourful but comprehensive wall-chart on first aid for electrocuted persons. Our own sister magazine, Spam Radio Today, is hoping to publish details of a transceiver project using these devices.

Coming Of Age

The heady days of the development era of the FEVA are over. The name itself, harking back to the sixties, is nowadays thought to be too flippant for a technology which is to bring Britain back to world domination in the

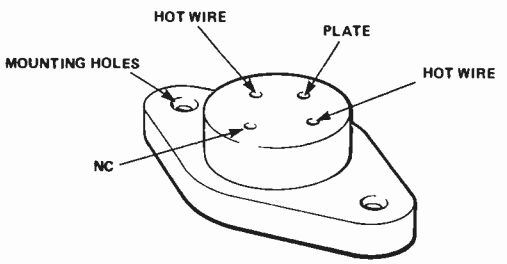
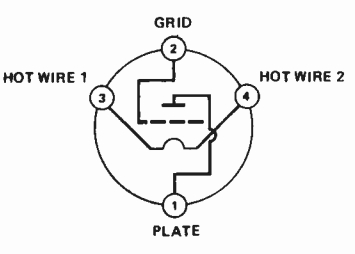


Fig. 2 Yet another type of socket to add to the massive range we already have. Known as the UX4, it is the new standard socket for FEVA diodes, and is available in a range of attractive colours: black, brown, grey or buff.

electronics of the twenty-first century (and beyond?). There is a strong move afoot to rename FEVAs even before their first name becomes a byword to the man in the street. For one thing, with the advent of the Shuttle, space technology is becoming commonplace and no longer excites the imagination as it once did. The new name for this technology firmly faces facts, replacing 'space channel' by 'vacuum'. So if you never hear anything more about FEVAs, the wonder of our age, keep a sharp look-out for their new designation — Vacuum Linked Voltage Expanders. The new name is sticking well and already the back-room boys have affectionately shortened this to 'VALVE'.



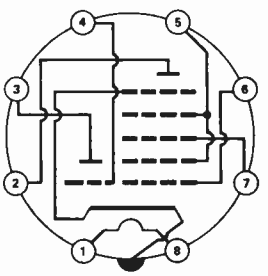


Fig. 3 (Left) Pin-out schematic of the PM2DX, the basic FEVA amplifier.

Fig. 4 (Right) Pin-out schematic of the ECH21, the FEVA technology frequency counter. Is this the first step towards a computer in a capsule?

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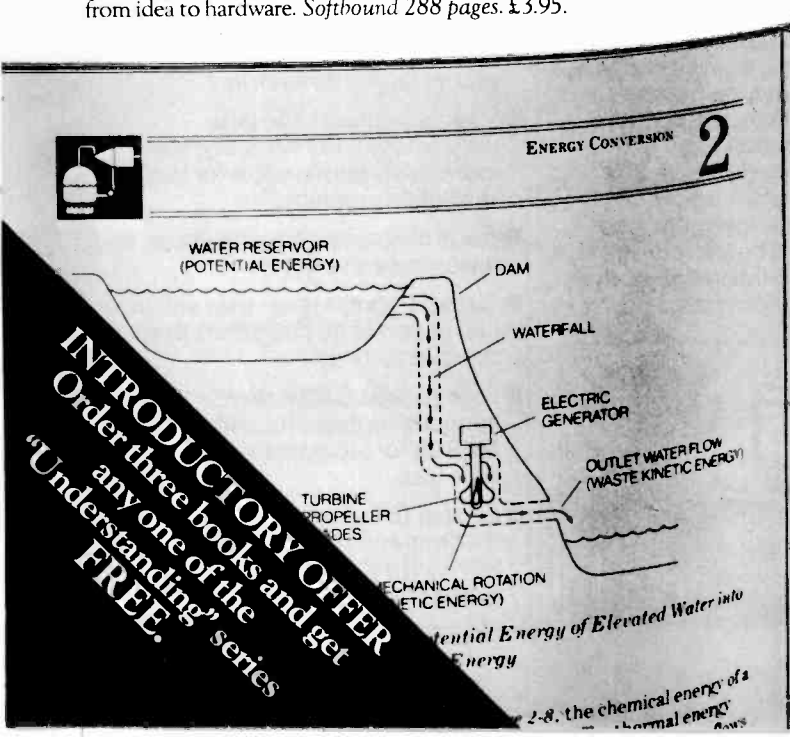

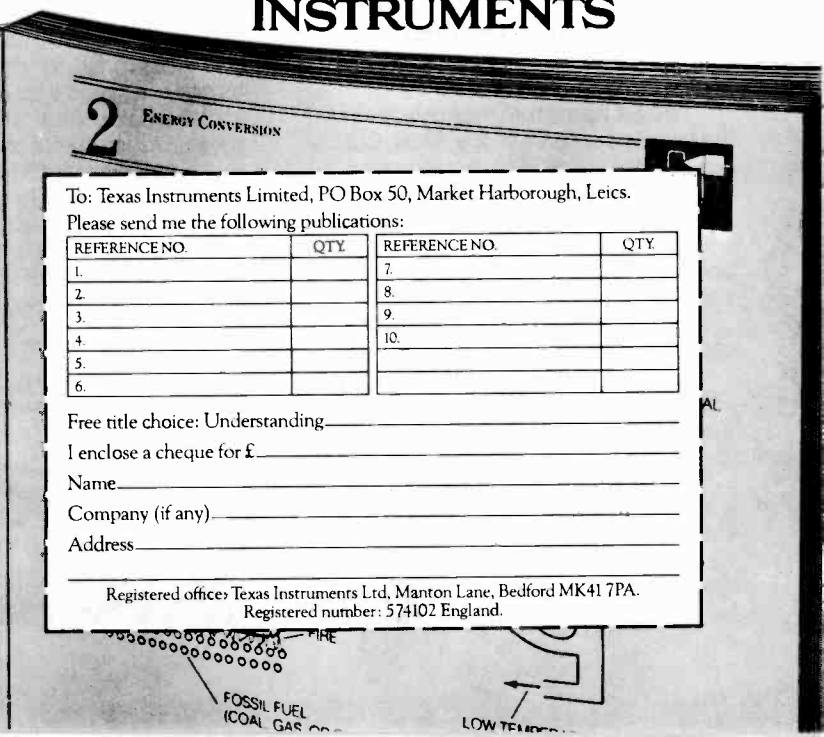

Sinclair ZX Spectr

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Yet the price of the Spectrum 16K is an amazing £125! Even the popular 48K version costs only £175!

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Ready to use today, easy to expand tomorrow

Your ZX Spectrum comes with a mains adaptor and all the necessary leads to connect to most cassette recorders and TVs (colour or black and white).

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Key features of the Sinclair ZX Spectrum

- Full colour – 8 colours each for foreground, background and border, plus flashing and brightness-intensity control.
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- Full-size moving-key keyboard – all keys at normal typewriter pitch, with repeat facility on each key.
- High-resolution – 256 dots horizontally x 192 vertically, each individually addressable for true high-resolution graphics.
- ASCII character set – with upper- and lower-case characters.
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ZX Expansion Module

This module incorporates the three functions of Microdrive controller, local area network, and RS232 interface. Connect it to your Spectrum and you can control up to eight Microdrives, communicate with other computers, and drive a wide range of printers.

The potential is enormous, and the module will be available in the early part of 1983 for around £30.

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Tel: Camberley (0276) 685311.

The ZX Printer – available now

Designed exclusively for use with the Sinclair ZX range of computers, the printer offers ZX Spectrum owners the full ASCII character set – including lower-case characters and high-resolution graphics.

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The ZX Printer connects to the rear of your ZX Spectrum. A roll of paper (65ft long and 4in wide) is supplied, along with full instructions. Further supplies of paper are available in packs of five rolls.

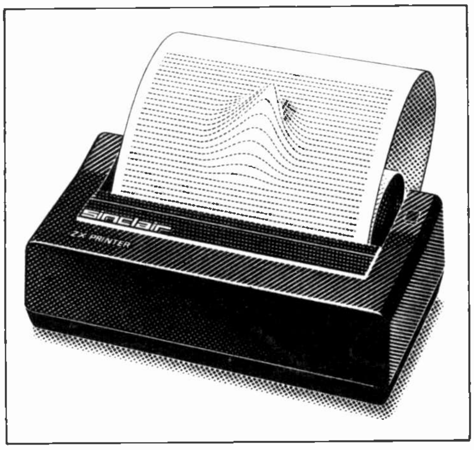
The ZX Microdrive – coming soon

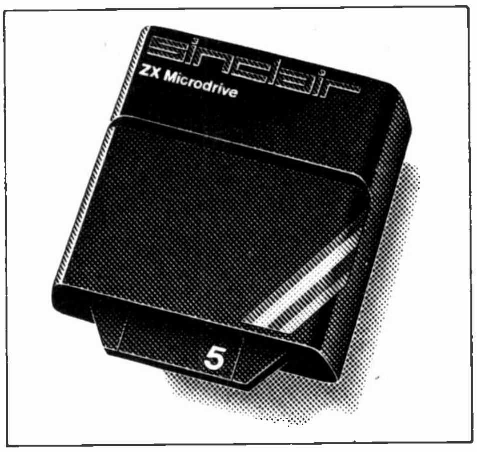
The new Microdrives, designed especially for the ZX Spectrum, are set to change the face of personal computing by providing mass on-line storage.

Each Microdrive can hold up to 100K bytes using a single interchangeable storage medium.

The transfer rate is 16K bytes per second, with an average access time of 3.5 seconds. And you'll be able to connect up to 8 Microdrives to your Spectrum via the ZX Expansion Module.

A remarkable breakthrough at a remarkable price. The Microdrives will be available in the early part of 1983 for around £50.





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Setting Up

Set SW5, the manual/auto switch, to manual for the channel designated '0'. Check that the master blackout switch is off, and that RV1 for that channel is set to minimum (the manual slide pot). Set the speed-up switch SW4 to off, and turn PR8 to minimum. Now switch on the mains and set PR9 to mid-position. Slide RV1 to maximum and adjust PR7 for maximum light output. Then slide RV1 to minimum and set PR8 to give minimum light output (the bulb should just glow). Repeat these adjustments until the light glows at the minimum setting of RV1 and is full on at the maximum setting.

To set up the auto-fade units, first set SW5 for the channel to automatic, with RV1 at minimum. Set PR6 on the channel to be calibrated to minimum and set the scene select switches to '00'. Now, using the keyboard, program the channel, '00', the lighting level, '0', and the time duration, '37'. Press the enter button; the display should now read '00 0 37'. Enter the following:

SCENE	DATA
01	00137
02	00237
03	00337
04	00437
05	00537
06	00637
07	00737

Remember to press the enter button after each entry of five digits. Now set the scene selector switches to '07' and press SW1. Set PR5 one-third of a rotation clockwise from minimum, set PR13 to maximum, and adjust PR6 to give the maximum light output. Now set the scene selector switch to '00' and press SW1 again. Adjust PR1 for minimum light output (the light should just glow). Now by using the scene select switches and the scene change switch to step through the data sequence just programmed in, the remaining presets PR2,3,4,10,11 and 12 may be adjusted as appropriate to give the eight lighting levels.

To adjust for an even ramp rate, reset the scene select switch and press the scene change switch so as to compare the time between the light rising to the preset level and falling to zero. If there is any difference, adjust PR5 until the time rise and fall times of the light level are about the same. Alternatively, if you have a scope you can inject a signal at pin 2 of IC29 and look at the output (pin 6). Adjust PR5 to give a square wave with equal mark-space ratio.

This completes the setting-up for the first channel. Repeat for the other channels, but remember when programming to change the channel number as appropriate for the first two key presses ('01' for the next cannel and so on).

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R2-4	10k
R5	100R
R6	390R
R7-36	180R
R37,38	560R
R39	22k
R40,42-50	1k0
R41	1k5
R88,89	470R
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C1,3,4,26	100n polycarbonate or polyester
C2	33u 16 V tantalum
C5	1u0 35 V tantalum
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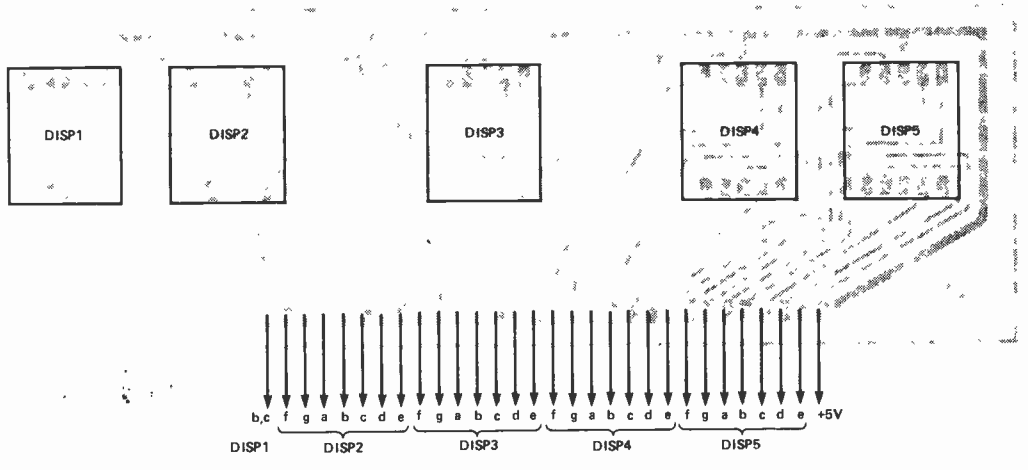
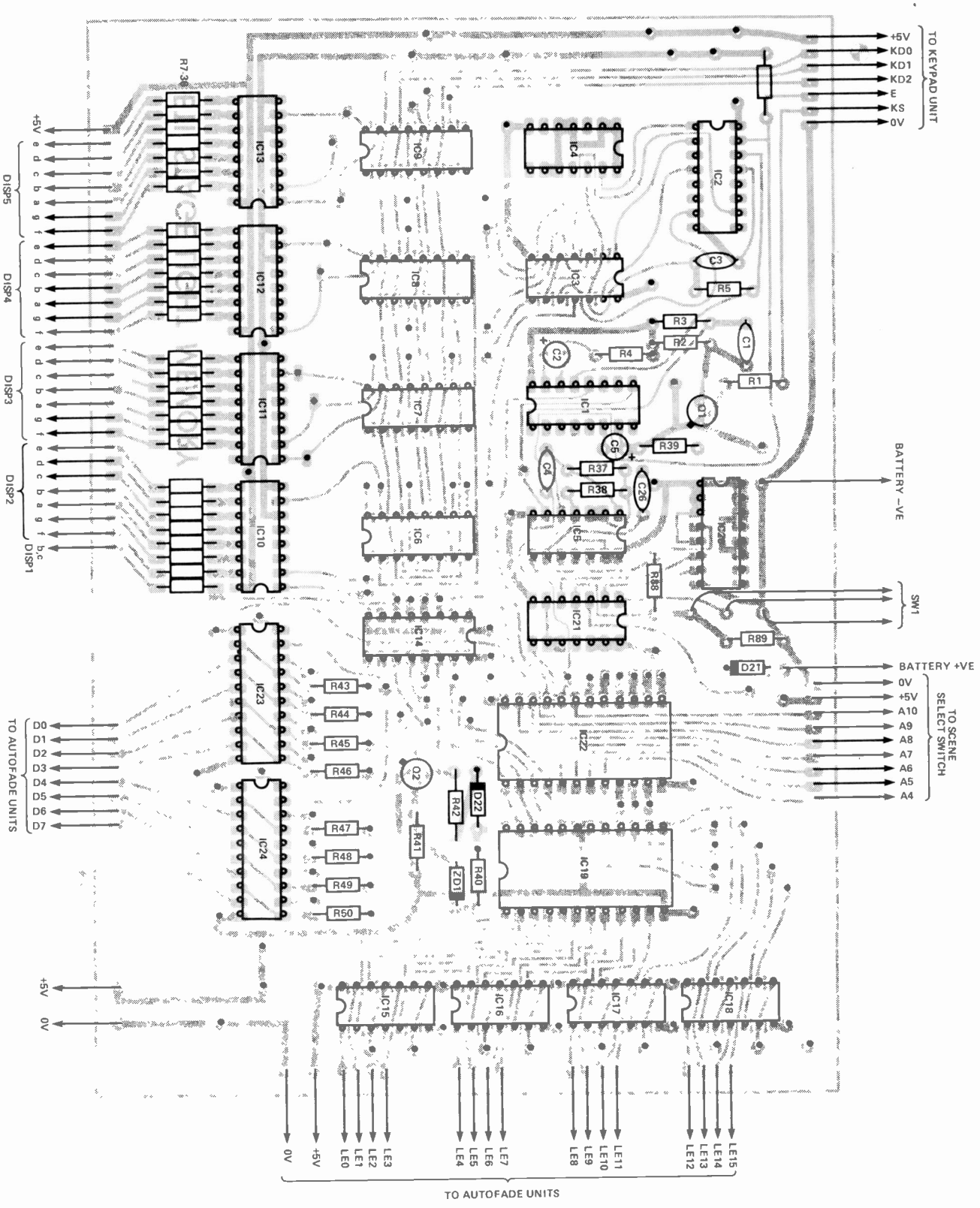
IC1	74LS123
IC2	4017
IC3,4	74LS08
IC5	74LS04
IC6-9	74LS75
IC10-13	74LS47
IC14	74LS163
IC15-18	74LS02
IC19	74LS154
IC20	74LS109
IC21	74LS00
IC22	6116
IC23,24	81LS97
Q1,2	BC108
D21,22	1N4148
ZD1	2V7 400 mW zener
DISP1-5	0.5" common-anode seven segment displays
Miscellaneous	
SW1	SPCO push-button or toggle
PCBs (see PCB Service ad on page 87).	




TO KEYPAD UNIT
+5V
KD0
KD1
KD2
E
KS
0V
BATTERY -VE
SW1
BATTERY +VE
0V
+5V
A10
A9
A8
A7
A6
A5
A4
TO SCENE SELECT SWITCH
TO AUTOFADE UNITS
D0
D1
D2
D3
D4
D5
D6
D7
DISP5
DISP4
DISP3
DISP2
DISP1
+5V
0V
0V
+5V
LE0
LE1
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TO AUTOFADE UNITS
IC1
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R49
R50
R88
R89
C1
C2
C3
C4
C5
C26
Q1
Q2
D21
D22
ZD1

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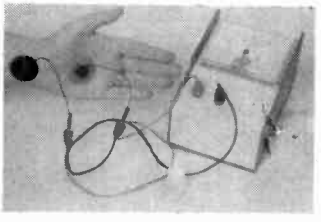

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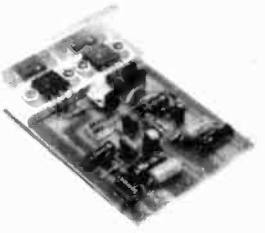

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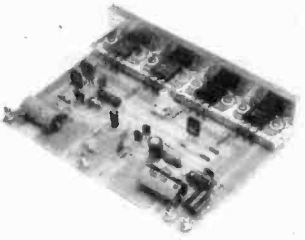

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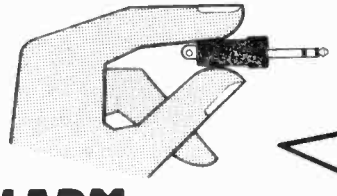

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DESIGNING NDFL AMPS

The use of nested differentiating feedback loops (NDFLs) is a new technique for reducing audible-frequency distortion in an amplifier to a vanishingly low level. As the name implies, NDFLs rely on negative feedback, but they use it in a new way. Edward M. Cherry, Associate Professor of the Department of Electrical Engineering, Monash University, explains the theory involved.

In order to understand just how far the new NDFL technique can improve an amplifier, we first need to know the fundamental limits to the reduction of distortion that can be achieved with conventional techniques. To begin with, we survey familiar negative-feedback theory.

Figure 1 is a block diagram of an amplifier with negative feedback. In this diagram, the forward path corresponds to the amplifier before feedback is applied, and its gain is traditionally designated by the Greek letter μ. The feedback network returns a fraction β of the output to the input circuit, where it is in some way subtracted from the true input to provide the actual input to the forward path.

In many practical amplifiers, the subtraction is accomplished by applying the input and feedback signals to the two inputs of a balanced differential first stage of the forward path. Figure 2 is an outline practical circuit. In this circuit the feedback factor β is the attenuation of the network comprising R_{F1} and R_{F2}

$$\beta = \frac{R_{F1}}{R_{F1} + R_{F2}} \qquad (1)$$

A typical value for an audio power amplifier might be 1/20. The forward-path gain μ in Fig. 2 corresponds to gain from input to output when the feedback network is removed. A typical value for a simple audio power amplifier might be 1000.

For Fig. 1, the overall closed-loop gain A is given precisely by

$$A = \frac{\text{Output}}{\text{Input}} = \frac{\mu}{1 + \mu\beta} \qquad (2)$$

The quantity $\mu\beta$ is called the loop gain. Physically, loop gain is the gain that would be observed if the feedback 'loop' in Fig. 1 was cut at some point, a signal was injected into one side of the cut, and the resulting signal at the other side of the cut was measured.

If the values of μ and β are such that loop gain is small compared with unity, the closed-loop gain is very nearly equal to the forward-path gain (that is, the gain without feedback)

$$A \rightarrow \mu \quad (\mu\beta \ll 1) \qquad (3)$$

However, if loop gain is large compared with unity, the closed-loop gain approaches the reciprocal of the feedback factor and becomes almost independent of the forward-path gain

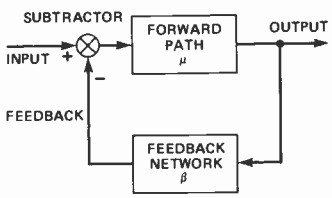


Fig. 1 Block diagram of a feedback amplifier.

$$A \rightarrow 1/\beta \quad (\mu\beta \gg 1) \qquad (4)$$

The quantity 1/B is often called the demanded gain, as it is the value the overall closed-loop gain would take in ideal circumstances.

As a numerical example, if we substitute the above values $\mu = 1000$ and $\beta = 1/20$ into Equation 2, the gain of our 'typical' audio power amplifier works out as A = 19.6. The approximate Equation 4 predicts A → 20, within 2% of the correct answer.

The quantity $1 + \mu\beta$ occurs often in feedback theory. It is called the return difference F.

$$F = 1 + \mu\beta \qquad (5)$$

Physically, return difference has the significance

$$F = \frac{\text{forward-path gain}}{\text{closed-loop gain}} \qquad (6)$$

For values of loop gain greater than about 10, loop gain and return difference are almost equal — in our 'typical' example the value are 50 and 51 respectively.

Simplified treatments of feedback theory show that, if the distortion generated in the forward path (that is, the amplifier without feedback) at a particular output signal amplitude is D_μ, then the resulting closed-loop distortion D_A at the same output signal amplitude is

$$D_A = D_\mu / F \qquad (7)$$

Distortion is improved when feedback is applied to an amplifier by a factor equal to the return difference. In our 'typical' amplifier, F = 51; if the distortion without feedback happened to be 10%, then feedback should reduce the distortion to 0.196%.

More rigorous treatments of feedback theory show that Equation 7 is no more than a poor approximation to the truth. In the first place, real amplifiers are far more complicated than Fig. 1 suggests, because several different feedback paths (not all intentional!) can be identified. For example, the collector-base capacitances of transistors inevitably provide some unintended feedback at high frequencies. There is a very real problem in interpreting just

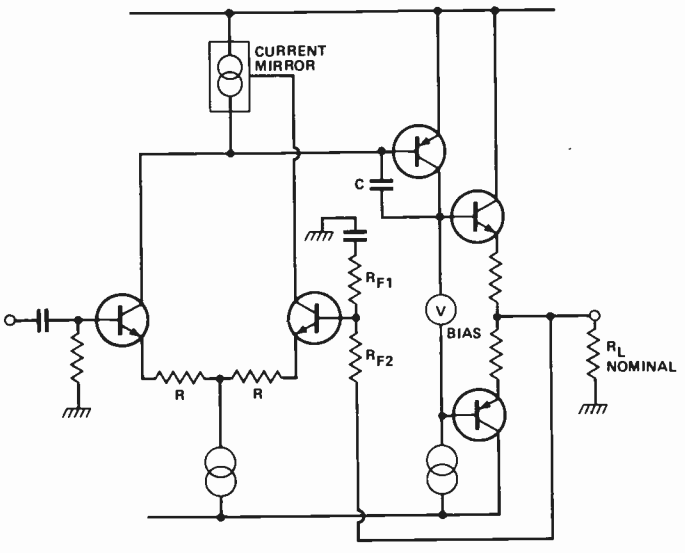


Fig. 2 Outline circuit of an audio power amplifier.

what loop gain and return difference mean when there is more than one feedback loop. Once the correct interpretation is established, return difference invariably turns out to be a function of frequency, and the reduction of distortion corresponding to Equation 7 depends on the value of return difference at the frequency of the distortion, not the frequency of the input. Feedback therefore, does not reduce all distortion components equally.

Finally, it is found that the closed-loop distortion of an amplifier can contain new components that were not present in the distortion that existed in the forward path before feedback was applied. These new distortion components initially increase as loop gain is increased, but they fall away again towards zero as loop gain is made large.

Despite all these complications, the fact remains that adequate negative feedback, properly applied, does reduce distortion. Why, then, do amplifier designers not simply apply some arbitrarily large amount of feedback and reduce amplifier distortion to the vanishing point?

TIM, IIM, PIM, . . .

In the last 10 years or so, readers of audio magazines have been made aware of a conjecture that goes something like this:

> "Harmonic distortion and the usual intermodulation distortion decrease with increasing feedback. Transient intermodulation distortion (TIM) increases with increasing feedback, and is approximately directly proportional to the feedback. Therefore, there is an optimum value for the feedback at which the subjective distortion sensation is least. This optimum feedback is unlikely to exceed about 20 dB."

More recently, there has been conjecture that heavy overall feedback should be applied with caution if interface intermodulation distortion (IIM) is to be avoided. An amplifier should provide a low open-loop output impedance so that the need for feedback-generated loudspeaker damping is minimised.

There has also been conjecture that negative feedback, which reduces the usual intermodulation distortion, may increase phase intermodulation distortion (PIM) by converting amplitude nonlinearities into phase nonlinearities.

Unequivocally, none of these conjectures has any basis in the new NDFL amplifiers. As an aside, there is a substantial body of opinion that none of these conjectures has any basis, full stop; interested readers should refer to References 1-9.

Instability And Oscillation

A fundamental limit to the amount of feedback that can be applied to an amplifier is set by the onset of instability and oscillation.

If the magnitudes of the forward-path gain and demanded gain of the idealised Fig. 1 are plotted versus angular frequency ω (in radian/second) on logarithmic scales, the resulting graph looks something like Fig. 3. The 3 dB bandwidth of the amplifier without feedback is $1/\tau_\mu$, and the gain-bandwidth product (at which gain drops to unity) is $1/\tau_1$.

Because the graph is on logarithmic scales, the separation between the curves of forward-path gain and demanded gain is the loop gain (remember that, to divide two numbers, you subtract their logarithms; if you divide μ by $1/\beta$, you get $\mu\beta$). The magnitude of loop gain falls to unity at the frequency $1/\tau_x$ where the curves intersect and their separation is zero (remember that the logarithm of unity is zero).

By a similar argument, return difference is the separation between the curves of forward-path gain and closed-loop gain, as indicated in Fig. 3.

We could make a similar graph to Fig. 3, showing the phases of μ and $1/\beta$. Again, the phase of loop gain would turn out to be the separation between the two curves. However, there is a remarkable piece of mathematics due to Bode, who used a transformation evolved by Hilbert (1862-1943), which shows that there is a relation between the magnitude and phase of the response of any linear system. Subject to some qualifications, our proposed graph of the phases is completely predictable from Fig. 3 and contains no new information. Interested readers may refer to Chapter 14 of Bode's book (Reference 10) but are warned that it is anything but easy going!

As an example, many readers will know that, if the forward-path in Figs. 1 and 3 has a high-frequency cut-off rate variously described as single pole, 20 dB/decade, or 6 dB/octave, then its phase shift is 45° at the 3 dB cut-off frequency $1/\tau_\mu$, and is asymptotic to 90° at very high frequencies.

In 1932, Nyquist applied a theorem which dates back to Cauchy (1789-1857) to derive the condition for a feedback amplifier to be stable and free from oscillation. If a polar plot is made of the magnitude and phase of return difference as frequency is varied, a vaguely 'snail-shaped' curve results. Such a polar plot is called a Nyquist diagram. Subject again to some qualifications, the stability criterion for a feedback amplifier is that its polar plot of return difference should not enclose the origin. Figure 4

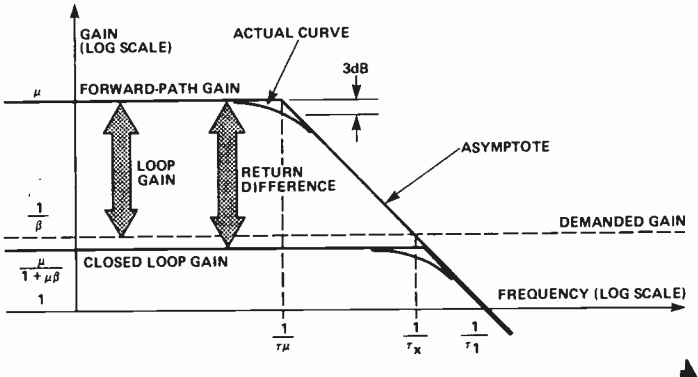


Fig. 3 Logarithmic plots of gain versus frequency for Fig. 1.

shows one example each of a stable situation and an unstable situation.

Because the phase of return difference can be predicted from Fig. 3 via Bode's result a Nyquist diagram can also be constructed from Fig. 3 and the onset of instability can be predicted. In 1945 Bode showed that Nyquist's criterion could in fact be expressed in terms of the gradients of the curves in Fig. 3, thereby eliminating the work of finding the phase explicitly and plotting the Nyquist diagram. Bode's exact rule is complicated, but a useful paraphrase is

> "If in graphs such as Fig. 3 the separation between the forward-path gain and demanded gain decreases toward zero at a rate not exceeding 30 dB/decade, the amplifier is unlikely to oscillate."

This paraphrase makes no allowance for the tolerances on components. It assumes, in effect, that everything about the forward path is well known and constant. In the audio context, the paraphase takes no cognizance of the fact that the capacitance of the leads that connect an amplifier and loudspeaker is anything but well known. A more conservative rule, applicable to the audio context, is therefore

> "In graphs such as Fig. 3, the separation between the forward-path gain and demanded gain should not decrease towards zero at a rate exceeding 20 dB/decade."

transistors is a fraction of a nanosecond, but for power transistors of the ubiquitous 2N3055 class the transit time may be as long as a few tenths of a microsecond. Thus, the output stage of Fig. 2 may have a pole in the vicinity of 1 MHz.

As we saw in the previous section, the unity-loop-gain frequency $1/\tau_x$ in Fig. 3 must be substantially less than the frequency of all poles except the dominant pole $1/\tau_\mu$ if an amplifier is to be stable. If the power transistors are of the 3055 class then, no matter how fast the other transistors may be, there is going to be one pole at about 1 MHz. Therefore $1/\tau_x$ must be chosen to correspond to something like 200 kHz. Even with more modern power transistors, $1/\tau_x$ is restricted to about 1 MHz. The art of designing a stable power amplifier involves choosing the lag compensating capacitor C such that $1/\chi_x$ is appropriate to the transistors actually used.

The geometry of Fig. 3 is such that, no matter how μ, β and τ_μ are separately chosen, the return difference $F(\omega)$ at any angular frequency ω cannot exceed

$$F(\omega) \leq 1/\omega\tau_x \qquad (8)$$

Thus, if $1/\tau_x$ is designed to correspond to 200 kHz, return difference at 20 kHz cannot exceed 10 (= 20 dB), and cannot exceed 200 (= 46 dB) at 1 kHz. An amplifier that boasts 80 dB of feedback (F = 10,000 at low frequencies) must have $1/\tau_\mu$ corresponding to about 20 Hz; return difference must begin falling above 20 Hz, and the former

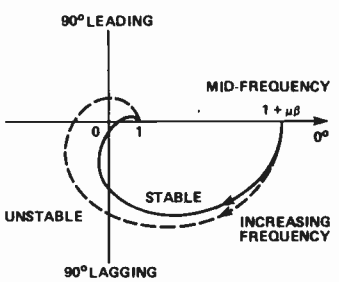


Fig. 4 Nyquist's stability criterion. The curves are polar plots of return difference for changing frequency.

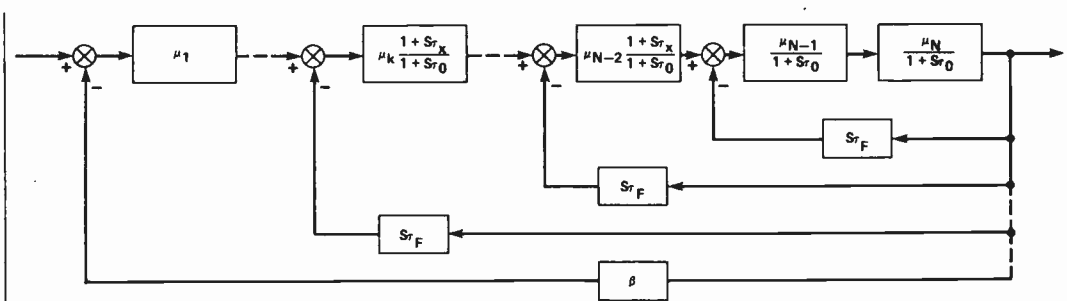


Fig. 5 Block diagram of an NDFL amplifier.

The practical consequence is that the forward path of an audio amplifier with conventional resistive feedback should have a single dominant pole which sets the fall-off of gain at frequencies above $1/\tau_\mu$. The second and subsequent poles should lie at frequencies substantially above $1/\tau_x$ (the frequency where the separation reaches zero), because each pole contributes a 20 dB/decade downwards slope to the graph of forward-gain path.

Maximum Available Feedback

In Fig. 2, the first stage is a long tailed pair with a current mirror at its output; the input and feedback signals are applied to the two bases to perform the subtraction process of Fig. 1. The second stage provides a large voltage gain, and the lag compensating capacitor C provides the dominant pole of the forward path corresponding to $1/\tau_\mu$ in Fig. 3. The third stage is a complementary class-B emitter follower whose function is to transfer the output voltage from the second stage to the loudspeaker load. In practice, the transistors in the second and third stages are often Darlingtons, and the input transistors are often replaced by FETs.

In any similar amplifier, there is at least one pole associated with the finite transit time of electrons through each transistor. The transit time for typical small-signal

values at 1 kHz and 20 kHz (46 dB and 20 dB) still apply.

Returning now to Equation 7, the effectiveness of feedback in reducing distortion is set by the frequency of the distortion, not the frequency of the input. The audible frequency range is generally reckoned to extend to about 20 kHz and, with the foregoing constraints, return difference at this frequency cannot exceed 10. Remembering that 20 kHz is the third harmonic of 6.667 kHz, we see that feedback cannot reduce offensive odd-harmonic distortion of mid-treble input signals by more than a factor of 10. Remembering too that 20 kHz is the seventh harmonic of 2.857 kHz, we see that feedback cannot reduce crossover distortion of mid-range input signals by more than a factor of 10.

Until recently there has been no way around this problem except to increase the unity-loop-gain frequency $1/\tau_x$, and this demands that the frequencies of the transistor poles must be increased if stability is to be preserved. Fragile, expensive power transistors, with narrow bases to achieve short transit times, become mandatory.

The NDFL Approach

There is, however, another solution to the stability problem. If the forward-path gain has two dominant poles, so that its gain falls at 40 dB/decade, the rate of closure

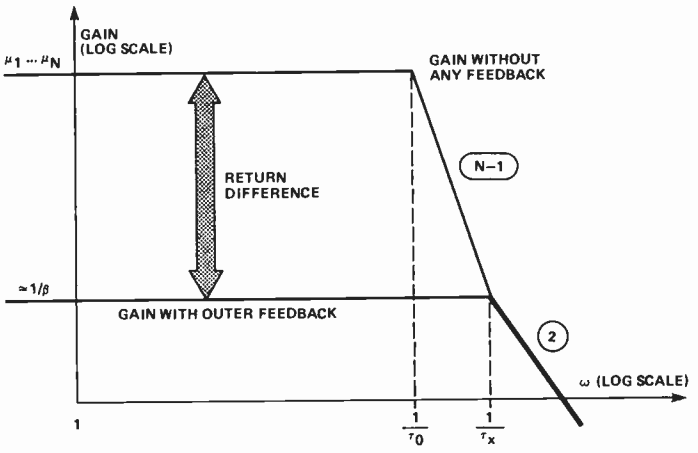


Fig. 6 Logarithmic plots of gain versus frequency for Fig. 5.

between the graphs of forward-path gain and demanded gain would still be 20 dB/decade provided the demanded gain itself were to fall at 20 dB/decade. In essentials, this requires that the usual frequency-independent resistive feedback factor β should be replaced by something having a frequency dependence of the form $\omega\tau_F$ (remember that the demanded gain is the reciprocal of the feedback factor). Mathematicians tell us that a linearly rising frequency response corresponds to differentiation with respect to time and, in hardware terms, a capacitive feedback network will perform just this action.

Figure 5 shows the outline of an amplifier incorporating nested differentiating feedback loops. Notice first that the forward path has been separated into a number of stages, whose mid-frequency gains are μ_1 to μ_N respectively. The variable s is what mathematicians call complex frequency; for sinusoidal signals its magnitude is equal to the angular frequency ω of the sinusoid. Factors of the form $(1 + s\tau_x)$ represent a frequency response that rises proportional to frequency above the frequency $1/\tau_x$ — that is, they represent a zero. Similarly, factors of the form $1/(1 + s\tau_.)$ represent a frequency response that falls inversely proportional to frequency above the frequency $1/\tau_0$ — that is they represent a pole. Thus, the stages in Fig. 5 have special frequency responses: all stages except the first have a pole at $1/\tau_.$, and all except the first and last two have a zero at $1/\tau_x$.

Notice also that there are differentiating feedback networks, each denoted by $s\tau_F$, linking the output back to various points in the forward path. The resulting feedback loops are arranged one inside another, like a nest of Chinese boxes — hence the name nested differentiating feedback loops.

The amplifier is completed by an overall resistive feedback network β.

If we removed all the feedback from Fig. 5, the forward-path gain would be shown in Fig. 6: constant up to the frequency $1/\tau_0$, then falling at an (N – 1)-pole rate (20(N – 1) dB/decade) up to $1/\tau_x$, and finally levelling off somewhat to a two-pole rate (40 dB/decade).

If we now applied just the overall resistive feedback β, the return difference would be as shown in Fig. 6. Distortion would be reduced by a constant large amount, approximately $\mu_1\ \mu_2 \ldots \mu_N\ \beta$, at all frequencies up to $1/\tau_0$. Choosing $1/\tau_0$ to correspond to 20 kHz would virtually eliminate audible-frequency distortion. *But the amplifier would be unusable because of oscillation.*

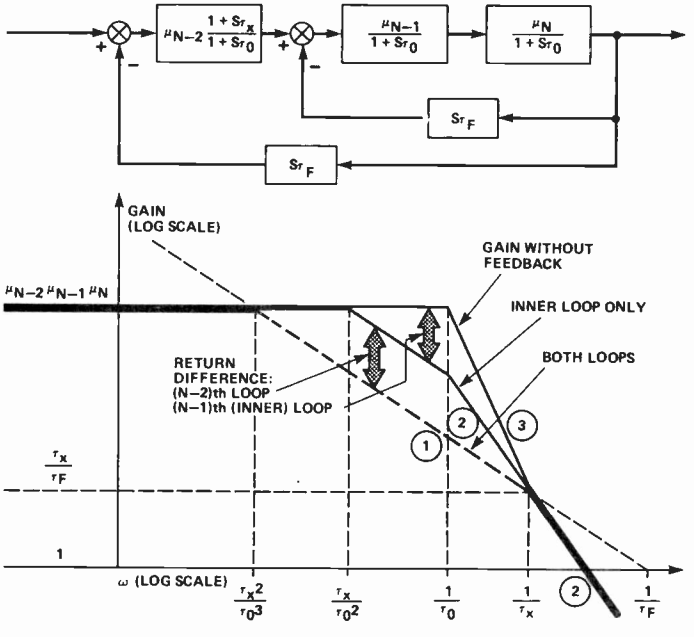


Fig. 8 The (N-2)th loop of Fig. 5.

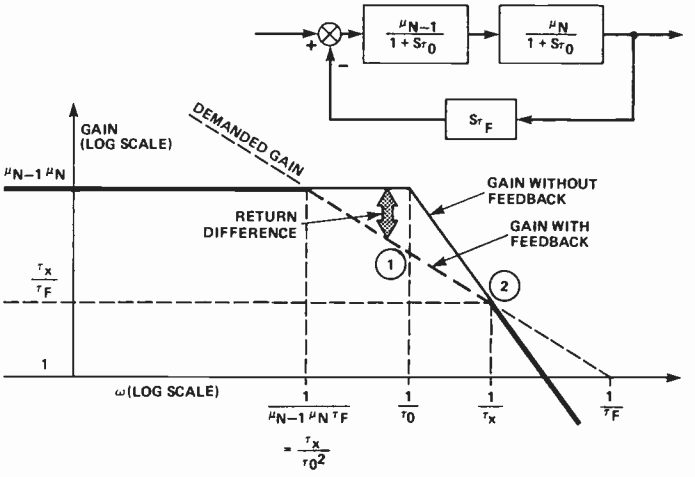


Fig. 7 The inner loop of Fig. 5.

The rate of closure of the forward-path gain and demanded gain curves breaks the rule of 20 dB/decade. Let us see how inclusion of the nested differentiating feedback loops solves the problem.

Figure 7 shows just the last two stages and the inner differentiating feedback factor. This 'clump' is a feedback amplifier in its own right, and Fig. 7 shows its forward-path gain (that is, the gain of the last two stages without any feedback), the demanded gain, and the resulting closed-loop gain. Although the forward-path gain falls at a two-pole rate (40 dB/decade), the demanded gain falls at a one-pole rate (20 dB/decade), and their rate of closure is 20 dB/decade. By itself, this 'clump' is stable.

Figure 8 shows what happens when we add the antepenultimate stage and another differentiating feedback factor. Again this 'clump' can be considered as a feedback amplifier in its own right. Provided we choose.

$$\mu_{N-2} = \tau_0/\tau_x$$

the various gains line up as shown. The forward-path gain is the combined gain of stage (N – 2) and stages (N – 1) and N with their local feedback, and this is the middle solid curve in Fig. 8. The demanded gain is the dashed curve passing through $1/\tau_F$. Once again the forward-path gain and demanded gain close at 20 dB/decade, so the stability criterion is satisfied for this larger 'clump'.

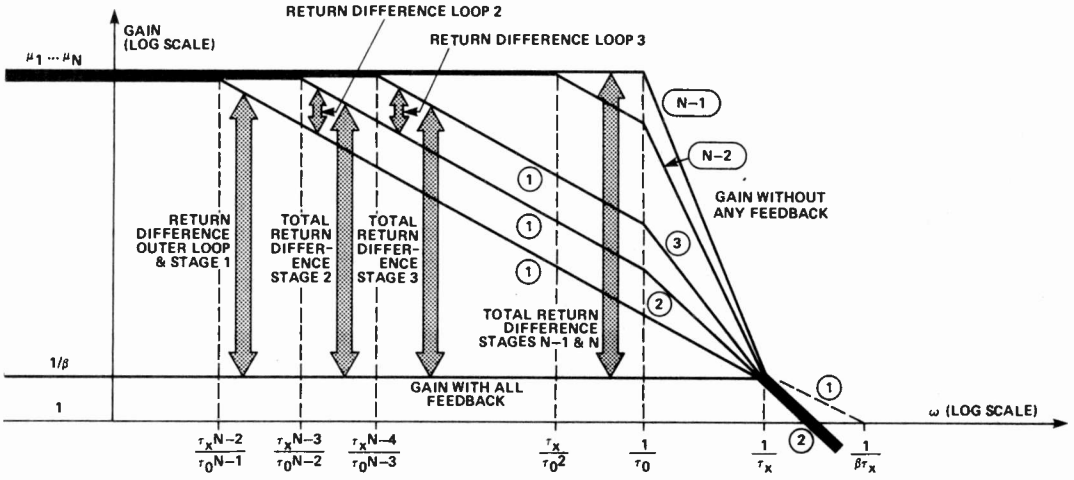


Fig. 9 Complete plots of gain versus frequency for Fig. 5.

And so it goes on. We can add more stages and differentiating feedback factors, and each time the curves line up as required for stability provided we choose

$$\mu_1 \mu_{N-1} \mu_N B = (\tau_0/\tau_x)^2, \quad (9)$$

$$\tau_F = \mu_1 \beta \tau_x, \quad (10)$$

$$\mu_K = \tau_0/\tau_x \text{ for } 2 \leqslant k \leqslant N-2. \quad (11)$$

Figure 9 shows the gain curves for the complete amplifier.

In designing an NDFL amplifier, the starting point is to choose the frequency $1/\tau_x$ so that the various transistor poles are sure to lie at substantially higher frequencies. Next choose the frequency $1/\tau_0$ up to which the return difference should remain constant; 20 kHz is a suitable value for audio amplifiers. After this, the circuit more or less designs itself via Equations 9-11 above.

Outline Practical Circuit

Figure 10 shows how an amplifier of the basic topology of Fig. 2 can be modified to include two NDFLs. Interested readers should refer to references 11, 12 for more details.

Notice first that the lag compensating capacitor, C, in the penultimate stage of Fig. 2 has been removed in Fig. 10. In its place are two capacitors (C) linking the output back to various points in the forward path. These capacitors are the feedback networks of the nested differentiating feedback loops.

The output stage has been changed to include a modified form of Thiele's load-stabilising network. Some form of LRC filter is required to locate one of the poles correctly, and with the circuit shown we get double value from the components.

The input stage itself is unchanged, but an inexpensive small capacitor in the overall feedback network β can be used to correct the group delay and improve the reproduction of transient waveforms.

Another essential addition is an amplifying stage between the two nested differentiating feeback factors. This rather peculiar circuit (which dates back to Rush in 1964) seems largely to have been forgotten. It uses one NPN transistor and one PNP to provide a well-defined gain (13).

As already suggested, once the demanded gain $1/\beta$ and the critical frequency $1/\tau_x$ are chosen, the circuit almost designs itself. The equations are:

$$\frac{R_{F1}}{R_{F1} + R_{F2}} = \beta, \quad (12)$$

$$RC = \beta\tau_x, \quad (13)$$

$$R_Y C_Y = \tau_x, \quad (14)$$

$$\tau_L = (\sqrt{3} - 1)\tau_x. \quad (15)$$

All stage gains and poles and zeros automatically look after themselves.

Figure 11(a) shows the 5 kHz square-wave response of Fig. 10 as built from 5%-tolerance resistors, 20%-tolerance capacitors, and unselected production transistors. Evidently the circuit is 'designable'; Equations 12-15 really do predict component values for good transient response.

A nice feature of the modified Thiele circuit in Fig. 10 is that, when the load is made capacitive (a well-known source of high-frequency oscillation in amplifiers), the voltage waveform at the FEEDBACK POINT is the waveform the amplifier would have delivered into its nominal resistance load. Figures 11(b) and (c) illustrate this; the violent ringing in Fig. 11(b) is simply an LC resonance between the filter inductor and the load capacitance, and is in no way indicative of approaching instability.

Figure 12 shows details of the 1 kHz sinusoidal response under overdrive conditions. Note the quick,

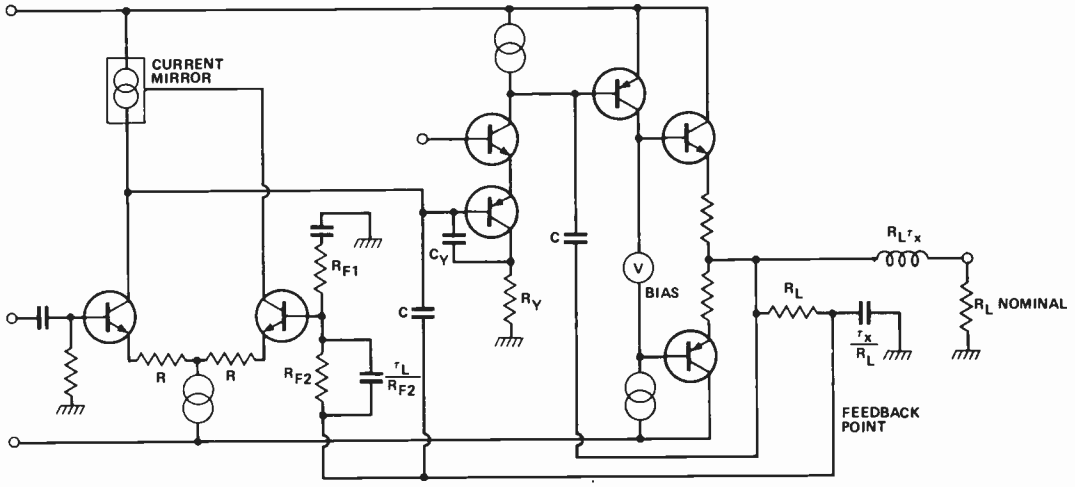
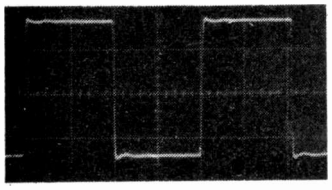
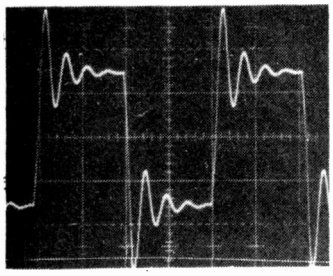


Fig. 10 Outline circuit for an NDFL amplifier.

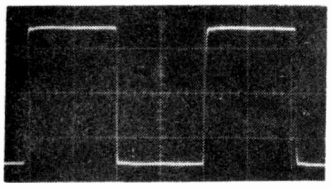
Fig. 11 5 kHz square wave response of Fig. 10.



(a) 8 ohm resistance load.



(b) 8 ohm and 2uF parallel load.



(c) waveform at feedback point for (b).

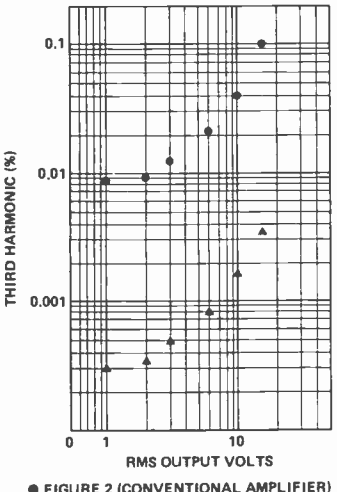


Fig. 13 1 kHz harmonic distortion.

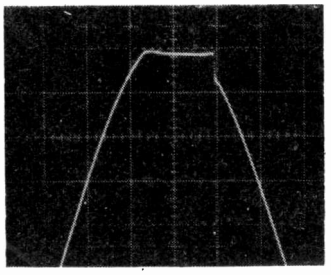
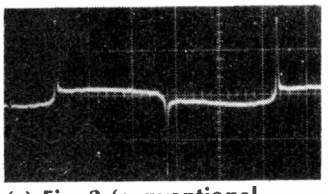
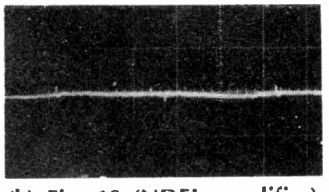


Fig. 12 Detail of output waveform from Fig. 10 under overdrive.

Fig. 14 2 kHz crossover distortion when bias is set wrongly.



(a) Fig. 2 (conventional amplifier).



(b) Fig. 10 (NDFL amplifier).

clean recovery.

An amplifier has been built in which the circuit can be switched from Fig. 2 to Fig. 10, to illustrate the improvement in performance of adding two NDFLs. Figure 13 compares the measured third-harmonic distortions of 1 kHz. Notice how the distortion of Fig. 10 drops away to below three parts per million at small signal amplitudes. Such behaviour is more typical of class-A amplifiers than class-B amplifiers, and may account for the clean sound of NDFL amplifiers.

Crossover distortion associated with incorrect bias of the output stage is one of the most audibly annoying forms of distortion. Audio amplifiers based on Fig. 2 sometimes have a type of crossover distortion that does not show up in normal measurements. Correct biasing of the output stage relies on close tracking of the thermally-compensated biasing device and the power transistors. At best the biasing device can be thermally bonded to the power transistor case. More usually it is bonded to the heatsink, but there is no way it can simultaneously sense the actual junction temperatures of all the power transistors. Under rapidly-fluctuating dynamic signal conditions, the junction temperatures may be wildly different from each other and from the case or heatsink temperatures, and therefore the biasing may be wrong.

Figure 14 compares the static cross-over distortion of Figs. 2 and 10 when the bias is deliberately set 0V5 too low. Dynamic mistracking of the biasing circuit should not introduce audible crossover distortion in an NDFL amplifier.

One final point. The NDFL technique maximises the return difference (and hence minimises distortion components) at frequencies up to $1/\tau_0$. Above this frequency the return difference falls away rapidly, and distortion rises. Choosing $1/\tau_0$ to correspond to 20 kHz minimises audible-frequency distortion, but does not minimise ultrasonic distortion.

For example, a common specification for audio power amplifiers is their THD at 20 kHz. The harmonics of 20 kHz lie at 40 kHz, 60 kHz, 80 kHz, and so on. All are ultrasonic (and hence inaudible) and the NDFL technique does not minimise them. A measurement of THD at 20 kHz may therefore give a quite misleading indication of an NDFL amplifier's audible performance. Valid objective tests include the SMPTE and CCIF tests for two-tone intermodulation distortion, the proposed IEC test for TIM (14), Cordell's proposed three-tone test for TIM (15) and the proposed test for input-output intermodulation distortion IOD (6). The distinguishing feature of all these tests is that they measure the distortion at audible frequencies.

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4012	0.16
4013	0.20
4014	0.40
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4016	0.20
4017	0.32
4018	0.36
4019	0.36
4020	0.36
4021	0.40
4022	0.40
4023	0.13
4024	0.32
4025	0.13
4026	0.74
4027	0.20
4028	0.32
4031	0.94
4033	1.80
4034	0.94
4035	0.38
4040	0.36
4041	0.36
4042	0.34
4043	0.36
4044	0.36
4045	1.35
4046	0.42
4047	0.70
4048	0.38
4049	0.23
4050	0.23
4051	0.38
4052	0.44
4053	0.44
4054	0.85
4055	0.85
4060	0.39
4063	0.85
4066	0.24
4068	0.14
4069	0.14
4070	0.13
4071	0.13
4072	0.13
4073	0.14
4075	0.13
4076	0.43
4077	0.13
4078	0.15
4081	0.13
4082	0.13
4085	0.50
4086	0.44
4093	0.20
4502	0.46
4507	0.32
4508	0.96
4510	0.40
4511	0.41
4512	0.40
4514	0.98
4515	0.98
4516	0.40
4518	0.40
4519	0.27
4520	0.40
4521	0.90
4522	0.52
4526	0.52
4527	0.52
4528	0.41
4532	0.72
4541	0.50
4543	0.50
4553	1.57
4555	0.35
4556	0.35
4585	0.75

74LS SERIES

00	0.11
01	0.11
02	0.11
03	0.12
04	0.12
05	0.12
08	0.12
09	0.12
10	0.12
11	0.12
12	0.12
13	0.12
14	0.25
15	0.12
20	0.12
21	0.12
22	0.12
26	0.12
27	0.12
28	0.12
30	0.12
32	0.12
33	0.12
37	0.12
40	0.12
42	0.28
47	0.35
48	0.45
49	0.12
51	0.12
54	0.12
55	0.12
73	0.18
74	0.16
75	0.18
76A	0.17
78A	0.18
83A	0.36
85	0.42
86	0.16
90	0.22
91	0.60
92	0.32
93	0.22
95B	0.40
109A	0.27
112A	0.20
113A	0.20
114A	0.22
122	0.28
123	0.34
125A	0.24
126A	0.25
132	0.34
136	0.25
138	0.25
139	0.27
145	0.57
148	0.70
151	0.40
153	0.40
155	0.30
156	0.35
157	0.25
158	0.30
160A	0.32
161A	0.35
162A	0.35
163A	0.35
164	0.40
165A	0.50
166A	0.80
173A	0.55
174	0.40
175	0.38
181	0.90
190	0.35
191	0.35
192	0.35
193	0.35
194A	0.35
195A	0.35
196	0.45
197	0.45
221	0.46
240	0.55
241	0.55
242	0.55
243	0.55
244	0.55
245	0.70
248	0.55
249	0.55
251	0.30
253	0.35
257A	0.30
258A	0.35
259	0.55
261	1.00
266	0.20
273	0.54
279	0.30
283	0.40
290	0.39
293	0.39
365	0.27
366	0.27
367	0.27
368	0.27
373	0.62
374	0.62
375	0.35
377	0.60
378	0.60
379	0.90
386	0.35
390	0.45
393	0.45

OIL JUMPERS

Single Ended 24"

14 PIN	1.45
16 PIN	1.65
24 PIN	2.40
40 PIN	3.80

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	6"	12"	18"
14 PIN	1.85	1.98	2.42
16 PIN	2.05	2.15	2.68
24 PIN	3.00	3.15	3.96
40 PIN	4.65	4.90	6.18

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10 PIN	0.86
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26 PIN	1.76
34 PIN	2.06
40 PIN	2.32
50 PIN	2.35
60 PIN	3.20

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10 PIN	1.40
14 PIN	1.82
16 PIN	2.10
20 PIN	2.48
26 PIN	3.24
34 PIN	3.80
40 PIN	4.90
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60 PIN	6.38

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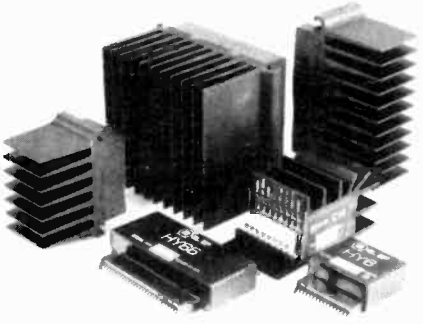

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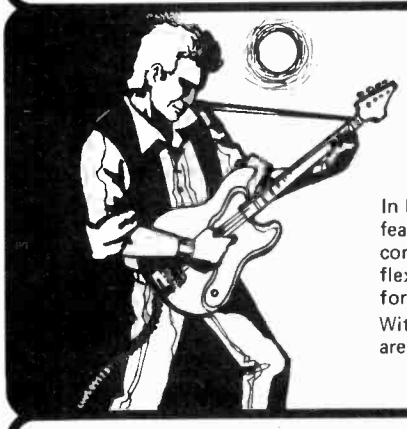
the third generation

Due to continous improvements in components and design ILP now launch the largest and most advanced generation of modules ever.



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With over 10 years experience in audio amplifier technology ILP are recognised as world leaders.

BIPOLAR MODULES

Module Number	Output Power Watts rms	Load Impedance Ω	DISTORTION T.H.D. Typ at 1KHz	DISTORTION I.M.D. 50Hz/ 7KHz 4:1	Supply Voltage Typ	Size mm	WT gms	Price inc. VAT
HY40	15	4-8	0.015%	<0.006%	± 18	76 x 68 x 40	240	£8.40
HY60	30	4-8	0.015%	<0.006%	± 25	76 x 68 x 40	240	£9.55
HY6060	30 + 30	4-8	0.015%	<0.006%	± 25	120 x 78 x 40	420	£18.69
HY124	60	4	0.01%	<0.006%	± 26	120 x 78 x 40	410	£20.75
HY128	60	8	0.01%	<0.006%	± 35	120 x 78 x 40	410	£20.75
HY244	120	4	0.01%	<0.006%	± 35	120 x 78 x 50	520	£25.47
HY248	120	8	0.01%	<0.006%	± 50	120 x 78 x 50	520	£25.47
HY364	180	4	0.01%	<0.006%	± 45	120 x 78 x 100	1030	£38.41
HY368	180	8	0.01%	<0.006%	± 60	120 x 78 x 100	1030	£38.41

Protection: Full load line. Slew Rate: 15v/µs. Risetime: 5µs. S/N ratio: 100db.
Frequency response (−3dB) 15Hz – 50KHz. Input sensitivity: 500mV rms.
Input Impedance: 100KΩ. Damping factor: 100Hz >400.

PRE-AMP SYSTEMS

Module Number	Module	Functions	Current Required	Price inc. VAT
HY6	Mono pre amp	Mic/Mag. Cartridge/Tuner/Tape/ Aux + Vol/Bass/Treble	10mA	£7.60
HY66	Stereo pre amp	Mic/Mag. Cartridge/Tuner/Tape/ Aux + Vol/Bass/Treble/Balance	20mA	£14.32
HY73	Guitar pre amp	Two Guitar (Bass Lead) and Mic + separate Volume Bass Treble + Mix	20mA	£15.36
HY78	Stereo pre amp	As HY66 less tone controls	20mA	£14.20

Most pre-amp modules can be driven by the PSU driving the main power amp.
A separate PSU 30 is available purely for pre amp modules if required for £5.47 (inc. VAT). Pre-amp and mixing modules in 18 different variations.
Please send for details.

Mounting Boards
For ease of construction we recommend the B6 for modules HY6—HY13 £1.05 (inc. VAT) and the B66 for modules HY66—HY78 £1.29 (inc. VAT).

POWER SUPPLY UNITS (Incorporating our own toroidal transformers)

Model Number	For Use With	Price inc. VAT
PSU 21X	1 or 2 HY30	£11.93
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PSU 42X	1 x HY128	£15.90
PSU 43X	1 x MOS128	£16.70
PSU 51X	2 x HY128, 1 x HY244	£17.07
PSU 52X	2 x HY124	£17.07
PSU 53X	2 x MOS128	£17.86
PSU 54X	1 x HY248	£17.86
PSU 55X	1 x MOS248	£19.52
PSU 71X	2 x HY244	£21.75
PSU 72X	2 x HY248	£22.54
PSU 73X	1 x HY364	£22.54
PSU 74X	1 x HY368	£24.20
PSU 75X	2 x MOS248, 1 x MOS368	£24.20

Please note: X in part no. indicates primary voltage. Please insert "0" in place of X for 110V, "1" in place of X for 220V, and "2" in place of X for 240V.

MOSFET MODULES

Module Number	Output Power Watts rms	Load Impedance Ω	DISTORTION T.H.D. Typ at 1KHz	DISTORTION I.M.D. 60Hz/ 7KHz 4:1	Supply Voltage Typ	Size mm	WT gms	Price inc. VAT
MOS 128	60	4-8	<0.005%	<0.006%	± 45	120 x 78 x 40	420	£30.41
MOS 248	120	4-8	<0.005%	<0.006%	± 55	120 x 78 x 80	850	£39.86
MOS 364	180	4	<0.005%	<0.006%	± 55	120 x 78 x 100	1025	£45.54

Protection: Able to cope with complex loads without the need for very special protection circuitry (fuses will suffice).
Slew rate: 20v/µs. Rise time: 3µs. S/N ratio: 100db
Frequency response (−3dB): 15Hz – 100KHz. Input sensitivity: 500mV rms
Input impedance: 100KΩ. Damping factor: 100Hz >400.

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Mono Power Booster Amplifier to increase the output of your existing car radio or cassette player to a nominal 15 watts rms.

Very easy to use.

Robust construction. **£9.14 (inc. VAT)**

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Frequency response (−3dB) 15Hz to 30KHz, T.H.D. 0.1% at 10w 1KHz
S/N ratio (DIN AUDIO) 80dB, Load Impedance 3Ω
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Stereo version of C15. **£17.19 (inc. VAT)**

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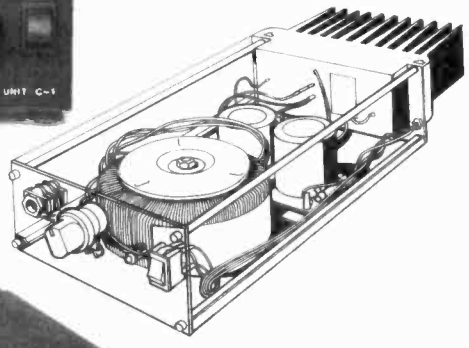

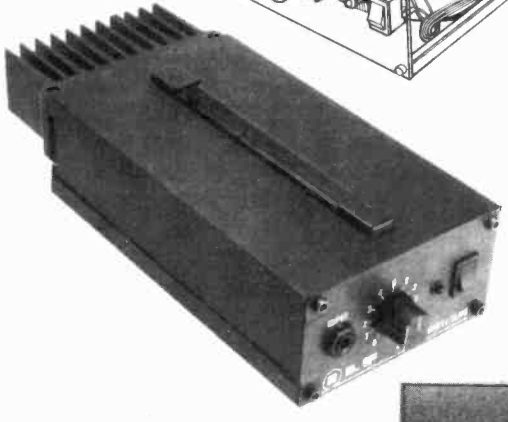

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Over the years ILP has been aware of the need for a complete packaging system for it's products, it has now developed a unique system which meets all the requirements for ease of assembly, adaptability, ruggedness, modern styling and above all price.

Each Unicase kit contains all the hardware required down to the last nut and bolt to build a complete unit without the need for any special tools.

Because of ILP's modular approach, "open plan" construction is used and final assembly of the unit parts forms a compact aesthetic unit. By this method construction can be achieved in under two hours with little experience of electronic wiring and mechanical assembly.

Hi Fi Separates

UC1 PRE AMP UNIT: Incorporates the HY78 to provide a "no frills", low distortion, (<0.01%), stereo control unit, providing inputs for magnetic cartridge, tuner, and tape/monitor facilities. This unit provides the heart of the hi fi system and can be used in conjunction with any of the UP Unicase series of power amps. For ultimate hum rejection the UC1 draws its power from the power amp unit.

POWER AMPS: The UP series feature a clean line front panel incorporating on/off switch and concealed indicator. They are designed to compliment the style of the UC1 pre-amp. Performance for each unit which includes the appropriate power supply, is as specified on the facing page.

Power Slaves

Our power slaves, which have numerous uses i.e. instrument, discotheque, sound reinforcement, feature in addition to the hi fi series, front panel input jack, level control, and a carrying handle. Providing the smallest, lowest cost, slave on the market in this format.

UNICASES

HIFI Separates					Price inc. VAT
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UP3X	60W/8Ω	Bipolar	Mono	HiFi	£54.95
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US3X	60W/4–8Ω	MOS	Power	Slave	£69.96
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ORGAN PART 3

Design by Richard Watts.

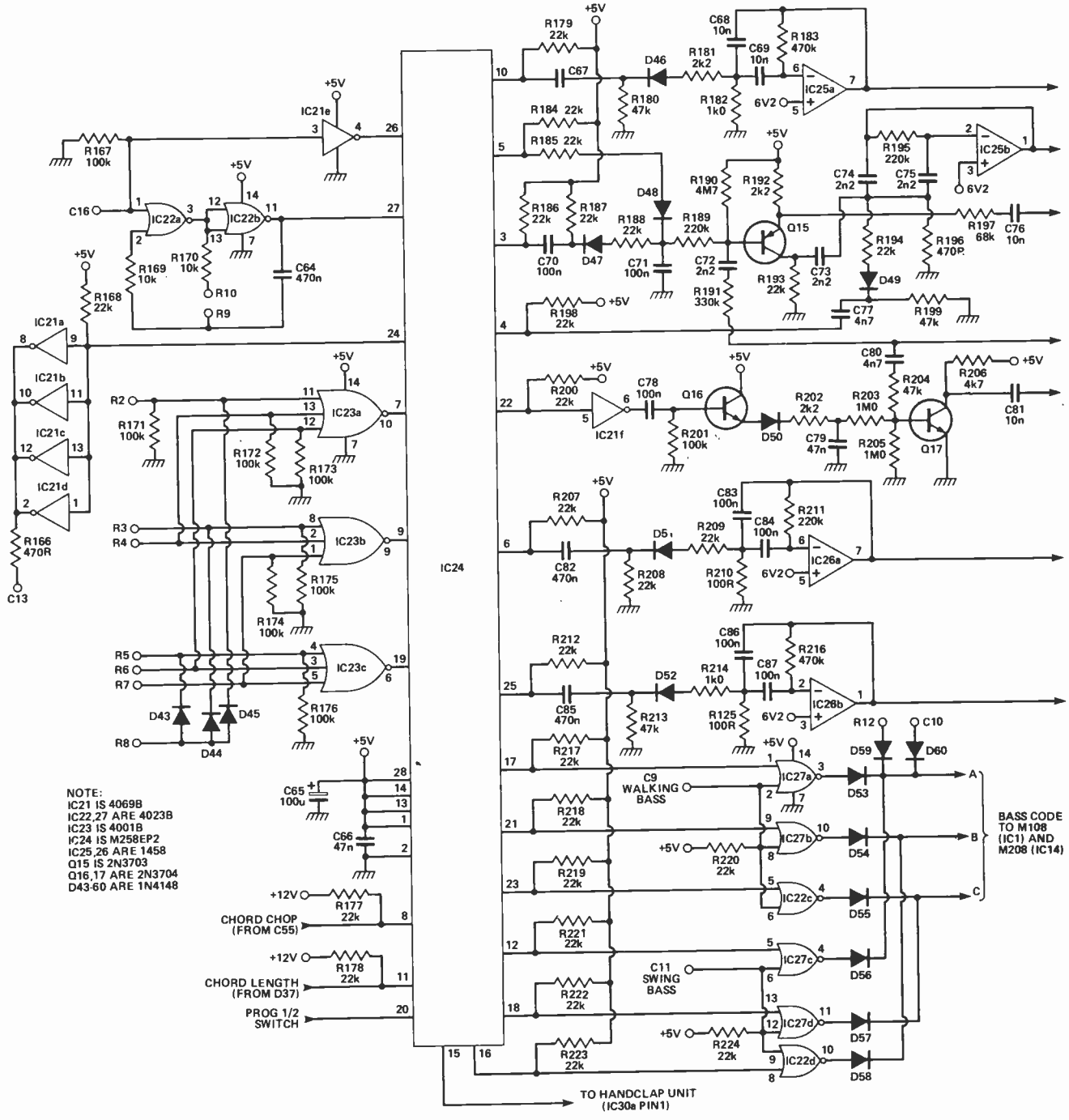


Fig. 1 Circuit diagram of the rhythm section of the Victory organ, including the handclap generator.

This month we conclude the description of the organ circuitry ready for the constructional notes next month. Before doing so, some minor notational changes are required due to continuing development work on the prototype and the consequent re-allocation of certain switches. In Fig. 1 of the February article, the terminal marked R15 (by D6) is now C17, and the terminal marked C15 in Fig. 4 of last month's article should be connected to +12 V, not +5 V. Mark these changes, spread out the two previous issues for reference, and away we go with the rhythm unit.

I Got Rhythm

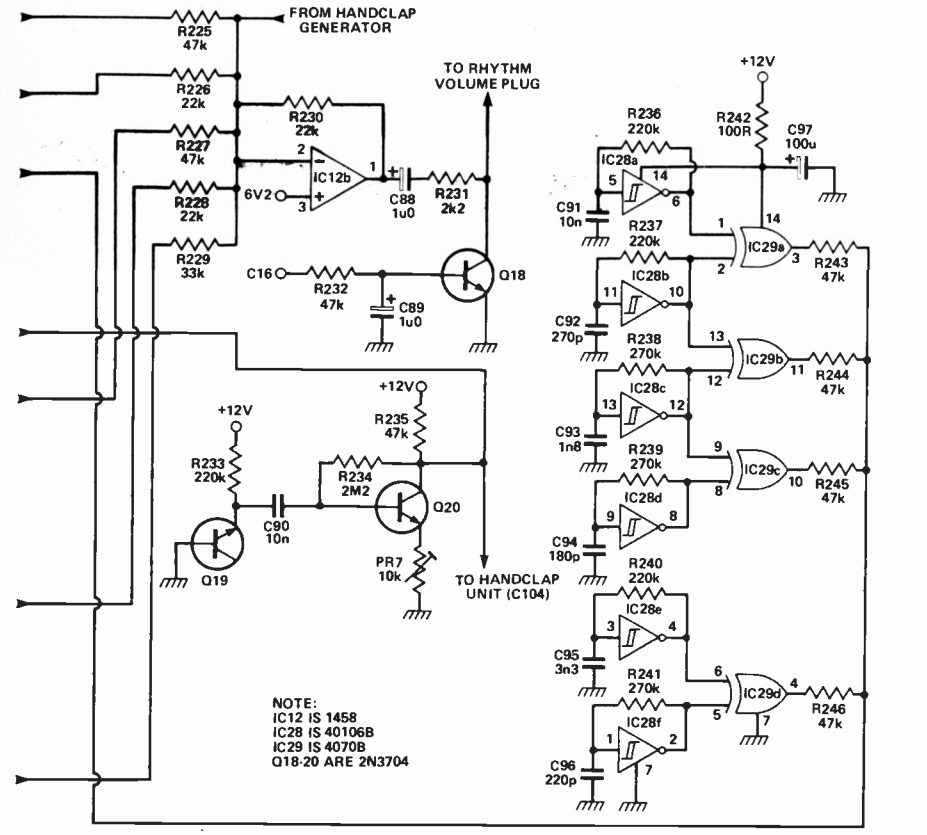
The heart of the rhythm unit is the M258 ROM (IC24). This has a maximum capacity of 8K, organised as 16 rhythms of 32 counts with 16 outputs. In fact this is not all used, as some rhythms have only a 24 count requirement. All inputs to and outputs from the IC are active low.

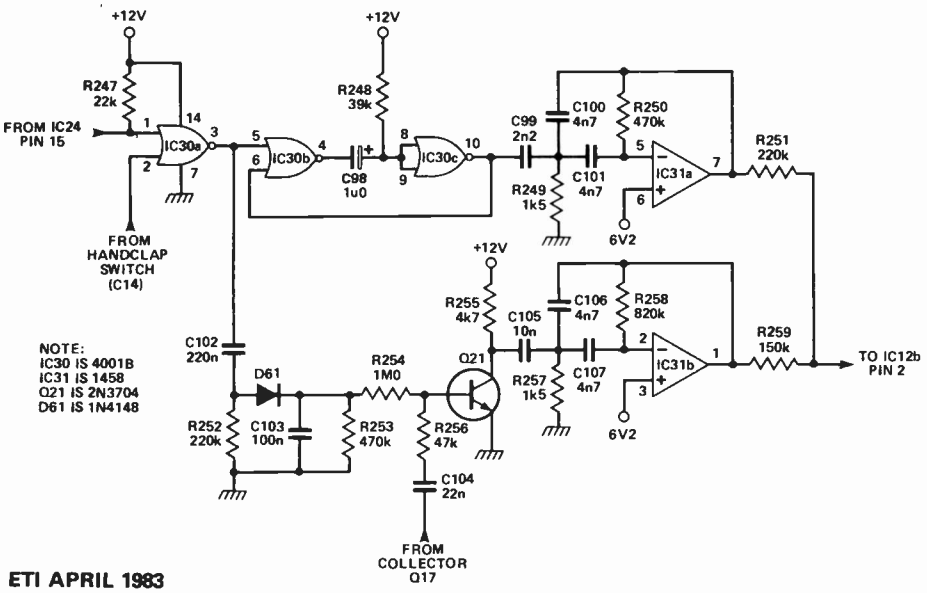
When the rhythm on/off switch is on, connector C13 is taken low. This low is applied to inverter IC21e, which causes a high to be input to pin 26 of the ROM. Although this is a bi-directional connection capable of outputting sync pulses, it is used in this case as the reset input. The low on terminal C16 is also taken to pin 1 of IC22a. This NOR gate, together with IC22b, R169, R170, C64 and the tempo potentiometer (which is connected a across terminals R9, R10) form the rhythm clock generator. The clock input is supplied to pin 27 of the M258. Selection of a rhythm is achieved by switching four input lines (pins 7, 19, 9 and 20) which the IC then decodes using an internal four-to-16 line decoder.

The 16 rhythms are available from nine switches such that each of the first eight is used for two rhythms, called up by the ninth switch (called program 1/2). The eight rhythm switches are mechanically latched and self-cancelling on a new selection. The switches connect +5 V to each of the terminals R2 to R8 which connect to triple three-input NOR gate IC25, used here as an eight-to-three line encoder. Notice that the leftmost rhythm switch does not connect to any points, but due to the mechanical cancelling action of the switches removes +5 V from any of the NOR gate inputs, thus giving the eighth state of all outputs high. The program selector switch provides the fourth bit of information to pin 20 of IC24. The final input requirements are that pins 28, 14, 3 and 1 be at +5 V and pin 2 at ground. This covers the input requirements for the M258: now to the outputs.

Timing within the M258 is arranged such that each count of a rhythm lasts for two cycles of the clock input. The 16 active-low outputs normally remain active for one clock cycle only, but eight of them have the option that they may remain active for the whole count (two clock cycles). This gives the facility of selecting whether the output is pulsed per clock cycle or can be either high or low. In the first state the output must always return to high; in the second it may not, depending on programming. In this ETI organ application pins 5 and 11 are programmed in the second manner: their full purpose in life will be described later.

Output pins 17, 21, 23, 12, 18 and 16 are all used to control the automatic bass patterns when the walking bass 1 and 2 features are selected. If walking bass 1 is selected, point C9 is taken low and enables the NOR gates on the outputs from pins 17, 21 and 23. These gates act as inverters and supply positive pulses through diodes D53-55 to pins 8-10 of both the M108 and M208 ICs.





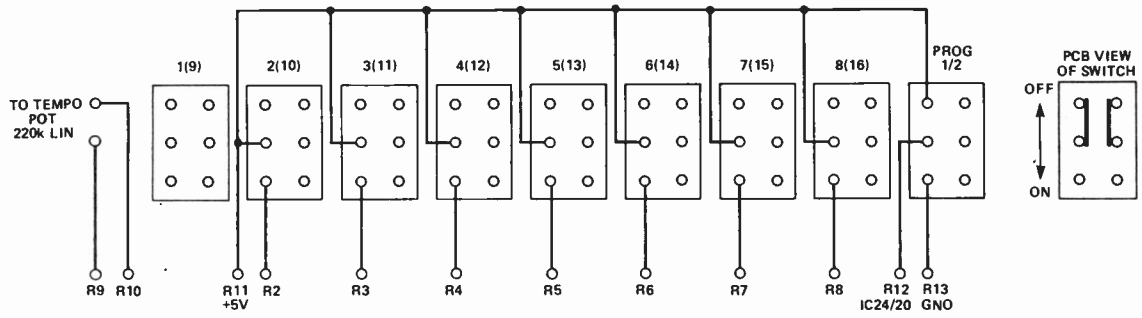


Fig. 2 Connection details for the rhythm switch.

The effect of this is to cause any bass note being played (from either the lower keyboard or the pedals) to be varied in accordance with the codes appearing on pins 8-10. When walking bass 2 is selected, point C9 is pulled high through R220 to +5 V since the grounding by the walking bass switch is cancelled; point C11 is also taken low. This now enables the outputs from the other set of M258 pins (12, 16 and 18) to control the bass note.

Triggering for the bass envelope is is developed in either of these modes from pin 12 of the M108/208 which provides an active-low pulse named TDB (trigger decay bass) every time the bass code changes. This pulse is inverted by either IC5b or IC5d, which are enabled since the selection of either walking bass 1 or 2 removes the high (+12 V) from point C10. This turns off IC7a, thus letting the input of IC6a go high and hence its output low. This low enables the NOR gates as inverters and allows them to pass trigger pulses to the bass output gating circuits. If both walking bass 1 and 2 are switched off while the rhythm is still running, the outputs from the M258 are prevented from passing through the NOR gates (IC27a-d and IC22c,d) and their outputs will be low. Point C10 going high also enables other triggering arrangements for the bass since the TDB signal will no longer be present. If either walking bass 1 or 2 is selected and the rhythm switched off then all the outputs from the M258 will be disabled (high) and therefore all the outputs from the NOR gates will be low. Pin 8 of the M108/208 is now taken high by point C16 from the rhythm on/off switch via D59.

Bass trigger changeover is made by point C17 going low (through the rhythm on/off switch) and pulling the input to inverter IC6a low via D6. Point C17 going low also causes IC2a to turn off momentarily due to the coupling by C8. This briefly removes $\overline{F5}$ from B6, which connection normally gives the latched output at pin 7 of the M208. This is necessary to ensure that, when the rhythm is stopped, the pedals do not continue of their own accord. This momentary disable circuitry is also used on the input side of the M108 to cancel any memorised chord if the rhythm is switched off. It is worth pointing out here that the M258 and the NOR gates supplying the bass codes run from +5 V while the M108/208 run from +12 V. This does not cause a problem since the bass code inputs of the M108/208 will accept anything from +4 V to +18 V as a high level input on these pins when running from +12 V itself.

The M258 output pin 24 is a downbeat indicator and goes low on the first count of any selected rhythm. This signal is connected to four parallel inverters from IC21 to provide current drive to the LED downbeat indicator. Output pin 8 was discussed last month with the lower manual rhythm guitar voice and is used to trigger this voice. The length of decay for the rhythm guitar is determined by the state of output pin 11: this output is one which has the steady state output programmed. If this pin is high the discharge time of C54 is long, thus giving a long chord from the guitar. If the pin is low the discharge time is shortened by putting R145 across C54 and thus giving the short guitar chord. This feature is very important in providing a good, musically interesting backing, and emulates the 'real' guitarist's performance more correctly.

Rhythm Voices

Eight different 'instruments' can be triggered by the M258 outputs. These are cymbal long, cymbal short, cymbal strike tone, handclap, tom-tom, clave, snare drum and bass drum. The bass drum, clave and tom-tom all use similar damped oscillator circuits but with different resonant frequencies. As an example of their operation, the clave voice is triggered by pin 10 of IC24. The oscillator comprises IC25a, R182,183, C68 and C69, the resistors and capacitors determining the frequency of oscillation. Normally the circuit does not oscillate but when a low appears on pin 10 of the M258 a pulse is generated by C67, D46 and R181 which causes the circuit to oscillate momentarily. This damped oscillation synthesizes the sound of the clave and is fed via R225 to IC12b, which is the rhythm mixer/preamp. After decoupling by C88 and the output impedance raised by the series resistance R231, the rhythm sounds pass to the rhythm volume control and then to the final mixer/preamp. Q18 is connected to the rhythm on/off switch so that with the switch-off, Q18 is turned on and shorts out any residual rhythm noise.

The cymbal voice is more complex than any other because of its importance in rhythms. It is developed by triggering a mixture of two noise sources and, optionally, a cymbal strike tone generator which also doubles as cymbal voicer. The first noise source develops white noise and comprises the reverse-biased base-emitter junction of Q19 connected to Q20, which is the amplifier. The output level of this circuit is adjusted by PR7 and is coupled through R191 and C72 to the base of Q15.

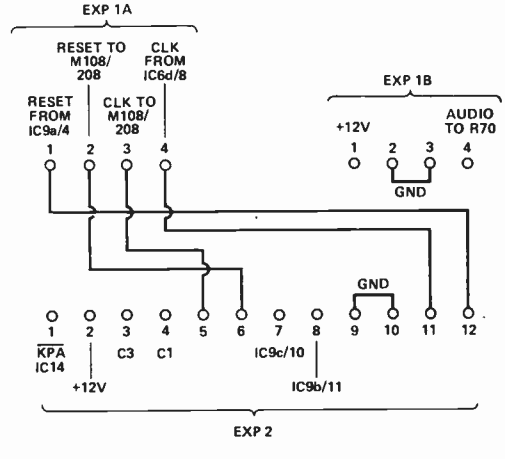


Fig. 3 The wiring of the expansion socket.

The other noise source is responsible for the metallic 'ring' content of the cymbal sound and comprises hex Schmitt inverter IC28 and quad EXOR gate IC29. IC28 is used to form six oscillators, which are EXORed in various combinations and and finally mixed together and coupled via C76 and R197 to the emitter of Q15.

The cymbal trigger pulse from pin 3 of the M258 passes via C70 and causes Q15, normally biased off by R190, to conduct and output a mixture of the two noise sources to its collector, where it is filtered by IC25b. The duration of the cymbal sound is largely determined by how long C71 in the base circuit of Q15 remains discharged. If the M258 output on pin 5 is not active, ie is high, C71 will be charged fairly quickly via R185 (22k) and D48 in parallel with R190. If, however, pin 5 is low, C71 will take much longer to charge through R190 (4M7) alone. These two time constants give the long and short cymbal sounds. Output pin 5 is the other output referred to which does not always return to its high state with each clock cycle. The cymbal strike tone is derived from output pin 4 and makes use of the cymbal filter as a damped oscillator. By careful programming of the ROM, excellent hi-hat effects can be produced in conjunction with the short cymbal sound.

The snare noise trigger is from pin 22 of the M258 and is inverted by IC21f. This positive-going pulse is then coupled via C78 to the emitter follower Q16: D50, R202, C79 and R203 provide shaping for the pulse which is fed to the base of Q17. This transistor is also fed with white noise from Q19, 20 and is normally off: hence no snare noise. When the trigger pulse arrives, Q17 is switched on and amplifies the white noise, which then appears on its collector. Thus the snare drum noise is developed from a passive strike tone, resultant from the fast rise time of the trigger, together with the white noise. The drum part of the snare is produced by the tom-tom generator IC26a.

The last voice on the rhythm unit is the handclap generator, which is gradually appearing on commercial units and will become an industry standard during the year. The generator is enabled by taking pin 2 of IC30a (a NOR) low. Note that IC30 is connected to a +12 V supply, which is necessary for one of the gates to be used elsewhere on the organ. (This highlights one other useful feature of the M258 — all outputs are open-drain and can therefore be pulled up to whatever voltage is required. A quick look at the schematic will show this feature used to effect.) The positive-going output from IC30a pin 3 is fed to Q21, which gates white noise from Q19,20, and also to IC30b,c which are connected as a monostable. The rising and falling edges of this monostable will trigger the damped oscillator of IC31a, producing two beats of the handclap. This is overlayed with white noise from Q21 and filtered by IC31b. Both sound components are summed in the rhythm mixer IC12b.

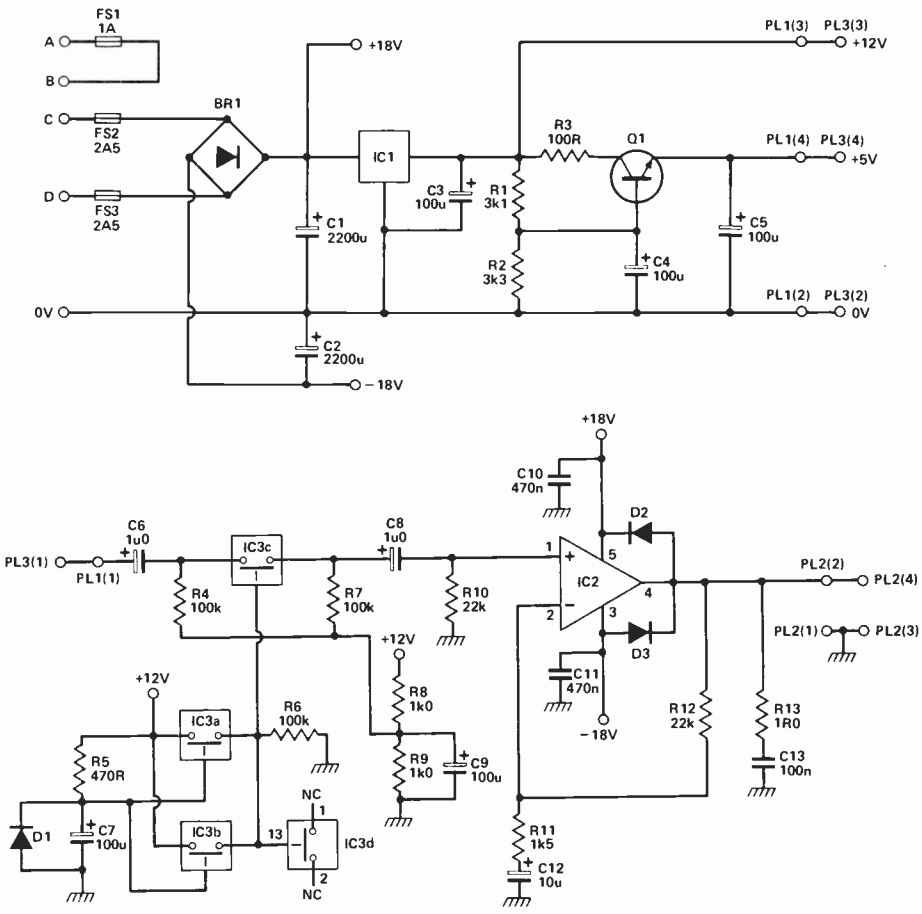


Fig. 4 Circuit diagram of the PSU and amplifier (component numbers restart from 1).

Amplifier/Power Supply

The power supply is of a standard configuration, the ±18 V supplies being used for the amplifier IC. The 12 V supply is obtained from a 7812 regulator IC fed from the +18 V rail and the +5 V (used only in the rhythm section) is derived from the +12 V by Q1.

The power amplifier is an integrated circuit type TDA2030L. Its output is fed to a four ohm loudspeaker via a headphone socket which breaks the connection to the speaker when used. Signal reduction for headphone use is made by a 100R resistor attached to the headphone socket.

The input to the power amplifier is made via IC3c (part of a 4016) which is used to keep the audio line disconnected for a short period immediately after switch-on. This eliminates spurious outputs from both the generator ICs and the rhythm unit caused by switching transients. The audio line both into and out of IC3c is biased at +6 V by R4 and R7, fed from the junction of R8,9 and C9. This is necessary since IC3 is running from a single supply.

At switch-on, IC3c is off because pin 5 is tied to ground through R6. C7 is allowed to charge through R5 until the voltage on C7 is sufficient to turn on IC3a and IC3b, which are connected in parallel. This then applies the +12 V to pin 5 of IC3c, turning it on and connecting the audio line to the power amplifier.

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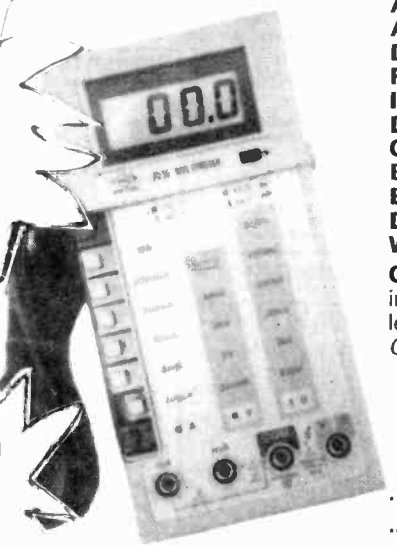

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PUTTING THE BEST WITHIN YOUR GRASP

DESIGNER'S NOTEBOOK 2

Our second Notebook topic is that much-misunderstood beast, the switched mode power supply. P.S. Wilson of International Rectifier gives a step-by-step explanation of the various types and design examples.

The term 'switching mode power supply' is used to describe DC-to-DC converters and AC-to-DC converters which operate on a switching principle. Using switching techniques, voltage step-up and voltage inversion can be achieved, as well as the more common voltage step-down function. The advantages of using switching techniques over a linear solution are the reduction in the size of components (such as power transformers and output filter capacitors) by operating at high frequency, and dramatic improvements in efficiency, since the power elements are either fully turned 'on' or 'off' and do not operate in the linear mode. The disadvantages of switching mode solutions are increased noise and radio frequency interference (RFI) which is generated during the switching transitions. Circuit complexity is increased, as in addition to the control circuit, a power switch, rectifier, high frequency transformer or inductor and drive circuitry is required.

Switching mode solutions are, however, cost-competitive with linear power supplies in off-line applications at and above the 100 W level. Switch mode power supplies are also used at lower power levels in DC-to-DC converters where there is a special requirement such as high efficiency, for example in solar energy conversion, or small size for mobile communications equipment.

Basic Principles

The circuit and waveforms in Fig. 1 illustrate the basic principle of the switching mode supply by comparison with a linear regulator. The circuit configuration shown is for a voltage step-down conversion. When switch SW1 is closed the input supply voltage is applied to the inductor L1, and current flow in the inductor will rise with a ramp waveform, charging capacitor C1 and also supplying the load connected at the output of the supply. When SW1 is opened (equivalent to turning off a semiconductor device) the inductor current diverts into the rectifier, D1. The voltage at circuit node 'P' falls instantaneously to a rectifier forward voltage drop below the 0 V line, and the current flow in the inductor follows a negative ramp waveform. The power supply load is now supplied both from the inductor and from the output capacitor, C1. When SW1 again closes, D1 becomes reverse biased and the inductor is again connected to the input supply. In the steady state condition, the positive volt-second product applied to the inductor must balance the negative volt-second product applied when the rectifier conducts. The voltage at the output of the supply is regulated by controlling the 'on'/'off' ratio, or duty cycle of the switch SW1. Because the switching element is either 'on' or 'off' the power loss is small and the efficiency of the supply approaches 100%. Comparison with the linear regulator (Fig. 1b) shows an efficiency of approximately V_O/V_{IN}.

Figure 2 illustrates how, by rearranging the circuit elements SW1, L1 and D1, voltage step-up and voltage inversion can be achieved. Provided that the current flowing in L1 does not fall to zero between the conduction phases of SW1, the circuit configuration in Fig. 2a can be said to provide a 'non-pulsating' output current. This feature allows low output ripple voltage to be achieved. The configuration shown in Fig. 2b, however, will exhibit a 'pulsating' output current as the inductor current is diverted from the output when SW1 closes. The input current flow, however, can be arranged to be non-pulsating, so reducing the ripple voltage on the input supply. The voltage inverting circuit, Fig. 2c has pulsating current waveforms at both input and output terminals.

To overcome this apparent restriction on operating mode, transformer-coupled circuits can be used. The voltage conversion achieved is then defined by the transformer turns ratio and the polarity of the output rectifiers. Figure 3 illustrates the most common circuit configurations in use today. In addition to increasing flexibility, the transformer-coupled solution offers the option of an isolated output supply.

Figure 3a shows a transformer-coupled circuit configuration analagous to the voltage step-up circuit in Fig. 2b. The dots against the transformer windings indicate

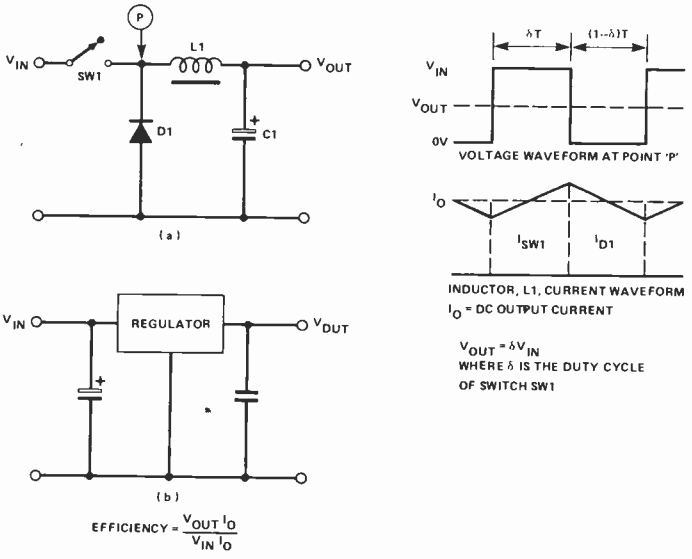

Fig. 1 Basic principles. (a) The forward converter (buck converter). (b) The basic linear regulator.

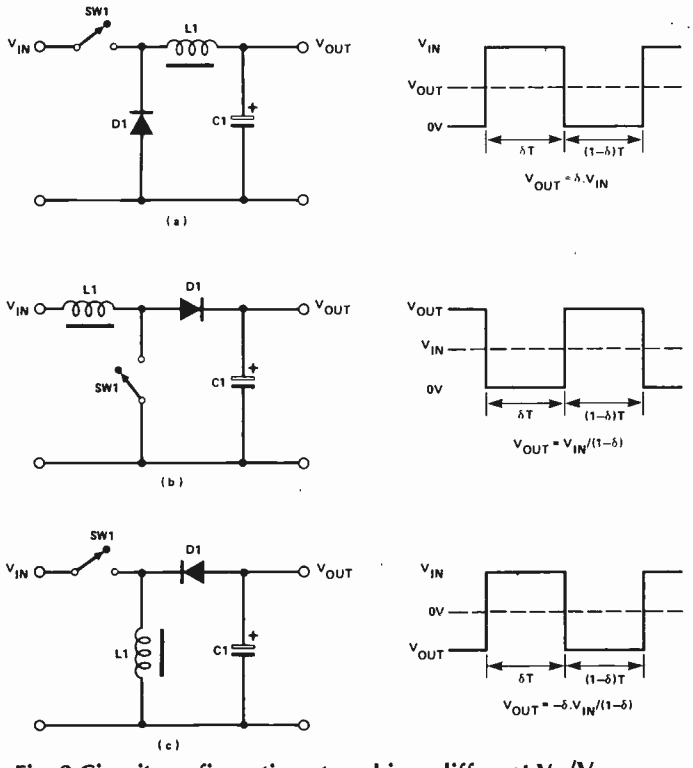

Fig. 2 Circuit configurations to achieve different V_{IN}/V_{OUT}. (a) Voltage step-down. (b) Voltage step-up. (c) Voltage inversion.

their polarity. SW1 and D1 conduct during opposite phases of the drive signal, that is, they conduct non-simultaneously.

Figure 3b is analagous to the voltage step-down circuit in Fig. 2a. SW1 and D1 conduct simultaneously. During the switch 'off' time, current flow in L1 is diverted through a second rectifier, D2. The purpose of the third winding on the transformer is to reset the magnetic core of the transformer during the switch 'off' time. If this was not done, the magnetic core would become DC-biased and may saturate, resulting in poor performance (low efficiency and high pulse currents in the primary winding and SW1).

Figure 3c, the push-pull converter, is again analagous to the circuit in Fig. 2a. The difference between this circuit configuration and the forward converter shown in Fig. 3b is that the transformer is biased bidirectionally by switches SW1 and SW2 which conduct alternately. Consequently the 'reset' winding shown in Fig. 3b is not required. The output filter components L1, C1 operate at twice the switching frequency, allowing some size reduction. Each switching device (SW1, SW2) passes only one half of the output current divided by the transformer turns ratio, n. Consequently this solution may be preferred to the solution shown in Fig. 3b at higher power levels (greater than 100 W).

Figure 3d illustrates a type of push-pull converter commonly used in off-line applications. Its main advantage, apart from the automatic resetting of the transformer core, is that the maximum voltage seen by either switch does not substantially exceed the input supply line voltage. Consequently, 400 V switches can be used when working directly from the rectified 240 V mains supply. Capacitor C2 prevents DC biasing of the transformer core which may otherwise arise through asymmetry in the switching waveforms of SW1 and SW2. Capacitors C3, C4 effectively divide the supply to the transformer by two.

Finally, Fig. 3e represents a further modification to the basic forward converter in Fig. 2a. The capacitors C3, C4 in the previous figure are replaced by two more switches; SW3, SW4. DC magnetisation of the transformer core is prevented by capacitor C2. The full supply voltage is now applied across the transformer primary as switches SW1 and SW4 and then SW2 and SW3 close simultaneously. The maximum voltage applied to any of the switches will not exceed the supply voltage significantly. This 'full bridge' configuration is used in high power switching power supplies where the size and cost of capacitors C3, C4 to replace the switches would be prohibitive. The same circuit configuration is used to drive reversible DC motors.

Switching power supplies can use capacitive elements as the energy transfer medium, rather than magnetic components which have been considered so far. Generally, capacitive circuits are limited to use at high frequency (greater than 10 kHz) and relatively low power levels. Figure 4 shows a capacitive voltage multiplier and a voltage inverting circuit. An example of such a circuit, which is available in integrated form, is the ICL7660 from Intersil Inc.

Operation of the circuit in Fig. 4a is as follows. Initially, SW2 is closed and SW1 'off'. Capacitor C1 is charged to V_{IN} through rectifier D2 and SW2. SW2 then opens and SW1 is closed. This causes the voltage seen at the anode of rectifier D1 to rise from V_{IN} to a value determined by the relative sizes of capacitors C1, C2. When C1 = C2, the voltage at the output of the supply will rise toward $2V_{IN}$. SW1 is then opened and SW2 closed to repeat the cycle.

The circuit in Fig. 4b operates on the same principle. SW1 charges capacitor C1 to V_{IN}. SW2 is then closed, taking the cathode of rectifier D1 negative to a value determined by C1, C2. Capacitor C1 is then recharged through SW1 and D2.

What Semiconductor?

As is inferred by the name 'switching mode' the semiconductor devices required for this application are primarily switching devices. The requirements for the switches are:

- Low conduction losses.
- Fast switching times.
- Voltage rating to match the circuit configuration and input supply voltage.
- Ability to withstand an overload.
- Good safe operating area (SOA) when used in an inductive load switching circuit.

These requirements can be met, largely, by a wide variety of bipolar transistors, thyristors and SCRs. More recently, power MOSFETS have been introduced with voltage and current ratings suitable for use in switching power supplies (current ratings to 40 A and voltage ratings to 500 V). These devices offer substantial advantages over bipolar transistors in the following areas:

- Low gate drive power — simplifying the driver stage.
- Fast switching times which are largely temperature insensitive — allowing operation at frequencies greater than 50 kHz.
- Good overload capability — the device is not limited by gain or second breakdown. Power dissipation is the limiting factor.
- The positive temperature coefficient of 'on' resistance assists current sharing when devices are parallel-connected to achieve higher current ratings.

Rectifiers for switching power supplies have similar requirements to the switching devices. The type of rectifier used is governed by the circuit application as indicated in Table 1.

Monolithic switching regulator circuits of limited output power capability are available (Fairchild uA78S40,

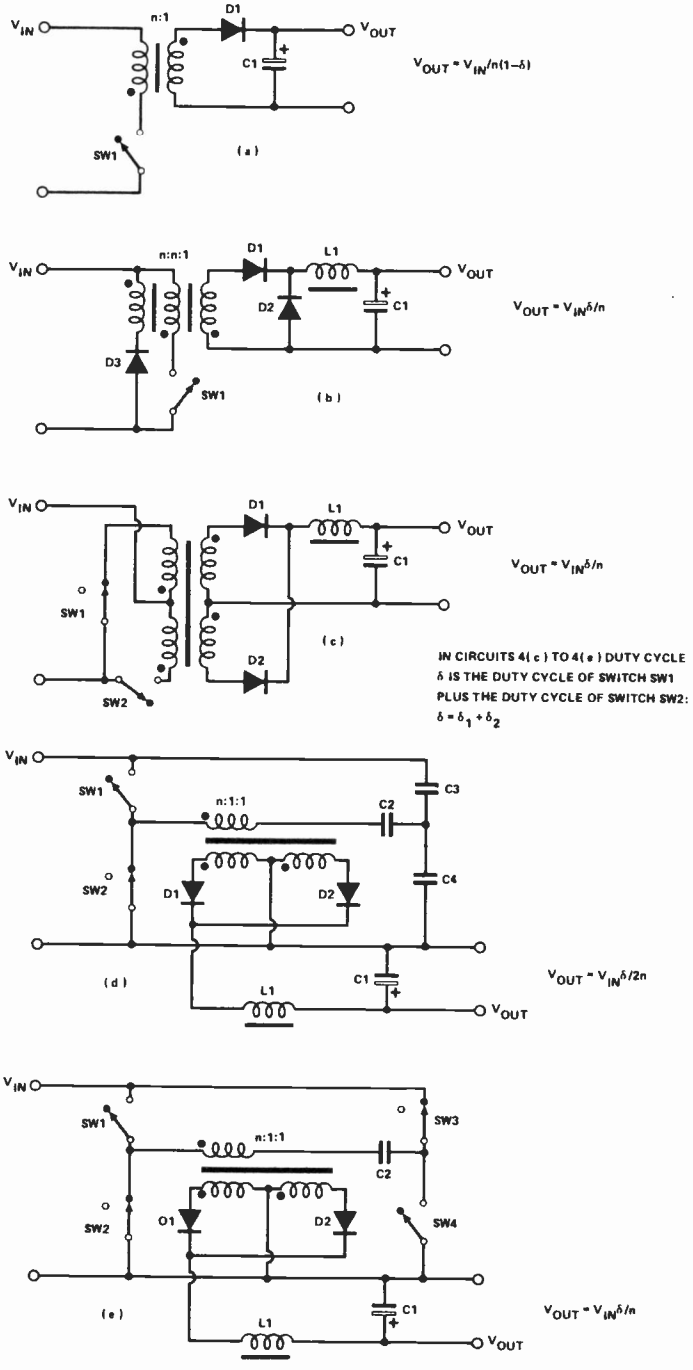

Fig. 3 Transformer-coupled switching mode circuits. (a) Flyback converter. (b) Single-ended forward converter. (c) Push-pull converter. (d) Half bridge circuit. (e) Full bridge circuit.

Texas TL497A), and the trend toward integrated power functions can be expected to accelerate. There are a number of integrated control circuits for switching mode power supplies available, allowing the control circuit board complexity to be reduced. The functions available in these circuits include: an oscillator, a voltage reference, a regulator, a current limit function and a driver stage. Some of the more common devices are: Philips TDA1060 which is pin-for-pin compatible with the Signetics NE5560, the Silicon General SG3524 which is multi-sourced, the Texas Instruments TL494 which is also available from Motorola, Fairchild and Fujitsu (as MB3759) and the Motorola MC3420.

TABLE 1

Application	Rectifier type
High Frequency Switching	Schottky Epitaxial Fast recovery, diffused
High Current, Low Voltage Switching	Schottky Epitaxial Germanium
High Voltage Switching	Silicon diffused Rectifier stack

Magnetic Component Design

Magnetic components are used in the majority of switching mode power supplies. It is, generally, only at low power and high frequency that capacitive circuits can be used. Magnetic components are used not only as high frequency transformers and DC inductors, but also as drive transformers, providing isolation between the control circuit and the power switching elements, and as current sensing elements.

Some of the criteria for the selection of a magnetic component as a high frequency transformer core are:

- Operating frequency range.
- Maximum magnetic flux density.
- Loss coefficient at the operating frequency.
- Available winding area.
- Primary to secondary coupling factor, and isolation.

Ferrite cores in a variety of shapes and materials are available. Metal powder cores, laminated and tape wound cores are also available for specialist applications.

Transformer Design

As an example, consider the design of a switching mode transformer to operate at 50 kHz in a half bridge circuit (refer to Fig. 3d). The input voltage is 310 V + 5%, – 10% and the output required is 5 V at 40 A.

Step 1. Select a core material suitable for operation at 50 kHz and a core size commensurate with the power loading. Example: Mullard FX3740 core, A16 material; Philips EC52/24/14 core, 3C8 material.

Step 2. Calculate the number of primary turns required to avoid saturation of the transformer core under worst case loading. Check that the worst case core losses do not cause excessive core operating temperature. Check that the winding area is adequate. Check that the magnetising current is less than 10% of the load current for efficient

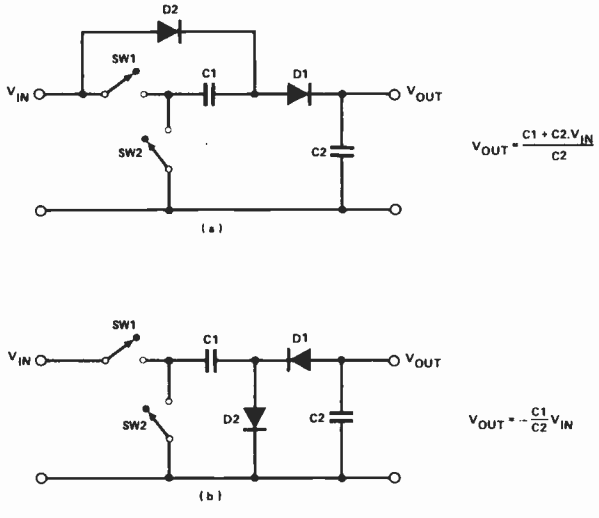

Fig. 4 Capacitive converter circuits. (a) Capacitive voltage multiplier. (b) Capacitive voltage inverter.

operation. Example: Worst case loading will occur with maximum input supply voltage and maximum duty cycle for the switches.

$$\frac{V_{IN}\,max\;\delta\,max}{f_o} = \hat{B}.\,Ae.\,n$$

where V_{IN}max is the maximum voltage applied to the transformer $= \frac{310 + 5\%\,V}{2}$

f_o is the operating frequency = 50 kHz

B is the peak working flux density of the core, at elevated temperature = 200 mT

Ae is the magnetic cross secitonal area of the core = 180 mm^2

n is the minimum required number of turns

Hence n_{min} = 40.7 turns

Working at a peak flux of 200 mT, at 50 kHz, core losses are approximately 1W8. This corresponds to a rise in core temperature above ambient of approximately 20°C. Assuming a conversion efficiency of 70%, the input power requirement is 286 W. The lowest input voltage, applied across the transformer primary is (310 – 10%)/2 V = 139 V. This gives a primary winding current, assuming 0.9 duty cycle, of approximately 2A3.

Assuming a current density in the transformer winding of 4 A/mm^2, the cross-sectional area of wire used for the primary winding should be 0.57 mm^2, corresponding to a wire of diameter 0.85 mm. Assuming a packing factor of two (because a circular cross-section conductor is used) the winding area consumed by the primary winding will be 2n × 0.57 mm^2 = 46.7 mm^2. The available winding area on the core, after making an allowance for isolation is 304 mm^2. The primary winding will take only 1/6 of the available area.

The magnetising inductance of the winding is determined by:

$$L_m = \frac{\mu_o\,\mu_a\,n^2\,Ae}{l_e}$$

where L_m is the magnetising inductance in Henries

μ_o is the permeability of free space = 4×10^{-7} H/m

μ_a is the amplitude permeability of the core = 10^3

l_e is the magnetic path length in the core = 105 mm

$$L_m = 3.62\ mH$$

The peak magnetising current is given by the equation:

$$\frac{V_{in}\,min}{2} = \frac{2.L_m\,I_m\,f_o}{\delta\,max}$$

So

$$I_m = \frac{V_{in}\,min\,.\,\delta\,max}{4.\,L_m.f_o} = 86\ mA$$

The peak magnetising current represents 4% of the load current, which is acceptable.

Step 3. Establish the transformer turns ratio. Example: The voltage required at the secondary winding of the transformer is a function of the power supply output voltage (5 V), the duty cycle of the switches SW1, SW2, and the voltage dropped across the rectifiers and resistance of the output inductor L1. Disregarding the circuit losses initially, the transformer output voltage can be found by balancing the volt-second products for the output inductor in the minimum input supply condition, when the duty cycle is 0.9.

$$(V_x - V_O) = (V_O + V_F)\,(1 - \delta)$$

where V_x is the transformer output voltage.

V_O is the supply output voltage = 5 V

δ is the duty cycle = 0.9

V_F is the rectifier forward drop = 1V

$$V_x = 5V7$$

To this figure must be added the circuit losses, $V_F + I_O.R_L$, where I_O is the rated output current, and R_L is the series resistance of L1 and the circuit wiring.

A minimum output voltage of 7 V can be used. The minimum input voltage is 139 V, so the transformer turns ratio is 20:1. Assuming a primary winding of 40 turns (marginally below the minimum, resulting in a slightly higher peak flux density, $\hat{B}$, which can be tolerated in this example), each secondary winding comprises two turns.

Step 4. Transformer winding design. The correct design of the transformer windings will result in a reproducible and efficient transformer design.The conductor size and placement can have a significant effect on winding losses in a high frequency design. Example: The primary winding consists of 40 turns of 0.85 mm diameter wire, which can be wound in two layers each comprising 20 turns. The available winding breadth on the transformer core is approximately 20 mm after an allowance of 4 mm at either end for isolation. The secondary consists of two windings, each of two turns. The conductor for these windings is in strip form, being 8 mm in width and 0.625 mm thick. The windings are wound side by side on the former. Electrostatic screens and isolation are wound between primary and secondary windings. Worst case windings losses arise at maximum loading. Primary winding loss is 3W4 maximum, and the secondary winding loss 1W25 watts maximum. When added to the transformer core losses of 1W8 the worst case transformer loss is 6W45 at a core temperature of 100°C. The transformer is capable of operating in ambient temperatures up to 35°C without additional heatsinking. (Core data and ratings are drawn from the manufacturers' literature).

Inductor Design

The operating conditions of the magnetic core in the inductor are significantly different from those of the switching mode transformer. The core must withstand a DC magnetising field, without saturation. For this reason, an air gap is commonly introduced into a magnetic circuit. This can be either in the form of a single gap introduced, say, in the centre pole of an 'E' core, or can be a distributed gap throughout the core material. The distributed gap solution presents a lower radiated magnetic field. When a gapped core is used, the magnetic flux is sorted mainly in the gap. There are small flux excursions as the load current ramps up and down. As an example, consider the design of an output filter inductor to be used with the 50 kHz transformer previously designed. The operating frequency will be 100 kHz. The maximum output current is 40 A and the minimum output current for continuous current flow in the inductor is 4 A.

Step 1. Calculate inductance value required, and the energy storage capability required. Example: The minimum voltage applied to the inductor by the transformer secondary winding is 5V7 with a 0.9 duty cycle. The current in the inductor can be allowed to rise by 8 A maximum during this time if the current flow is to remain continuous when the output loading is minimum, ie 4 A.

$$(V_{IN}\,min - V_O) = L\,min.\ \frac{I_L.\,fo}{\delta\,max}$$

where V_{IN} min is the voltage applied to the inductor = 5V7

V_O is the output supply voltage = 5V

Lmin is the minimum inductance value

I_L is the peak to peak inductor current = 8 A

fo is the operating frequency = 100 kHz

δ max is the switch duty cycle = 0.9

$$Imin = 1.6\ microhenries$$

The energy storage capability is $L.I_m^2$ where I_m is the peak current flowing in the inductor = 44 A, so $L.I_m^2$ = 3.1 mJ.

Step 2. Select a suitable inductor core and determine the air gap required (if it is not a distributed gap material). The majority of magnetic core manufacturers provide selection charts/guides for this purpose. Example: Philips core EC35/17/10 with a 0.9 mm air gap will meet the energy storage requirement (equivalent to the Mullard FX3720).

Step 3. Calculate the number of turns required and determine the inductor losses. The core data gives an effective permeability or an A_L value (inductance per turn of the coil) for gapped cores, which enables the number of turns to be calculated and rounded up to the nearest half turn. The inductor losses are primarily in the winding and these can be determined using a similar method to that used to calculate the transformer winding losses. Example: For the Philips EC35/17/10 core with a minimum air gap of 0.9 mm, 4 turns are required to give an inductance of 1.6 microhenries. The winding losses can be written as $I_{eff}^2.F_R.R_{DC}$ where

I_{eff} is the RMS current flowing in the inductor winding

F_R is a resistance multiplier to account for high frequency operation

R_{DC} is the DC resistance of the winding.

The high frequency impedance of the winding is a minimum for a conductor of thickness 0.57 mm. Making the winding with copper strip of thickness 0.5 mm and width 20 mm gives a 100°C AC winding resistance of 0.58 mR. The winding loss is 0W93, resulting in an inductor temperature rise above ambient of 18°C when fully loaded.

Drive Transformer Design

Various approaches to the design can be made, though the choice is frequently restricted by the operating conditions and the drive requirements of the semiconductor switch. Thyristors and power MOSFETS can be driven by pulse transformers. The length of the trigger pulse and the circuit impedance are designed to comprehend the drive requirements of the worst case drive. Bipolar transistors require a continuous base current supply which often results in a larger transformer core being needed. The need for a wide variation in switch duty cycle often results in the drive supplied to the switching device being compromised: the forward base current supplied during long duty-cycle operation may be the bare minimum to maintain the transistor in saturation. At short duty-cycles the base current supplied can be far in excess of the device requirements, compromising its switching performance. This effect is less severe when power MOSFETS are used as the switches, since they do not exhibit storage time effects.

As an example, conside the design of drive transformers for power MOSFETS when used as the switches in the 50 kHz switching mode power supply. A single transformer with two primary and two isolated secondary windings culd be used. A disadvantage of this approach, however, is the absence of negative gate bias to turn off the MOSFETs at any duty cycle other than the maximum of 0.5, which would give poor noise immunity in normal operation. Instead, separate transformers are used and the magnetising energy stored in the transformer core during the conduction phase is used to assist turn-off. The transformer design is similar to that required for a single-ended forward converter, Fig. 3b.

Step 1. Select a suitable magnetic material and core size. Example: The operating frequency is 50 kHz and the average current flow in the windings will be low. A core material with a high permeability is desirable to maintain a low level of magnetising current. Winding area is a significant factor in determining the core size and will depend on the isolation voltage rating desired. For this application consider the Philips core P1418 in 3B7 material, with an A_L value of 2,200 nH/1000 turns and a total winding area of 9.4 mm^2.

Step 2. Calculate the number of turns required for the primary winding and the magnetising inductance and current. Example: To avoid core saturation when operating at maximum duty cycle, with a supply voltage of 15 V, the minimum number of turns required in the primary winding is given by:

$$\frac{V_{in} . \delta \text{ max}}{f_o} = \hat{B}. Ae. n_{min}$$

where V_{IN} is the supply voltage = 15 V

δ max is the maximum duty cycle = 0.45

f_o is the operating frequency = 50 kHz

$\hat{B}$ is the peak magnetic flux density in the core = 180 mT

Ae is the magnetic cross sectional area of the core = 25.1 mm^2

n_{min} is the minimum number of primary turns

Hence n_{min} = 30 turns

The magnetising inductance, with n, the number of turns equal to n_{min} is given by:

$$n_{min} = 10^3 \sqrt{\frac{L_M}{A_L}}$$

where:

L_M is the magnetising inductance in millihenries

A_L is the inductance factor in nanohenries/1000 turns = 2,200

Hence L_m = 2.0 mH

The magnetising current at maximum duty cycle is

$$I_M = \frac{V_{IN} . \delta \text{ max}}{L_M \text{ fo}} = 67.5 \text{ mA}$$

Step 3. Check that the winding area on the ferrite core is adequate. Example: To calculate the winding area required for the primary winding, we must first estimate the average current flow. The current required to drive the power MOSFET IRF720, which would be used in this application, at 50 kHz, is low compared to the magnetising current (1.7 mA averaged over a switching cycle). So, the average magnetising current level can be assumed. A suitable wire gauge is 0.1 mm diameter. Because of handling difficulties, a 0.2 mm wire may be preferred. The winding area consumed is approximately 20% of the total winding area of the transformer. Assuming that the drive transformer has a 1:1 turns ratio, giving a ± 15 V gate drive to the power MOSFET, the winding area is adequate, after an allowance for isolation spacing has been made.

Step 4. Calculate the minimum permitted drive pulse for safe turn-off. Example: Because this design relies on the transformer magnetising energy to switch off the power MOSFET, a minimum drive pulse must be defined where by the magnetising energy equals the worst case turn-off energy for the MOSFET. Turn-off energy requirements for the MOSFET = $Q_G . \Delta V$ where Q_G is the maximum gate charge figure.

ΔV is the gate voltage swing = 30 V

Magnetising energy in the transformer

$= (V_{IN} . t_{on} \text{ min})^2/L_M$

where t_{on} min is the duration of the minimum drive pulse. Equating these figures, assuming Q_G = 17 nC for the IRF720 device, gives a minimum drive pulse of t_{on} min = 2.15 microseconds, which represents a minimum duty cycle, at 50 kHz, of 0.22.

In the June ETI we will be publishing a switching mode power supply similar to the half bridge design used for the examples here: the project will look more closely at the functions of the actual controller IC.

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	1x012	12 + 12	1.25	
	1x013	15 + 15	1.00	
	1x014	18 + 18	0.83	
	1x015	22 + 22	0.68	
	1x016	25 + 25	0.60	
	1x017	30 + 30	0.50	
50 VA 80 × 35mm 0.9 Kg Regulation 13%	2x010	6 + 6	4.16	**£5.70** + p&p £1.30 + VAT £1.05 TOTAL £8.05
	2x011	9 + 9	2.77	
	2x012	12 + 12	2.08	
	2x013	15 + 15	1.66	
	2x014	18 + 18	1.38	
	2x015	22 + 22	1.13	
	2x016	25 + 25	1.00	
	2x017	30 + 30	0.83	
	2x028	110	0.45	
	2x029	220	0.22	
	2x030	240	0.20	
80 VA 90 × 30mm 1 Kg Regulation 12%	3x010	6 + 6	6.64	**£6.08** + p&p £1.67 + VAT £1.16 TOTAL £8.91
	3x011	9 + 9	4.44	
	3x012	12 + 12	3.33	
	3x013	15 + 15	2.66	
	3x014	18 + 18	2.22	
	3x015	22 + 22	1.81	
	3x016	25 + 25	1.60	
	3x017	30 + 30	1.33	
	3x028	110	0.72	
	3x029	220	0.36	
	3x030	240	0.33	
120 VA 90 × 40mm 1.2 Kg Regulation 11%	4x010	6 + 6	10.00	**£6.90** + p&p £1.67 + VAT £1.29 TOTAL £9.86
	4x011	9 + 9	6.66	
	4x012	12 + 12	5.00	
	4x013	15 + 15	4.00	
	4x014	18 + 18	3.33	
	4x015	22 + 22	2.72	
	4x016	25 + 25	2.40	
	4x017	30 + 30	2.00	
	4x018	35 + 35	1.71	
	4x028	110	1.09	
	4x029	220	0.54	
	4x030	240	0.50	
160 VA 110 × 40mm 1.8 Kg Regulation 8%	5x011	9 + 9	8.89	**£7.91** + p&p £1.67 + VAT £1.44 TOTAL £11.02
	5x012	12 + 12	6.66	
	5x013	15 + 15	5.33	
	5x014	18 + 18	4.44	
	5x015	22 + 22	3.63	
	5x016	25 + 25	3.20	
	5x017	30 + 30	2.66	
	5x018	35 + 35	2.28	
	5x026	40 + 40	2.00	
	5x028	110	1.45	
	5x029	220	0.72	
	5x030	240	0.66	

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	6x013	15 + 15	7.50	
	6x014	18 + 18	6.25	
	6x015	22 + 22	5.11	
	6x016	25 + 25	4.50	
	6x017	30 + 30	3.75	
	6x018	35 + 35	3.21	
	6x026	40 + 40	2.81	
	6x025	45 + 45	2.50	
	6x033	50 + 50	2.25	
	6x028	110	2.04	
	6x029	220	1.02	
	6x030	240	0.93	
300 VA 110 × 50mm 2.6 Kg Regulation 6%	7x013	15 + 15	10.00	**£10.17** + p&p £2.00 + VAT £1.83 TOTAL £14.00
	7x014	18 + 18	8.33	
	7x015	22 + 22	6.82	
	7x016	25 + 25	6.00	
	7x017	30 + 30	5.00	
	7x018	35 + 35	4.28	
	7x026	40 + 40	3.75	
	7x025	45 + 45	3.33	
	7x033	50 + 50	3.00	
	7x028	110	2.72	
	7x029	220	1.36	
	7x030	240	1.25	
500 VA 140 × 60mm 4 Kg Regulation 4%	8x016	25 + 25	10.00	**£13.53** + p&p £2.35 + VAT £2.38 TOTAL £18.26
	8x017	30 + 30	8.33	
	8x018	35 + 35	7.14	
	8x026	40 + 40	6.25	
	8x025	45 + 45	5.55	
	8x033	50 + 50	5.00	
	8x042	55 + 55	4.54	
	8x028	110	4.54	
	8x029	220	2.27	
	8x030	240	2.08	
625 VA 140 × 75mm 5 Kg Regulation 4%	9x017	30 + 30	10.41	**£16.13** + p&p £2.50 + VAT £2.79 TOTAL £21.42
	9x018	35 + 35	8.92	
	9x026	40 + 40	7.81	
	9x025	45 + 45	6.94	
	9x033	50 + 50	6.25	
	9x042	55 + 55	5.68	
	9x028	110	5.68	
	9x029	220	2.84	
	9x030	240	2.60	

IMPORTANT: Regulation – All voltages quoted are FULL LOAD. Please add regulation figure to secondary voltage to obtain off load voltage.

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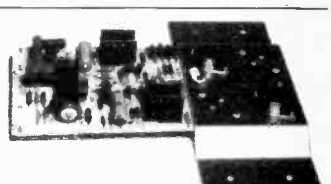

The power amp kit is a module for high power applications - disco units, guitar amplifiers, public address systems and even high power domestic systems. The unit is protected against short circuiting of the load and is safe in an open circuit condition. A large safety margin exists by use of generously rated components, result, a high powered rugged unit. The PC board is back printed, etched and ready to drill for ease of construction and the aluminium chassis is preformed and ready to use. Supplied with all parts, circuit diagrams and instructions.

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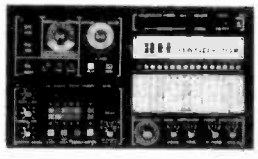

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- Decibels: -20 to +22dB
- DC Current: 0-50, 500μA, 0-5, 50, 500mA
- Ohmmeter: 0-6 Megohms in 4 ranges. 30 ohms Centre Scale
- Power Supply: One 1.5V size 'A' battery (incl)
- Size & Weight: 135 x 91 x 39mm, 280gr.

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- DC Current: 0-100mA
- Ohmmeter: 0-1 Megohm in 2 ranges, 60 ohms Centre Scale
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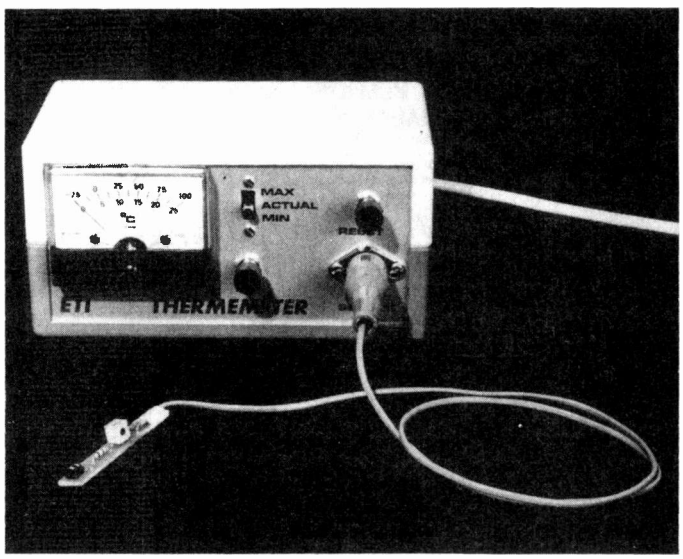
Time was when a maximum-minimum thermometer had alcohol and mercury and little magnetic things in the glass tube. The ETI version is less fragile, more versatile, and can interface to control equipment. Design by Phil Walker.



MAX/MIN THERMOMETER

This project can monitor the temperature of its surroundings while storing the maximum and minimum temperatures reached in digital form. While the normal readout is by analogue meter, the data on the maximum and minimum temperature can be read out as two eight-bit numbers, possibly into a micro system or other type of data or control system. The unit will store its information until the mains supply is switched off or the reset button is activated. Switching the readout mode will not change the date.

Units such as this are useful for checking the central heating, making sure that the greenhouse is not getting too hot or cold, weather forecasting, or even checking the freezer. With a few simple mods it would be possible to convert the unit to an under or over temperature alarm and program it digitally. (This is left as an exercise for the reader — *please* don't write to us!)

The Circuit

This can be considered as several main blocks. First we have the clock generator which produces a series of narrow pulses at a fairly low frequency. These pulses are deliberately made narrow to avoid the possibility of spurious clock pulses being generated by the comparator circuits when the analogue output voltage from the D-to-A converters changes. These clock pulses are applied to gating circuits which will allow them to go on to the D-to-A converters only when conditions are correct.

The D-to-A converters used in this project are of a type which contain an internal eight-bit counter. This allows us to make an A-to-D converter with few external components. Moreover we can stop and start the conversion process whenever required.

The method used for A-to-D conversion is to reset the counters to all zeros at which time the analogue output voltage will fall to 0 V, and then supply clock pulses to the counter until the analogue output rises sufficiently to cause a comparator to change output states and cut off the clock pulses. The analogue output voltage from the D-to-A converter will now match the voltage at the other input to the comparator and will stay at this level until the other input voltage changes in such a way that the comparator changes state again and re-enables the clock pulses to the counter.

The two configurations used in this project both work in this way, except that one D-to-A output is used direct for the 'MAX' detector

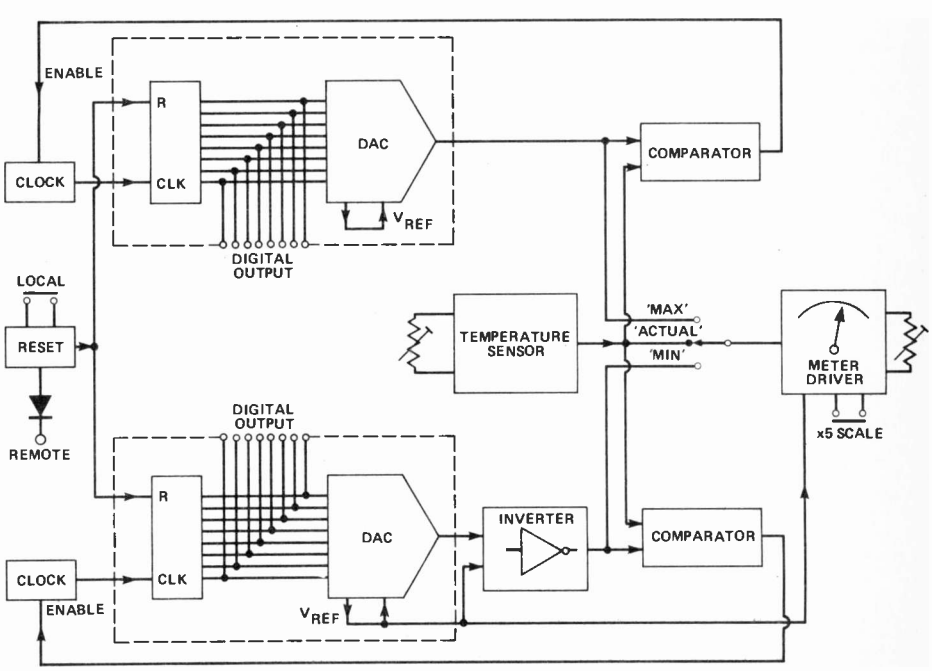


Fig. 1 Block diagram of the max/min thermemeter ('cos it remembers — geddit?).

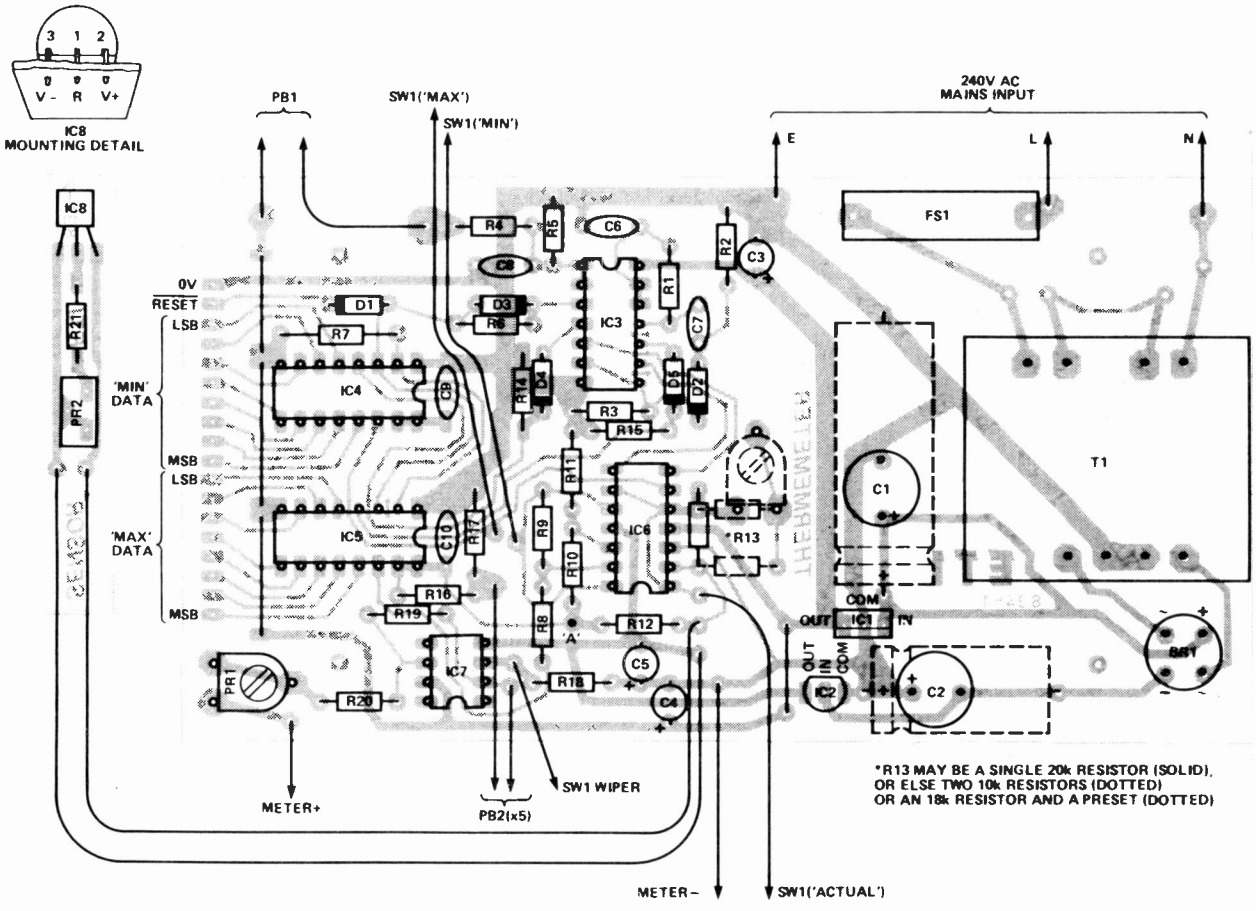


Fig. 2 Component overlay for both boards.

while the other is inverted, such that it starts at maximum volts and falls towards 0 V as the counter increments. This is used to drive the 'MIN' detector circuit. The result of the circuitry is that one D-to-A output follows and stores the maximum voltage while the other follows and stores the minimum.

The other input to the comparators mentioned above is a voltage proportional to temperature. In the first instance this is generated as a current by a LM334Z IC. The current through this device is directly proportional to *absolute* temperature. This current is fed into the summing input of an operational amplifier together with a constant offset current derived from the reference voltage source of the D-to-A converter. The resultant current generates a voltage at the output of the op-amp suitable for driving the comparator inputs.

The final part of the circuit is the readout. This is provided by a moving coil meter driven by a high impedance buffer. This can be switched to read 'MAX', 'MIN' or 'ACTUAL' temperatures over the ranges −25 to +100°C or 0 to +25°C.

PARTS LIST

Resistors (all ¼W, 5% except where stated)

R1, 3, 5, 14-16, 19	100k
R2	10k
R4, 6, 7	1k0
R8-11	100k 1%
R12	10k 1%
R13	20k 1% (see text)
R18	1M0
R20	3k9
R21	180R

Potentiometers

PR1	2k2 miniature horizontal preset
PR2	100R miniature vertical cermet preset

Capacitors

C1	470u 25V electrolytic (radial or axial)
C2	100u 25V electrolytic (radial or axial)
C3-5	10u 10 V electrolytic (PCB-mounting)
C6, 9, 10	220n polycarbonate
C7	470p ceramic
C8	100n polycarbonate

Semiconductors

IC1	7805
IC2	79L05
IC3	4093B
IC4, 5	ZN425E
IC6	TL084
IC7	TL081
IC8	LM334Z
D1-5	1N4148
BR1	Wo1 (100 V, 1 A potted bridge rectifier)

Miscellaneous

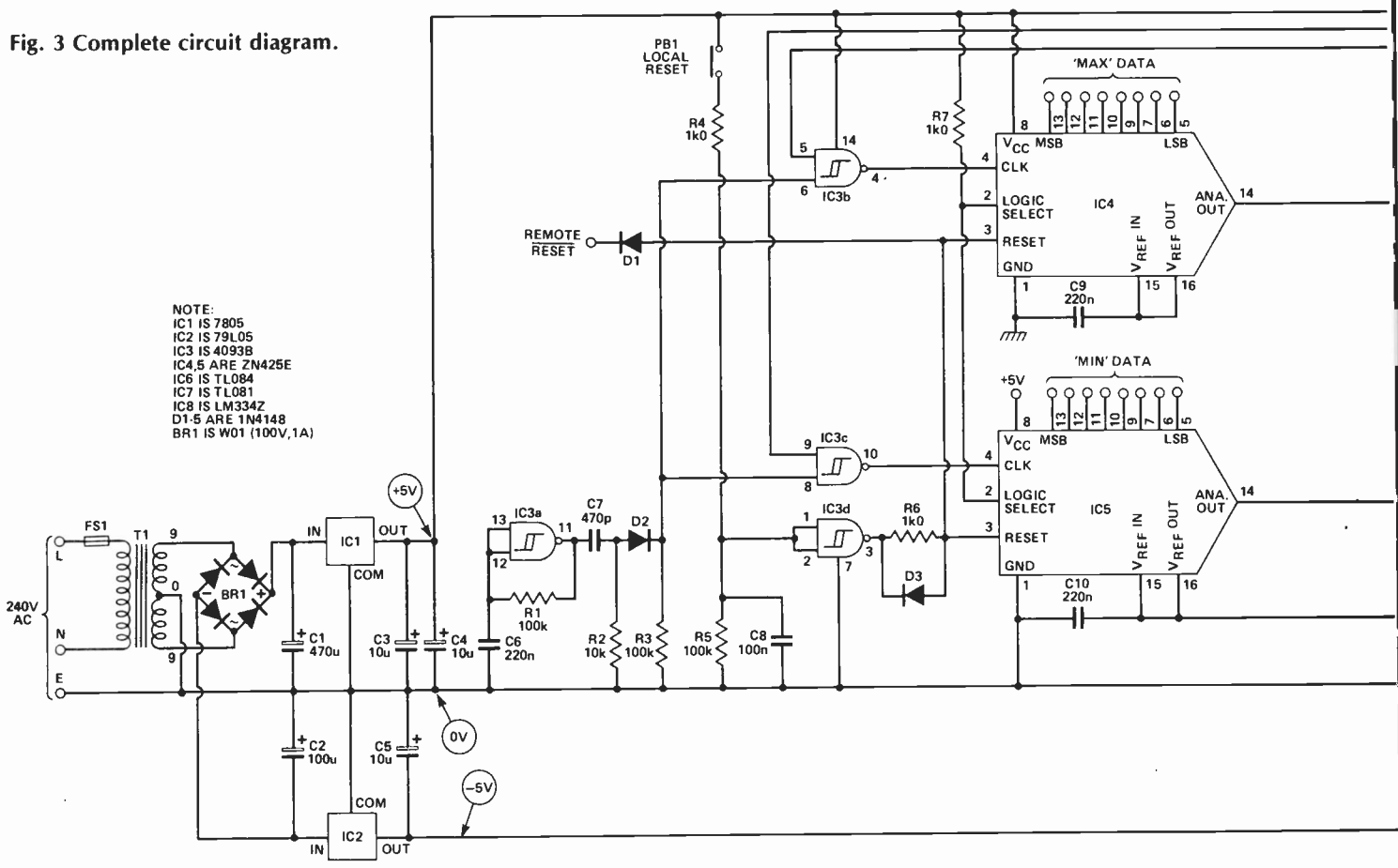
PB1, 2	Miniature push-to-make push-button
SW1	3-way slide switch, one pole only used
T1	9-0-9 V 3 VA miniature PCB-mounting mains transformer
FS1	500 mA, 20 mm fuse and PCB-mounting fuseholder
M1	500 uA moving coil meter (60 x 47 mm)

PCBs (see Buylines); Verocase, 155 x 85 x 80 mm; three-pin DIN plug and socket; cable, cable clamp, hardware etc.

Construction

Construction of the PCB for this project should cause no problems. The main things to be careful with are remembering to insert the four wire links, the orientation of the ICs, diodes, capacitors etc and BR1. R13 can be either a single 20k 1% resistor as shown, two 10k 1% resistors or even an 18k 5% and a 4k7 preset. Pads are available on

Fig. 3 Complete circuit diagram.



HOW IT WORKS

IC3a, R1 and C6 form the master clock circuit, which generates a square wave of around 50 Hz or so. This is differentiated by C7 and R2 and the positive spikes only are passed via D2 on to IC3b and IC3c. Only when the other inputs to these gates are high will the spikes be inverted and passed on to the D-to-A converters, IC4 and IC5, as clock pulses. IC3d, R4, R5 and C8 take the input from PB1 and produce a suitable reset signal for the two DACs. This can, however, be overridden by a direct input via D1 (take terminal low to reset), allowing remote control by a computer, for example.

The D-to-A converters, IC4 and IC5, contain an internal counter which can be used when pin 2 of the device is high. This condition is maintained by R7. The counter is reset by a low on pin 3 and will respond to clock pulses on pin 4. After reset the output from the device is at 0 V: at each clock pulse the output voltage rises by 10 mV to a maximum of 2V55 (another clock pulse at this point will take it back to 0 V). The output from IC4 is compared with the output from the temperature sensor circuit by comparator IC6c and while it is lower, IC6c output will be high, so IC3b pin 5 will be high and enable the clock signal to IC4. While this condition persists the output from IC4 will rise steadily until it equals and exceeds the output from the sensor circuit. Now the output from IC6c will go low, IC3b input will be low and no more clock pulses will reach IC4. The output from IC4 will stay at the same level until either the temperature sensor voltage exceeds it again or the reset function is used. The output from IC4 is thus a measure of the maximum temperature reached, since it can only increase unless reset.

The circuit around IC5 works in a very similar way except that its output is inverted by IC6a such that the voltage presented to the comparator IC6d starts at 2V55 and falls to 0 V as the counter in IC5 is incremented. In this case the output from IC6d is high while the output from IC6d is higher than the output from the temperature sensor circuit. This means that the voltage from IC6d will start from 2V55 at reset and fall until it matches the output from the temperature sensor. It will stay at that level until the temperature sensor output falls to a lower level or the reset is operated. This means that the output from IC6d is a measure of the minimum temperature, since it can only decrease unless reset.

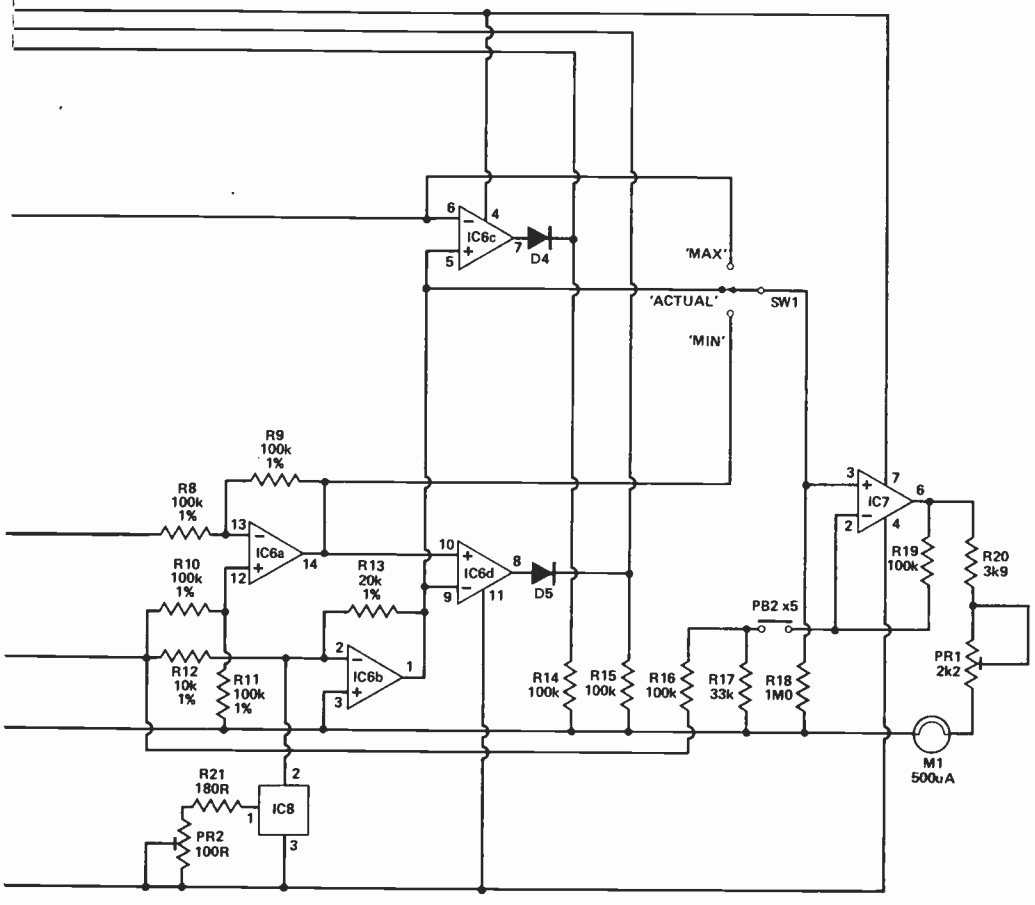
The temperature sensor device is an LM334Z. This IC is designed as a constant current device but has a linear temperature coefficient. In effect the current is proportional to the *absolute* temperature (0°C = 273°K or Absolute). In this circuit R12 supplies a constant 255 uA from the voltage reference terminal of IC5 to the virtual earth (inverting) input of IC6b. The temperature sensor IC8 is set up so that it takes this amount of current at −25°C: this means that the output voltage of IC6b will be 0 V at this temperature. As the temperature rises the current drawn by IC8 will increase and the output voltage from IC6b must rise so that the extra can be sent through R13. The voltage across R13 will be directly proportional to the temperature rise. Setting of the sensor current is accomplished by PR2 and R21.

The normal method of indication for this project is by means of a moving coil meter, with SW1 selecting the display of the maximum, minimum or actual temperature. IC7 is normally used as a high impedence buffer but by means of PB2 its gain can be increased to x5 for greater ease of reading in the range of 0 to 25°C. The sensitivity of the meter is set by PR1.

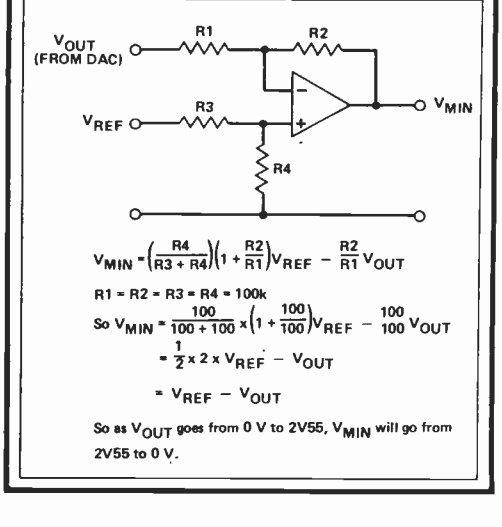
The power supplies for this project are quite simple but a mains-derived type was felt to be desirable as the drain on the +5 V rail is in the region of 70 mA.

the PCB for all these options.

C1 and C2 may be vertical or horizontally mounted as desired, although we had to make C2 an axial type so as not to foul any of the components mounted on the front panel of our tight-fit case. Take care to ensure that the mains input to the board cannot touch the rear panel (use insulating tape if necessary). Use a cable clamp to secure the wire. Wiring to the front panel components is straightforward: the sensor PCB is connected to the main board via a



OPERATION OF VOLTAGE INVERTER



$$V_{MIN} = \left(\frac{R4}{R3+R4}\right)\left(1+\frac{R2}{R1}\right)V_{REF} - \frac{R2}{R1}V_{OUT}$$

$R1 = R2 = R3 = R4 = 100k$

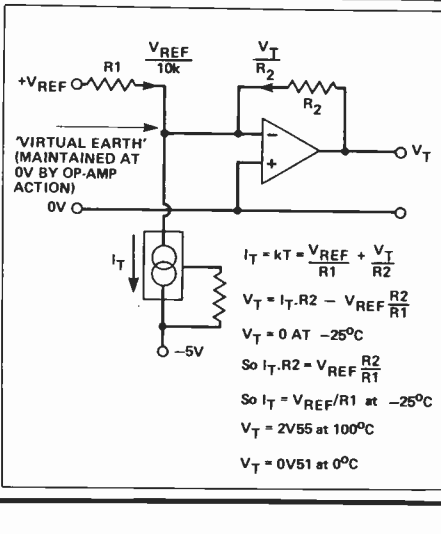
$$\text{So } V_{MIN} = \frac{100}{100+100} \times \left(1+\frac{100}{100}\right)V_{REF} - \frac{100}{100}V_{OUT}$$

$$= \frac{1}{2} \times 2 \times V_{REF} - V_{OUT}$$

$$= V_{REF} - V_{OUT}$$

So as V_{OUT} goes from 0 V to 2V55, V_{MIN} will go from 2V55 to 0 V.

OPERATION OF REFERENCE



$$I_T = kT = \frac{V_{REF}}{R1} + \frac{V_T}{R2}$$

$$V_T = I_T.R2 - V_{REF}\frac{R2}{R1}$$

$V_T = 0$ AT -25^oC

$$\text{So } I_T.R2 = V_{REF}\frac{R2}{R1}$$

So $I_T = V_{REF}/R1$ at -25^oC

$V_T = 2V55$ at 100^oC

$V_T = 0V51$ at 0^oC

length of cable and a three-pin DIN connected on the front panel. The length of the wire is not critical so long as its insulation is good; however, care must be taken to keep the polarity correct.

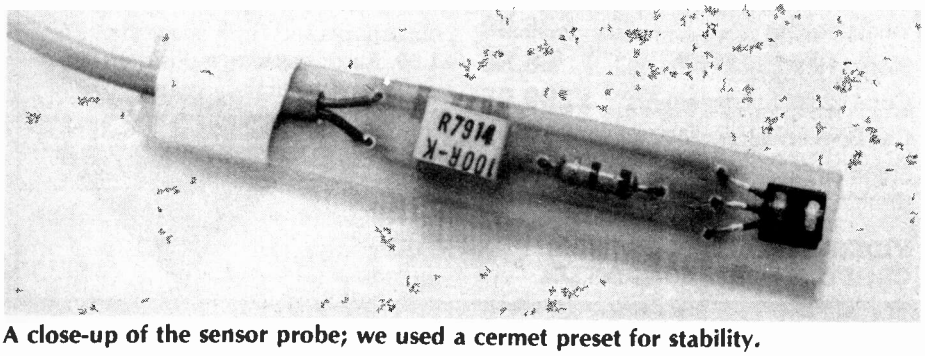
For those people using the same meter as us (see Buylines), we've reproduced the artwork we drew for our prototype meter scale at the back of the magazine with the foil patterns (page XX). If you wish you can cut it out (get Mummy to help you with this) and use it to replace the existing scale.

Setting Up

The Meter Circuit. Zero the meter mechanically with the power off. Connect the input of IC7 (pin 3) to point 'A' (marked on the overlay diagram at the junction of R10 and R12) instead of to the wiper of SW1, apply the power and set the meter to full scale deflection using PR1. Remove the power and restore the connection from IC7 input to SW1 wiper.

The Sensor Circuit. Ensure that the total value of R13 is twice that of R12. If desired, R13 can be two 10k 1% resistors in series, or an 18k 5% resistor and a 4k7 trimmer if a 20k 1% device is not available. Pads have been provided on the PCB for one or two resistors or a resistor and a preset — the alternative positions are shown dotted on the overlay. The theoretical value for R13 is actually 2.016 x R12 but this sort of value is not easily available.

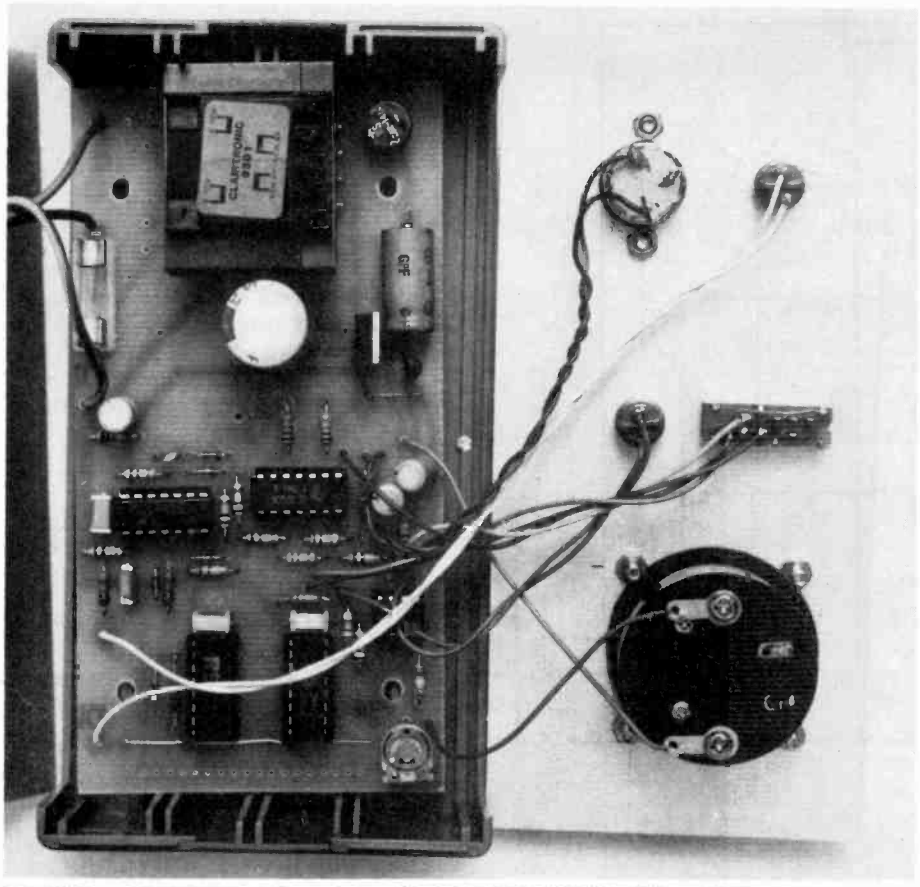
Connect the sensor, switch on the power and with the sensor immersed in a melting ice and water mixture, adjust PR2 until a reading of 0°C is obtained (one-fifth of full scale deflection). The unit should now be ready for use: coverage will be −25°C to +100°C in increments of 0.5°C approximately (256 steps) for the maximum and minimum functions, while the actual temperature is continuous.



A close-up of the sensor probe; we used a cermet preset for stability.

BUYLINES

All the tricky bits for this project can be obtained from Rapid Electronics Ltd, Unit 1, Hill Farm Industrial Estate, Boxted, Colchester, Essex C04 5RD. They stock the 1% resistors, the meter, the Verocase, the PCB-mounting transformer and the ZN425E. Everything else we've used is either readily available or not too criticial. Our PCB Service order form is on page 87 if you aren't able to etch your own board.



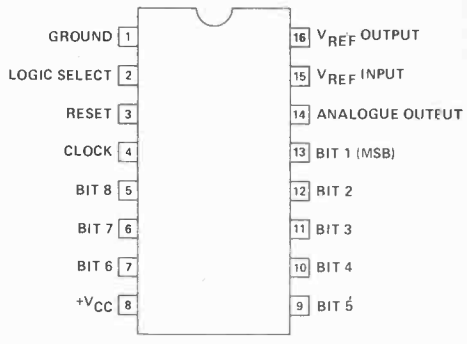
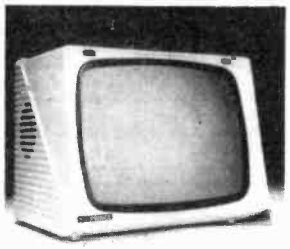


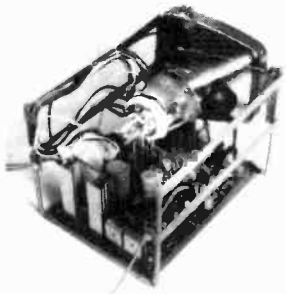
Fig. 4 (Above) The pin-out for the ZN425E digital-to-analogue converter.

(Right) Inside the box, you can see how cramped things are, and inexperienced constructors may wish to use a bigger box than the one we specify in Buylines. This is especially the case if you intend to fit some kind of interface socket for a digital readout of the data, to a control unit, for example. We didn't bother on the prototype.

ETI

MONITORS





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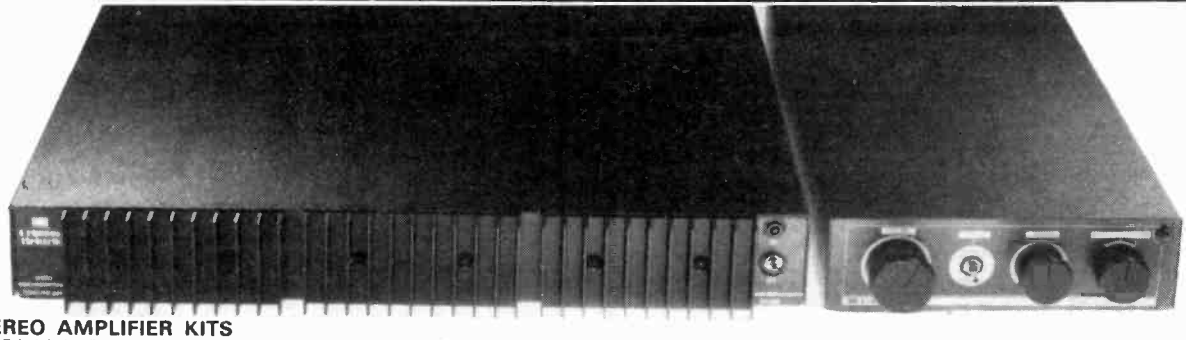

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CONFIGURATIONS

Power corrupts, and absolute power corrupts absolutely. At least, it can burn out the odd diode or two. This month Ian Sinclair examines the area of power supplies and some of the facts you aren't often told.

Power packs, you might think, are among the simpler of electronic circuits to design, and yet there is probably more cut-and-try used in the power supply section of a circuit than in all the rest of the circuitry that you construct. The reason seems to be a lack of coherent explanations of the action of the reservoir capacitor — only too often you are simply told that it "provides an earth route for AC ripple", and no more. We have to start this month, then, by putting that sort of misconception to rights.

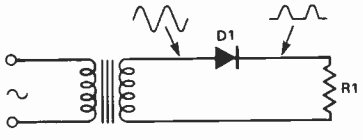

Fig. 1 Simple half-wave rectifier circuit with no reservoir capacitor. The waveform is unidirectional, but certainly not what we would call DC.

Consider for the sake of simplicity, a half-wave rectifier circuit and a load (Fig. 1). The waveform across the load will consist of about half of the input waveform, the positive half in this example because of the way we have chosen to connect the diode — reverse the diode and you will select the negative half of the wave. This type of output is called a *unidirectional* wave — the peaks are in one direction (positive) only, with no negative peaks — but it isn't exactly anyone's idea of DC. A DC voltmeter connected to the load of this circuit reads what DC voltmeters always read, the average voltage, which is around E_o/π; approximately 0.32 E_o, assuming that the diode is 'perfect' in the sense of having no forward voltage drop across it. We can allow for the forward drop, which can't be neglected if the output voltage is low, by subtracting its value from E_o, the peak AC input. This is only an approximation, but it is good enough for practical purposes.

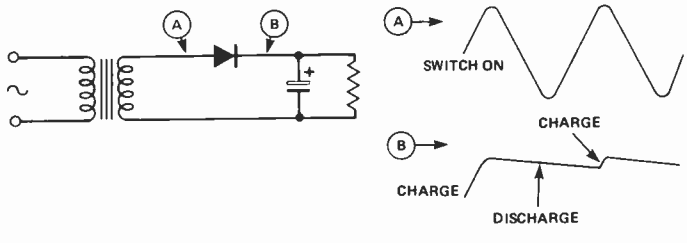

Fig. 2 A half-wave circuit with a reservoir capacitor added. The capacitor charges to the peak voltage of the input wave, and the charged capacitor supplies the load while the diode is reverse-biased.

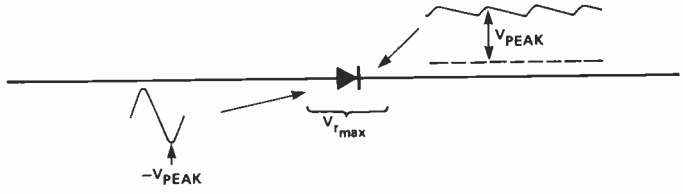

Fig. 3 This shows why the peak reverse voltage on the diode is doubled when a reservoir capacitor is used.

Bring On The Reserves

Now when a reservoir capacitor is connected to the circuit (Fig. 2), things change considerably. To start with, imagine that the load resistance is very high, so that only a small amount of current is being taken. Instead of the rectifier conducting for the whole positive cycle of the AC wave, it now conducts only for a tiny fraction of the time of the wave, right at the peak. The reason is that the first

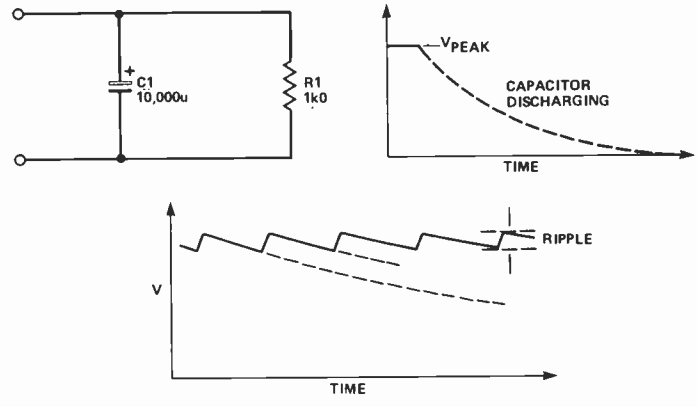

Fig. 4 The waveform of ripple, caused by the time constant of the reservoir capacitor and load resistance.

half-cycle, when the supply is switched on, will charge the reservoir capacitor to the peak positive value of the AC wave, less the forward diode drop, and when the AC input at the anode of the diode drops below this value, the diode will cut off. From this moment until the next positive peak of the wave comes along, all the current that is supplied to the load is supplied from the reservoir capacitor, which is why it's called a reservoir! Far from just being a bypass for AC, the reservoir is the main store and supplier of DC to the load.

All the current that dribbles out from the capacitor results in the voltage across the capacitor dropping as its charge is drained, so that the diode has to supply this

charge again next time it conducts. You don't get something for nothing — the diode passes large currents for short time intervals instead of conducting steadily over a half-cycle as it did when no reservoir was used. The overall result is that the diode has to be able to pass peak currents that are many times greater than the average current, it spends most of its time cut off, the maximum reverse voltage across the diode is twice the AC peak voltage (see Fig. 3), and there is a 'ripple' on the output wave which is caused by the drop in voltage as the reservoir capacitory discharges (Fig. 4). The waveform of this ripple is a sawtooth, rich in harmonics, not simply a piece of left-over sine wave as some explanations would hint at, so that it is a potent source of hum interference in the rest of the circuit.

The approximate amplitude (peak to peak) of the ripple is given by It/C, where I is the average current drawn by the load, C is the size of reservoir capacitor, and t is the time between positive wavepeaks. Using units of milliamps for I, microfarads for C and milliseconds for t, we get units of volts for the amplitude of ripple. For example, if you draw 100 mA from a 1000uF capacitor with a half-wave rectifier for which t is about 20 mS, then the

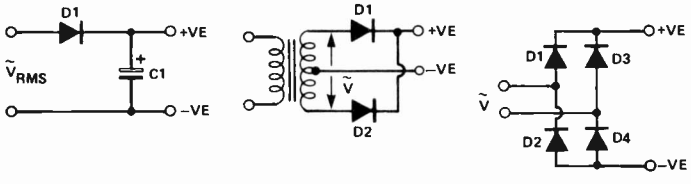

Fig. 5 A summary of the conditions for common power supply configurations.

ripple amplitude is (100 × 20)/1000, or 2 V, which isn't exactly negligible. Using a full-wave rectifier, which recharges the capacitor at 10 mS intervals, you get a 1 V ripple. This formula *isn't* foolproof — it applies only when you have the situation in hand, and will give silly answers if the reservoir capacitor is much too small or if the amplitude of the AC input is very small, but it's a good guide to realistic values for power supplies generally.

The voltage output of the circuit with no load current is equal to the AC peak voltage, but as the load current increases, the ripple also increases and the average DC output drops until it can become almost as low as the value you would get with no reservoir, 0.32 E_0 for half-wave, and twice as much as for full-wave (bridge or split-secondary type of circuit). Figure 5 summarises the operating conditions for different rectifier configurations. Ripple, and the drop of output voltage when output load

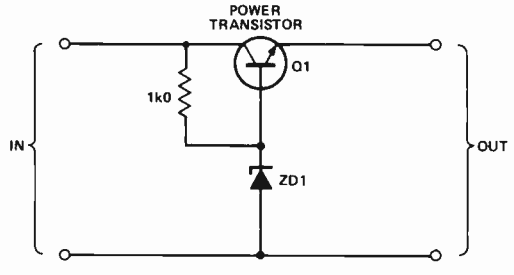

Fig. 6 An elementary stabiliser — the power transistor in this example would be a medium-power type with a high value of h_{fe}.

current is taken, can be minimised by increasing the size of the reservoir capacitor. Obviously, it is also an advantage to have a short time between recharging the reservoir, so that high-frequency supplies need less in the way of reservoir capacitance — one of the many reasons for the popularity of switch-mode power supplies these days.

A Stable Situation

Another defensive measure is stabilisation. Stabilisation does not mean that some circuit is used which will miraculously bump up the voltage output from the reservoir capacitor, it simply means making the best of what you have. Suppose you have a nominal 8 V supply, and that at the full planned output current of 150 mA it can have a 2 V peak-to-peak ripple. This value implies that the voltage will drop momentarily as low as 6 V twice on each AC cycle, assuming that full-wave rectification is used, so that if we use only 5 V of this supply, these changes caused by ripple will not affect the 5 V output at all. This is the action of a stabiliser — it's a circuit which is a voltage-dropper, but arranged so that the drop is variable, keeping the output voltage constant while the input voltage varies.

A stabiliser has to operate so as to fulfil two requirements. First it must keep its output voltage constant as the input voltage varies, and second, it must keep the output voltage constant as the load current varies. The two may sound identical at first glance, but they are not — the first calls for the output to be constant while the voltage across the stabiliser is varying, the second calls for the combination of the stabiliser and the rest of the power pack to have almost zero internal resistance.

Figure 6 shows a very basic form of stabiliser. The voltage at the output is set by the value of the zener diode, and because of the voltage across the base-emitter of a transistor, the output voltage will be around 0V6 less than the zener diode voltage. This should ensure that the voltage of the output is stabilised against changes at the input resistances of the order of a few milliohms can be ob-

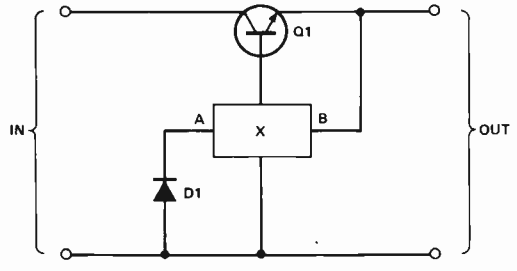

Fig. 7 A block diagram of the comparator type of power supply stabiliser. This type is rarely built nowadays because of the ready availability of IC equivalents.

tained using circuits of this type.
crease to some extent as the load current increases. Nevertheless the stabilisation is better than it would be in the absence of the circuit (something wrong if it were not!), and can be improved by amplifying the signal to the base of the regulator transistor — a variation on the circuit is shown in Fig. 7. The output voltage is compared with the zener voltage, and the output of the comparator is used to control the base of the regulator transistor. Very low output resistances of the order of a few milliohms can be obtained using circuits of this type.

I've drawn the circuit as a block diagram because it isn't very often nowadays that we have to build stabilisers with separate components. The reason, of course, is the ready availability of IC regulators, particularly the 78

series. These take advantage of being ICs (so that circuit complications are not a problem for production, only for design) to incorporate features such as current foldback, meaning that the current will be regulated if there is any risk of over-dissipation. This ought to prevent overload and give these regulators a very long life — I say ought, because in my experience these regulators quite frequently fail, and I suspect that the fold-back arrangements are not always completely effective.

The 78 series covers most of the 'popular' supply voltages, but if we should want an odd value then a modification to the circuitry, as shown in Fig. 8, can do the

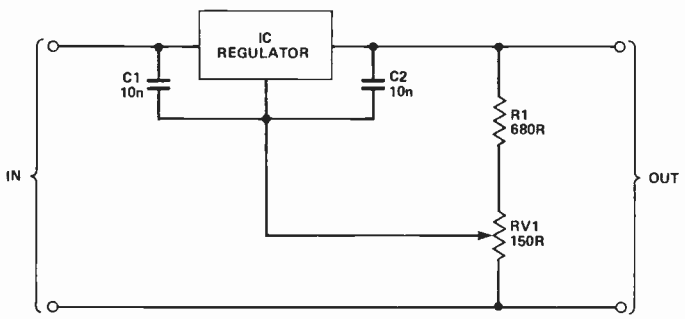

Fig. 8 Varying the output voltage of an IC stabiliser. A variable resistor is illustrated, but a fixed value resistor could be used once the correct value has been established.

needful, at the expense of a slight loss in stabilisation. Similarly, if we want a lot more current from the output than the normal 78 series can supply, then we can use the IC to control an external transistor, as shown in Fig. 9. Circuits like these can cope with about 99 per cent of our needs.

Switching The Subject

Having mentioned switch mode power supplies, however, I feel I should explain further because, unless you follow the development of TV circuitry, you may not have come across details of them (though a switch mode supply was used in the venerable Apple 2 computer, and a switch mode supply is now used in the BBC computer after early users complained that the old version burned the varnish off their tables). Basically the principle is to

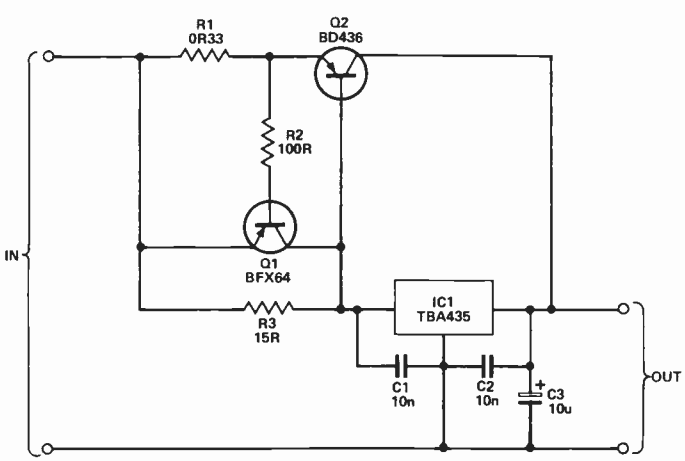

Fig. 9 Increasing the current-handling capability of an IC stabiliser. The stabiliser handles the rated current, and any amount beyond this value is handled by the auxiliary transistor circuit, preserving voltage stability.

dispense with a mains transformer, and rectify the mains voltage so as to produce a high voltage DC. By dispensing with the resistance of a mains transformer, and by using a reservoir capacitor of surprisingly modest capacitance (but rated for 500 V!), this supply voltage can be quite stable. It is then applied to a switching circuit which charges a capacitor several thousand times per second and discharges it just as frequently into the primary of a transformer which, because it operates with high-frequency signals, can be small and well-insulated. The outputs of this transformer are rectified, and need only small reservoir capacitances because of the high frequency that is used. There is no need for a stabiliser of the old-fashioned wasteful type either, because the output voltage can be sampled by a comparator, and the output of the comparator used to alter the switching times. The idea is that if the output voltage drops, the switch can spend more time passing current into the primary of the transformer; if the output voltage is too high, the switching circuits cut off earlier. There is no waste involved — what is not used is held in the reservoir capacitor ready for the next switching operation.

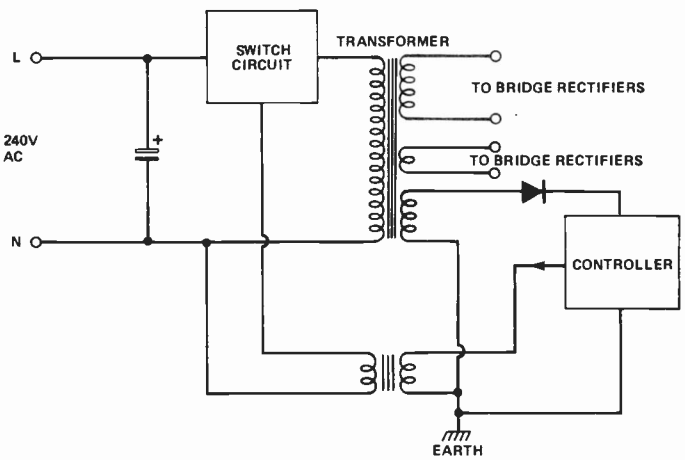

Fig. 10 An outline of a switched mode power supply. No values are shown, because the transformer is a critical component and the other circuitry can be obtained in IC form.

The main advantage is that the supply runs astonishingly cool, with no huge heatsinks needed for the regulator. The advantages for TVs and computers are obvious — I remember one computer which left scorch marks and which could have served as a sandwich toaster. Another advantage is that no AC voltage adjuster is needed — whatever the mains voltage happens to be will be compensated for by the switching process, and there are ICs which will take care of the whole operation. For a more detailed description of the operation of switched mode power supplies, see Designer's Notebook on page 63.

One point of caution concerns servicing. If you are working on a switch mode power supply, remember that it uses high voltages, and that part of the circuit is always live to the mains when it is operating. On many TV receivers, in accordance with the belief that a designer worth his salt will make the inside of a TV as dangerous as possible in order to kill off amateur mechanics, the whole chassis is live or at least not isolated from the mains. The growing trend to make TVs in monitor form so that they can be connected directly to video recorders instead of by the ridiculous method of re-modulating the signal may at last bring us electrically into line with the rest of the world in this respect.

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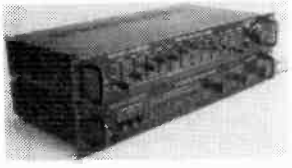

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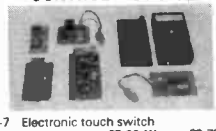

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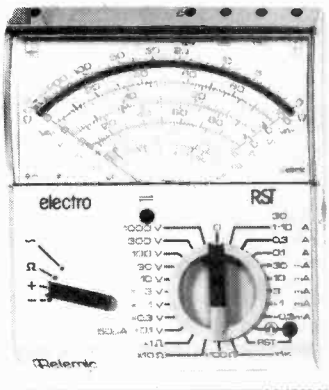

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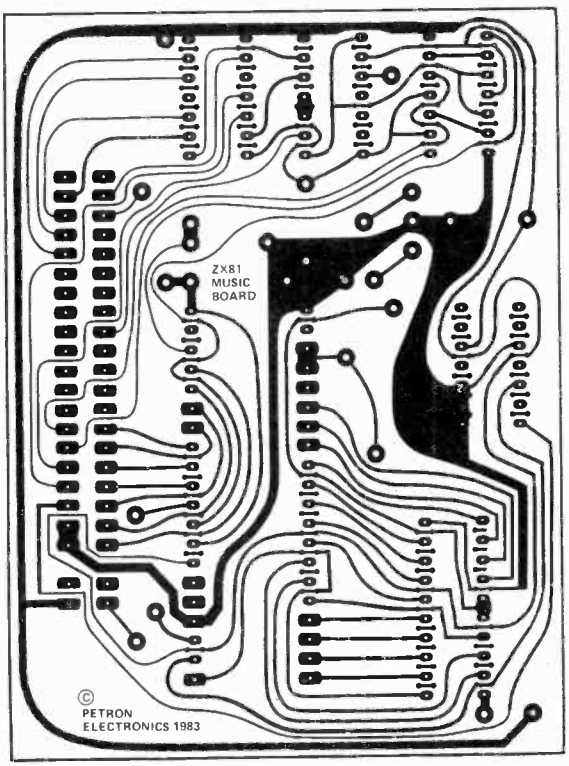

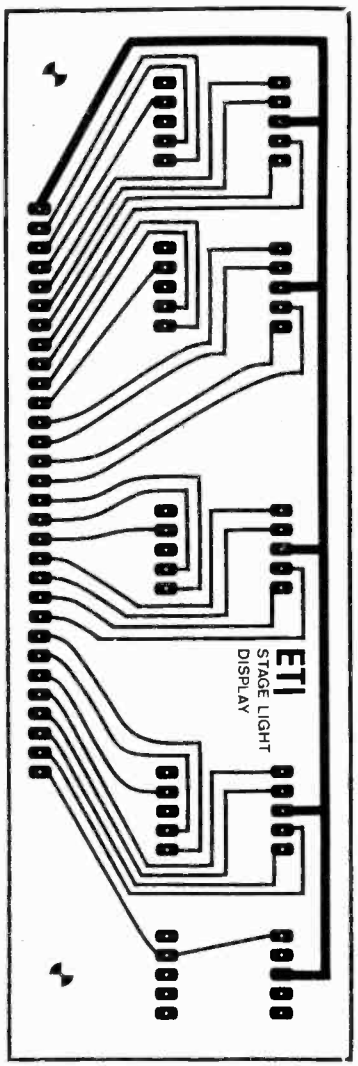

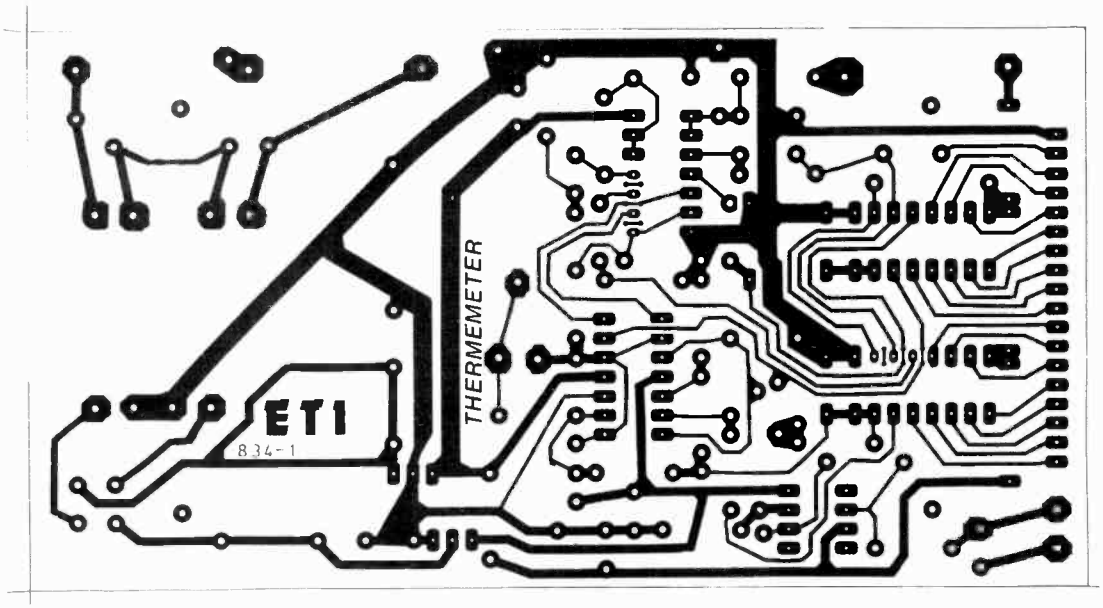

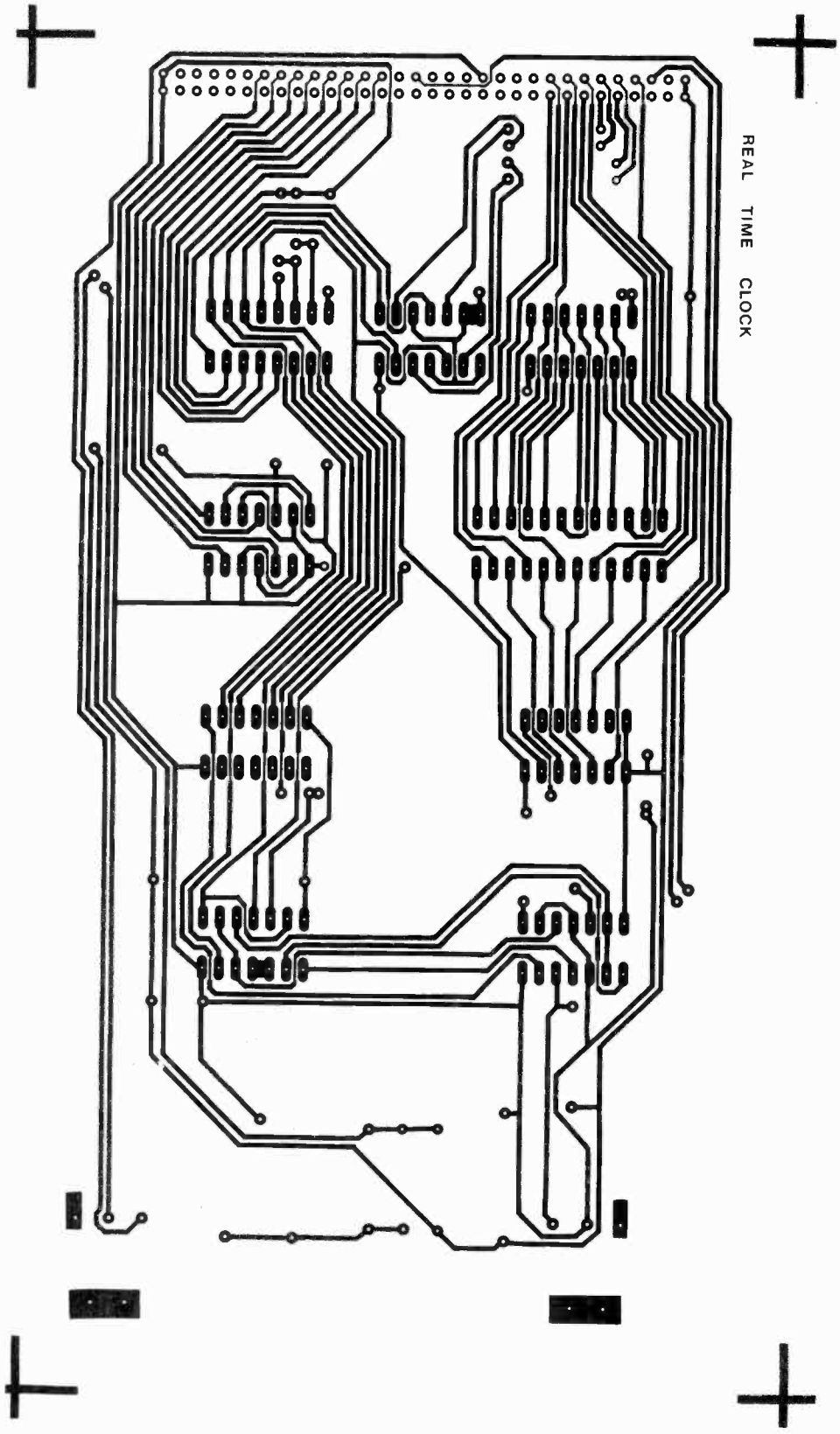

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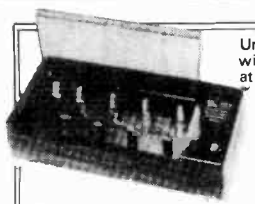

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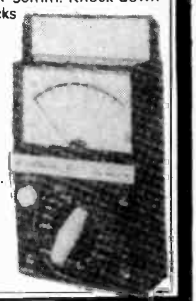

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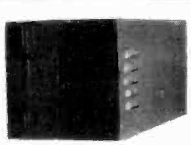

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In addition to the PCBs for this month's projects, we are making available some of the more popular designs from our recent past. See the list below for details. Please note that NO OTHER BOARDS ARE AVAILABLE. If it's not listed, we don't have it!

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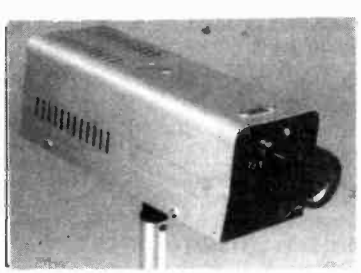

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(Electronics Today International December issue on CORTEX)

Example prices and specifications

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Lifting capacity: 1500gm
Arm lift: 6.6"
Weight: 29Kg

4 axis model in kit form	£425
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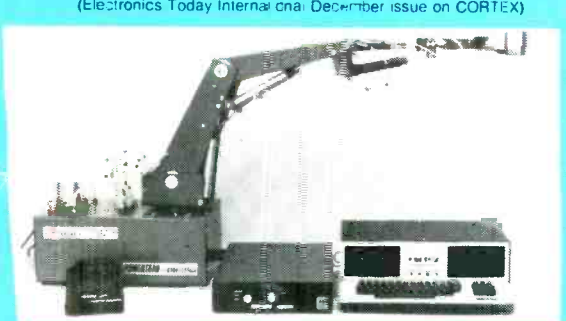

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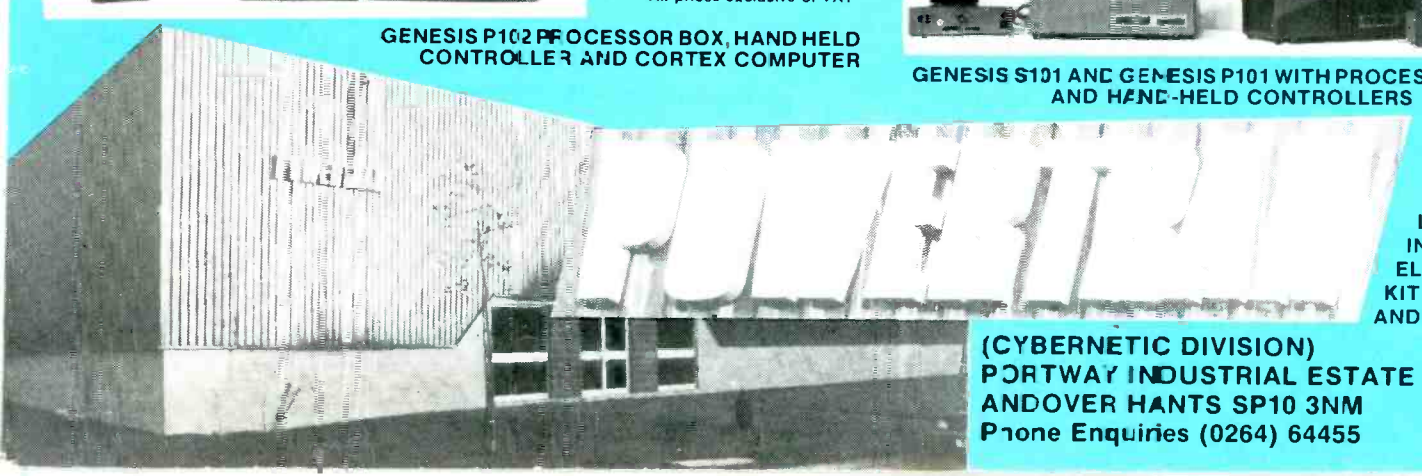

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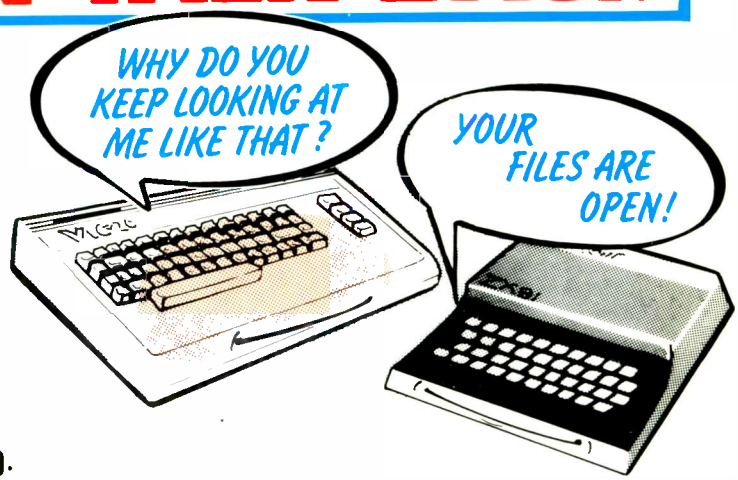

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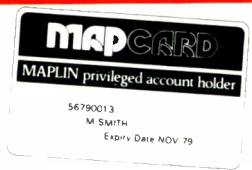

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Projects for Book 6 were in an advanced state at the time of writing, but contents may change prior to publication (due 11th February 1983).

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