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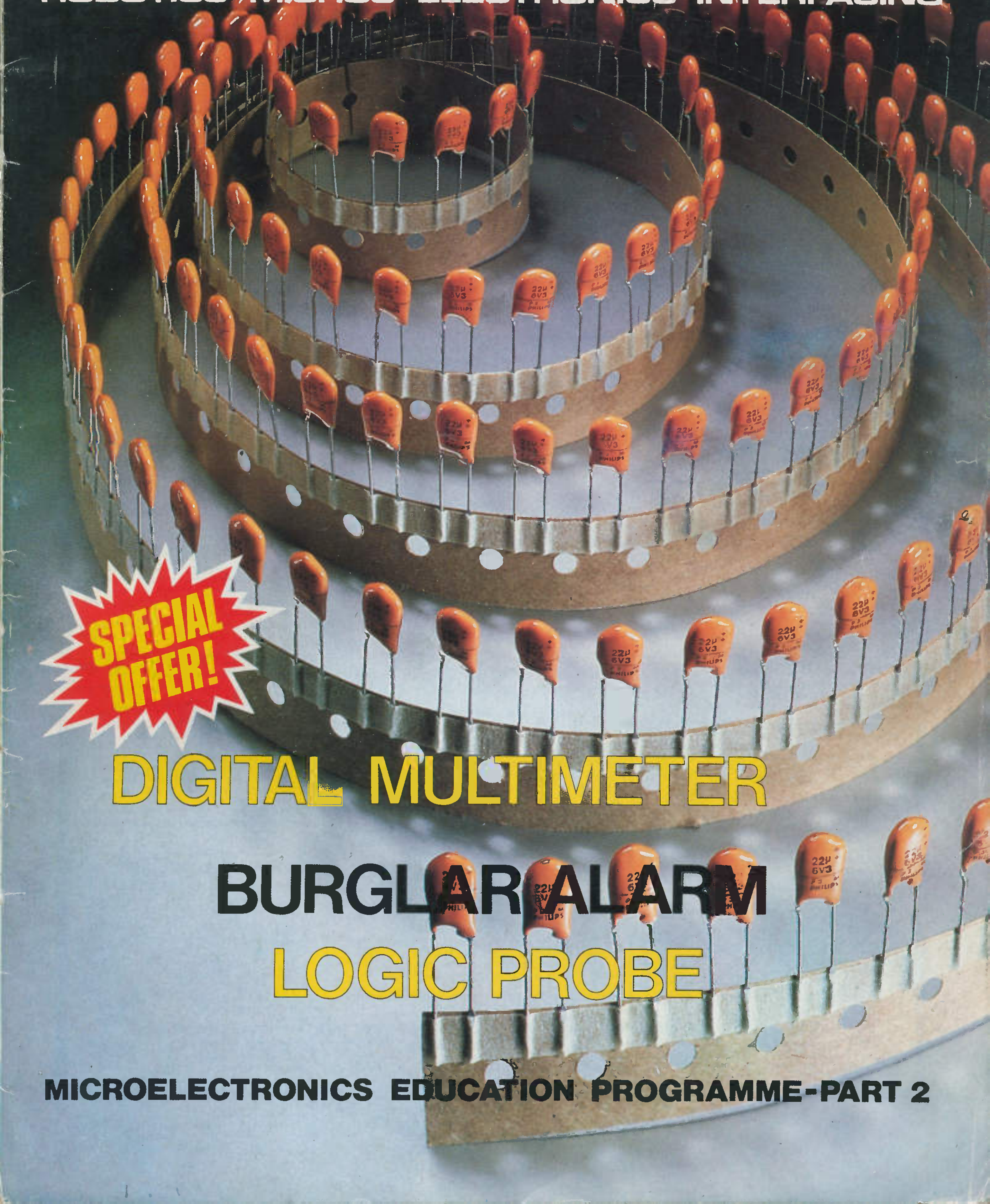
PRACTICAL FEBRUARY 1986 · £1·25

ELECTRONICS

ROBOTICS · MICROS · ELECTRONICS · INTERFACING



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DIGITAL MULTIMETER

BURGLAR ALARM

LOGIC PROBE

MICROELECTRONICS EDUCATION PROGRAMME-PART 2

PE ROBOTICS MICROS ELECTRONICS INTERFACING

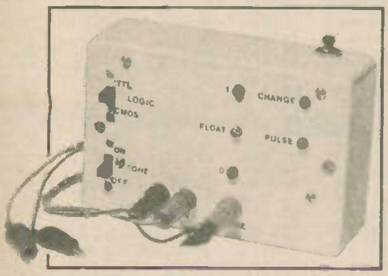
VOLUME 22 №2
FEBRUARY 1986

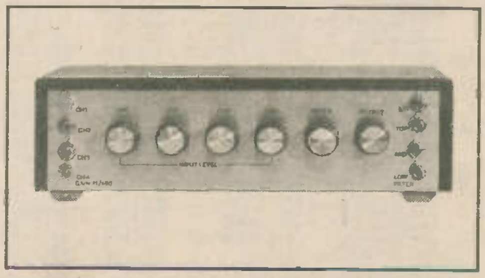
ISSN 0032-6372

FRONT COVER
This month's front cover picture shows a bandoleer of capacitors ready for automatic insertion.
Photograph by courtesy of Mullard.

PROJECTS

INTEREST





OUR MARCH 1986 ISSUE WILL BE ON SALE FRIDAY, FEBRUARY 7th, 1986 *(see page 33)*

WATFORD ELECTRONICS

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POLYESTER RADIAL LEAD CAPACITORS: 250V; 10n, 20n, 15n, 22n, 27n **6p**; 33n, 47n, 68n, 100n **8p**; 150n, 220n **10p**; 330n, 470n **15p**; 680n **19p**; 1µ **23p**; 1µ5 **40p**; 2µ2 **46p**.

ELECTROLYTIC CAPACITORS (Values in µF). **500V:** 10µF **52p**; 47 **78p**; **63V:** 0·47, 1·0, 1·5, 2·2, 3·3, **8p**; 4·7 **9p**; 10 **10p**; 15, 22 **12p**; 33 **15p**; 47 **12p**; 68 **16p**; 100 **19p**; 220 **26p**; 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:** 4·7, 10, 22, 47 **8p**; 100 **11p**; 150 **12p**; 220 **15p**; 330 **22p**; 470 **25p**; 680, 1000 **34p**; 1500 **42p**; 2200 **50p**; 3300 **76p**; 4700 **92p**; **16V:** 2·5, 40 **8p**; 47, 68, 100 **9p**; 125 **12p**; 220 **13p**; 330 **16p**; 470 **20p**; 680 **34p**; 1000 **27p**; 1500 **31p**; 2200 **36p**; 4700 **79p**.

TAG-END TYPE: 64V: 4700 **245p**; 3300 **145p**; 2200 **120p**; **50V:** 3300 **155p**; 2200 **95p**; **40V:** 4700 **160p**; 2200 **70p**; 3300 **85p**; 4000, 4700 **75p**; 10,000 **250p**; 15,000 **270p**; **16V:** 2200 **200p**; **25V:** 4700 **98p**; 10,000 **320p**; 15,000 **345p**.

TANTALUM BEAD CAPACITORS:
35V: 0·1µ, 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 **36p**; 33, 47 **50p**; 100 **95p**; 220 **100p**; **10V:** 15, 22 **26p**; 33, 47 **50p**; 100 **75p**.

POTENTIOMETERS: Carbon Track, 0·25W Log & Linear Values.

500W, 1K & 2K (LIN ONLY) Single	35p
5KΩ-2MΩ single gang	35p
5KΩ-2MΩ single gang D/P switch	95p
5KΩ-2MΩ dual gang stereo	99p

SLIDER POTENTIOMETERS
0·25W log and linear values 60mm track
5KΩ-500KΩ Single gang **80p**

PRESET POTENTIOMETERS

0·1W 50Ω-2·2M Mini Vert. & Horiz.	8p
0·25W 220Ω-4M7 Vert. & Horiz.	12p
¾" Cermet Multiturn Preset 100 to 500K	89p

RESISTORS Hi-stab, Miniature, 5% Carbon.

	RANGE	Val.	1-99	100+
0·25W	2Ω2 - 4·M7	E24	3p	1p
0·5W	2Ω2 - 4·M7	E12	3p	1p
1W	2Ω2 - 10M	E12	6p	4p
5W	0.22Ω - 1M		20p	10p
1% Metal Film 51Ω-1ME24			8p	6p

SILVER MICA (pf)
2, 3·3, 4·7, 6·8, 8·2, 10, 12, 18, 22, 27, 33, 39, 47, 50, 56, 68, 75, 82, 85, 100, 120, 150, 180 **15p**. 220, 250, 270, 330, 360, 390, 470, 600, 800 & 820pF **21p**. 1000, 1200, 1800 **30p each** 3300, 4700 **60p each**

SIEMENS multilayer miniature capacitors. **250V:** 1nF, 1n5, 2n2, 3n3, 4n7, 6n8, 8n2, 10n, 15n, 22n **7p**; 18n, 27n, 33n, 47n **8p**; 39n, 56n, 68n **9p**, 100nF **11p**. 100V: 100n, 120n, **10p**; 150n **11p**; 220n **13p**; 330n **18p**; 470n **23p**; 680n **30p**; 1MF **34p**; 2M2 **50p**.

CERAMIC Capacitors: 50V
Range 1pF to 6800pF **4p**; 10nF, 15n, 33n, 47nF **5p**; 100nF/20V **7p** 220nF/6V **8p**.

POLYSTYRENE Caps:
10pF to 1nF **8p**
1n5 to 12nF **10p**

RESISTORS S.I.L. Package: 7 Commoned, 100Ω, 470Ω, 680Ω, 1K, 2K2, 4K7, 10K, 47K, 100K **18p.**
8 Commoned: (9 pins) 150Ω, 180Ω, 270Ω, 330Ω, 330Ω, 1K, 2K2, 4K7, 6K8, 10K, 22K, 47K, 100K **20p.**

TRANSISTORS

AC126/7	30
AC127/8	35
AC141/2	35
AC176	25
AC187/8	25
AC188	25
AD142	120
AD149	79
AD161/2	42
AF118	95
AF124/6	60
AF139	40
AF239	55
BC107/8	12
BC107B	14
BC108B	14
BC108C	14
BC109	12
BC109B	14
BC109C	14
BC114/5	25
BC117/8	25
BC119	35
BC140	29
BC142/3	28
BC147/8	12
BC147B	15
BC148C	15
BC149	12
BC149C	14
BC153/4	30
BC157/8	14
BC159	11
BC167A	14
BC168C	12
BC169C	12
BC171/2	12
BC173	16
BC177/8	15
BC179/81	20
BC181	30
BC182/3	10
BC184	10
BC182L	10
BC183L	10
BC184L	10
BC186/7	28
BC212/3	12
BC212L	10
BC213L	12
BC214	10
BC214L	12

BC237/8	10
BC307B	15
BC308B	12
BC327/8	12
BC337/8	12
BC441	34
BC461	34
BC477/8	22
BC516/7	30
BC547/8	12
BC549C	15
BC556/7	15
BC558/9	15
BCY41/42	30
BCY70	18
BCY71	20
BCY72	18
BCY78	30
BD131/2	55
BD133	50
BD135	45
BD136/7	35
BD138/9	35
BD140	40
BD158	68
BD245	65
BD434	70
BD695A	150
BD696A	150
BF115	45
BF154/8	30
BF167	35
BF173	35
BF177	35
BF178	35
BF179	40
BF184	35
BF194/5	12
BF198/9	18
BF200	35
BF224	40
BF244A	28
BF244B	29
BF245	38
BF256B	45
BF257/8	32
BF259	30
BF394	40
BF451	40
BF494/5	40
BF594/5	30
BFR39/40	25

BFR41/79	25
BFR80/81	25
BFR98	105
BFX29/84	28
BFX84	35
BFX85/86	35
BFX87/88	28
BFY50/51	30
BFY52	30
BFY53	35
BFY55	35
BFY56	35
BFY64	40
BFY90	80
BRY39	50
BSX20	28
BSX29	32
BSY26	35
BSY95	35
BU105	180
BU205	160
BU206	200
BU208	170
MJ520	50
MJ521	90
MJ2955	90
MJE340	54
MJE371	100
MJE2955	99
MJE3055	70
MPF102	40
MPF103/4	30
MPF105	30
MPSA05	23
MPSA06	25
MPSA08	30
MPSA12	29
MPSA55	30
MPSA56	30
MPSA70	40
MPSU02	58
MPSU05	50
MPSU06	55
MPSU52	65
MPSU55	60
MPSU56	55
OC23	170
OC28/36	220
OC41/42	75
OC70	40
OC72	50
OC75/76	55
OC76	50
OC81/82	50
OC83/84	70

TIP29A	32
TIP29C	38
TIP30A	35
TIP30C	37
TIP31A	38
TIP31C	45
TIP32A	43
TIP32C	45
TIP33A	70
TIP33C	75
TIP34A	85
TIP34C	105
TIP35A	120
TIP35C	130
TIP36A	130
TIP36C	140
TIP41A	50
TIP41B	52
TIP42A	55
TIP42B	58
TIP120	70
TIP121	73
TIP141	120
TIP142	120
TIP147	120
TIP2955	70
TIP3055	70
TIS43	50
TIS44	45
TIS88A	50
TIS90	30
TIS91/93	32
VK1010	99
VN10KM	65
VN46AF	90
VN66AF	110
VN88AF	220
VN89AF	120
ZTX107/8	12
ZTX109	12
ZTX212	28
ZTX300	13
ZTX301/2	16
ZTX303	25
ZTX304	17
ZTX320/26	30
ZTX500/1	14
ZTX502/3	18
ZTX504	25
ZTX531	25
ZTX550	25
2N696	30
2N697	23
2N698	40
2N699	48

2N706A	25
2N708	25
2N914/5	32
2N918	40
2N930	20
2N1131/2	40
2N1303/4/5	
2N1307	70
2N1613	30
2N1671B	160
2N2160	325
2N2219A/20A/	
21A/22A	25
2N2369A	18
2N2646	45
2N2846	80
2N2904A/05A/	
06A/07A	26
2N2926G	10
2N3053	25
2N3054	55
2N3055	50
2N3442	140
2N3615	199
2N3663	20
2N3702/3	10
2N3704/5	10
2N3706/7	10
2N3708/9	10
2N3710	10
2N3771	179
2N3772	195
2N3773	210
2N3819	35
2N3820	60
2N3822/3	60
2N3866	90
2N3903/4	15
2N3906/5	15
2N4037	60
2N4058	15
2N4061/2	15
2N4264	30
2N4286	25
2N4289	25
2N4400	25
2N4427	80
2N4859	78
2N5135	30
2N5138	25
2N5172	25
2N5180	45
2N5191	75
2N5194	80
2N5305	24

2N5457	30
2N5458/9	30
2N5485	36
2N5777	45
2N6027	32
2N6109	60
2N6290	70
2SA636	250
2SA671	250
2SA715	75
2SC495/6	85
2SC1061	250
2SC1096	85
2SC1162	45
2SC1172/3	125
2SC1306	100
2SC1307	150
2SC1449	95
2SC1679	190
2SC1678	140
2SC1923	65
2SC1945	225
2SC1953	90
2SC1957	90
2SC1969	165
2SC2028	85
2SC2029	200
2SC2078	170
2SC2091	85
2SC2166	165
2SC2314	85
2SC2335	200
2SC2465	125
2SC2547	40
2SC2612	200
2SD234	75
2SK45	90
2SK288	225
2SJ83	225
2SJ85	225
3N128	115
3N140	115
40251	150
40311	60
40313	130
40361/62	70
40408	76
40412	90
40467	130
40468	85
40594	105
40595	110
40603	110
40673	70
40871/2	90

LINEAR IC's

555 CMOS	80
702	50
709C 8 pin	35
710	50
741	16
747C 14 pin	60
748C 8 pin	35
753 8 pin	185
810	160
9400CJ	375
ADCO808	£10
AY-1-1320	225
AY-1-5050	99
AY-1-6720	210
AY-3-1270	720
AY-3-8910	390
AY-3-8912	430
AY-5-1317A	630
AY-5-3500	650
AY-5-8100	650
CA3011	130
CA3012	175
CA3014	275
CA3018	86
CA3019	90
CA3020	210
CA3023	210
CA3028A	110
CA3035	255
CA3036	270
CA3043	275
CA3045	365
CA3046	65
CA3059	325
CA3075	215
CA3080E	65
CA3081	190
CA3085	160
CA3086	60
CA3090AQ	250
CA3123	165
CA3130	85
CA3140	40
CA3160	95
CA3161E	180
CA3162	540
CA3189	260
CA3240E	100
HA1366	175
HA1388	235
ICL7106	675
ICL7107	975
ICL7611	95
ICL7660	250
ICL8038CC	300
ICL8211	225
ICM7217A	£11
ICM7224	785
ICM7240	300
ICM7555	80
ICM7556	140
LA3350	250
LA4031P	340
LA4032	295
LA4400	350
LA4422	320
LC7120	300
LC7130	300
LC7137	350
LF347	120
LF351	40
LF353	75
LF355	90
LF356	90
LF357	100
LF398	495
LM10	325
LM301A	30
LM307	45
LM308	75
LM311	45
LM318	135
LM319	180
LM324	45
LM334Z	125
LM335Z	130
LM337	250
LM339	40
LM348	60

LM349	125
LM358	50
LM377	210
LM379	495
LM380	80
LM381N	150
LM382	130
LM384	140
LM386	90
LM387	120
LM389	160
LM393	60
LM394CH	380
LM558	170
LM725CN	300
LM733	65
LM1871	300
LM1889	400
LM2907	395
LM3900	45
LM3909	85
LM3911	175
LM3914	265
LM3915	265
LM3916	300
LM13600	110
LS7220	295
M51513L	230
M51515L	320
M51516L	430
MB3712	200
MB3756	440
MC1204	250
MC1301	110
MC1310P	135
MC1458	35
MC1469	300
MC1488	70
MC1489	70
MC1494	695
MC1495	300
MC1496L	70
MC1596	225
MC3302	75
MC3401	50
MC3403	65
MC3404	85
MC3405	150
MC3423P	80
MC4016	295
MF10	300
MFC6040	75
ML924	275
NE515	275
NE529	225
NE531	120
NE543	225
NE544	170
NE555	25
NE556DB	45
NE558	170
NE560	350
NE564	420
NE565A	115
NE566	140
NE567	130
NE570	370
NE571	370
NE5532	150
NE5534	105
OM335	650
RC4136D	55
RC4558	40
SAB3209	425
SAB3271	485
SAB4209	295
SG3402	295
SL490	300
SL924	395
SL6270	150
SN76003	350
SN76018	150
SN76131	135
SN76227	95
SN76477	380
SN76488	525
SN76489	400

SP0256AL	425
SP8629	350
TA7120	120
TA7130	125
TA7204	150
TA7205	90
TA7222	150
TA7310	120
TAA900	395
TAA700	275
TAD100	159
TBA120S	70
TBA540	275
TBA550Q	330
TBA641	290
TBA800	80
TBA810S	95
TBA820	80
TBA920Q	200
TBA990	350
TCA270	350
TCA280A	220
TCA940	175
TCA950	200
TCA965	180
TDA1008	310
TDA1010	220
TDA1022	400
TDA1024	110
TDA1034	350
TDA1054	110
TDA1490	350
TDA2002	325
TDA2003	190
TDA2004	230
TDA2006	320
TDA2020	320
TDA2030	190
TDB0791	420
TL061CP	40
TL062CP	60
TL064CN	95
TL071CP	40
TL072CP	60
TL074CN	110
TL081CP	30
TL082CP	50
TL083CP	75
TL084CP	100
TL091CP	60
TL170	50
TL497A	185
TL507	110
TL509	110
UA2240	120
UA78S40	225
UAA170	180
UAA180	180
ULN2003	75
ULN2004	75
ULN2283	150
ULN2803	190
UPC556	225
UPC575	275
UPC1025H	375
UPC1156H	295
UPC1181	395
UPC1182	425
UPC1366	195
XR2206	365
XR2207	400
XR2211	575
XR2216	675
XR2266	360
ZN409C	180
ZN414	80
ZN423E	130
ZN424E	130
ZN425E-8	350
ZN426E-8	300
ZN427E-8	600
ZN428E	450
ZN429E-8	240
ZN459	245
ZN1034E	200
ZN1040E	665
ZNA234E	925

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2147-3	£3
2516	300
2532-4	300
25L32	450
2564	£6
27L08	450
2716-5V	300
2732	350
2732A	585
27256-2	1055
2764-250	200
27C64	495
26501	75
27128/250n	300
256K DRAM	495
3242	675
4027	95
4116-200n	355
4164-150	225
4416-2	299
4532-3	250
4816-100ns	125
4864-15	225
6116-150	200
6116L-120ns	220
6117-100n	575
6167-6	795
6264L-15	400
63A03	£14
6464L-15	750
65C02	850
6502 CPU	325
6502A	545
6503	650
6520	175
6522A	545
6522 VIA	340
6530 RRIOT	£11
6532 RIOT	650
6545 CRTC	899
6551 ACIA	525
6800	220
6802	275
6803	850
6805	670
6809E	650
6810	150
68A02	345
6820	150
68B21	220
6821	150
6840	375
6843	800
6845	650
6845SP	750
6846	625
6847	650
6850	120
6852	250
6854	625
68B54	750
68000	£20
8017	275
8035	350
8080A	400
8085A	300
8088	895
81LS95	140
81LS96	170
81LS97/98	140
8123	160
8131	475
8150	800
8154	750
8155	380
8156	380
8202	£25
8212	220
8214	495
8216	150
8224	£3
8226	£3
8228	250
8243	290

8250	950
8251	325
8253	380
8255	350
8256A	£15
8257A	400
8259	400
8271	£45
8272	£15
8279	750
8282	450
8283	450
8284	550
8288	£11
8748	£33
8T26A	99
8T27	150
8T31	350
8T95N	90
8T97N	90
9364AP	550
9602	220
AM26LS31C	125
AM26LS32A	125
AM26LS33	150
AM7910	£19
AY-3-1015	300
AY-5-1013	300
AY-5-1350	388
AY-5-3600	750
CD4724	150
COM8017	275
DM8131	275
DP8303	450
DP8304BN	350
DS3647	600
DS3691N	350
DS8820	110
DS8830	140
DS8831	125
DS8832	150
DS88LS120	300
E9364	800
E9365	£28
FD1691	£15
FD1771	£15
FD1791	£22
FD1793	£23
FD1795	£28
FD1797	£28
HD26501	75
HD4315	250
HD6301	225
HM6845	755
IM6402	350
INS8060N	1250
M58174	825
MC1488	100
MC1489	100
MC14411	675
MC14412	725
MC3242	590
MC3446	250
MC3447P	315
MC3486	175
MC3487	175
MK3886-2M	£7
MM5280D	695
MM5303	635
MM5307	1275
MM5387A	865
MM58174	875
RO-3-2513L	700
RO-3-2513U	650
SAA5050	875
SFF96364E	800
SP0256AL2	475
TCM3101J	£13
TMS2716-3	725
TMS4047	100
TMS4164-15	255
TMS4416-2	355
TMS4500A	£12
TMS4532-3	350
TMS6011	500
TMS9914	895
TMS9927	£14
TMS9928	£10
TMS9929	£10
ULN2003	75

UPD7002	440
UPD7007	725
WD1691	£14
WD1770	£14
WD2143	850
Z80CPU 2·5	295
Z80ACPU4M	280
Z80ACTC	310
Z80B	£8
Z80DART	650
Z80ADART	800
Z80ADMA	900
Z80DMA	795
Z80P10	250
Z80AP10	315
Z80S10-1	850
Z80AS10	900
Z80AS10-2	£9

74S

74S00	40
74S02	40
74S03	40
74S04	40
74S05	40
74S08	40
74S09	40
74S10	40
74S11	50
74S15	60
74S20	40
74S30	60
74S22	60
74S30	50
74S32	50
74S37	50
74S38	70
74S40	40
74S51	40
74S64	40
74S65	40
74S74	70
74S85	295
74S86	100
74S112	150
74S113	120
74S114	120
74S124	300
74S132	90
74S133	50
74S134	60
74S135	110
74S138	170
74S139	170
74S140	75
74S151	140
74S153	140
74S157	200
74S158	190
74S162	300
74S163	300
74S168	300
74S169	300
74S174	250
74S175	300
74S181	£11
74S182	250
74S188	180
74S189	225
74S194	280
74S195	275
74S196	350
74S197	300
74S201	250
74S225	500
74S226	500
74S240	375
74S241	375
74S244	475
74S251	225
74S257	225
74S258	225
74S260	70
74S262	£10
74S274	00
74S275	00
74S280	00
74S281	00
74S283	00

74S287	200
74S288	180
74S289	200
74S299	540
74S301	350
74S365	250
74S373	375
74S374	375
74S412	380
74S470	325
74S471	600
74S472	400
74S473	00
74S474	400
74S475	425
74S571	300
74S573	450

75

75107/8/9	90
75110	90
75119	140
75121	130
75150	115
75151	180
75154	125
75158	150
75159	140
75160	350
75161	350
75162	450
75182/3	90
75183	105
75188/9	100
75322	140
75325	165
75353	140
75361	150
75365	185
75376	95
75376	210
75450	80
75451/2	50
75454	70
75491/2	65

TTL 74

7400	22
7401	22
7402	22
7403	25
7404	25
7405	25
7406	38
7407	38
7408	25
7409	25
7410	25
7411	25
7412	25
7413	35
7414	50
7416	35
7417	35
7420	25
7421	30
7422	30
7423	32
7425	32
7426	36
7427	30
7428	30
7430	22
7432	29
7433	35
7437	29
7438	39
7440	25
7441	85
7442	65
7443	95
7444	100
7445	100
7446	100
7447	95
7448	98
7450	25
7451	30
7453	25

7454	25
7460	25
7470	48
7472	35
7473	40
7474	36
7475	48
7476	40
7480	50
7481	175
7482	90
7483	85
7484	100
7485	100
7486	35
7489	170
7490	55
7491	65
7492	55
7493	50
7494	90
7495	65
7496	72
7497	170
74100	195
74104	68
74105	68
74107	40
74109	60
74110	55
74111	55
74112	170
74116	160
74118	100
74119	150
74120	90
74121	45
74122	50
74123	73
74125	50
74126	50
74128	55
74132	60
74136	63
74141	80
74142	230
74143	250
74144	225
74145	85
74147	130
74148	105
74150	130
74151	60
74153	70
74154	135
74155	75
74156	90
74157	75
74159	175
74160	90
74161	90
74162	90
74163	90
74164	110
74165	90
74166	130
74167	200
74170	160
74172	390
74173	100
74174	100
74175	80
74176	80
74177	80
74178	120
74179	90
74180	85
74181	230
74182	85
74184	160
74185	160
74186	70
74188	75
74190	117
74191	140
74192	191
74193	110
74194	90
74195	63
74196	120
74197	85

74198	190
74199	200
74221	95
74246	125
74247	120
74248	145
74249	172
74251	90
74259	140
74265	60
74273	150
74276	150
74278	150
74279	75
74283	110
74284	300
74285	310
74286	90
74290	85
74293	85
74297	165
74298	156
74351	175
74365	68
74366	68
74367	68
74368	65
74376	117
74390	100
74393	103
74425	60
74426	65
74490	89

74C

C244	195
C245	195
C373	220
C374	220
C922	400
C923	525
C925	595

74 HC

74HC00	40
74HC02	40
74HC04	55
74HC08	40
74HC10	40
74HC20	40
74HC32	50
74HC24	135
74HC42	65
74HC51	40
74HC74	40
74HC86	60
74HC107	50
74HC109	60
74HC139	75
74HC153	70
74HC160	35
74HC161	90
74HC164	90
74HC165	95
74HC173	100
74HC174	100

74LS

LS00	22
LS01	22
LS02	22
LS03	22
LS04	22
LS05	22
LS08	25
LS09	22
LS10	22
LS11	22
LS12	22
LS13	30
LS14	50
LS15	22
LS19	45
LS20	22
LS21	22
LS22	22
LS24	50
LS26	22

LS27	22
LS28	24
LS30	22
LS32	22
LS33	23
LS37	22
LS38	25
LS40	22
LS42	50
LS47	75
LS48	75
LS49	95
LS51	22
LS52	25
LS54	22
LS55	22
LS63	52
LS73	28
LS74	28
LS75	38
LS76	28
LS78	34
LS83	65
LS85	70
LS86	35
LS90	40
LS91	86
LS92	50
LS93	45
LS95	58
LS96	90
LS107	40
LS109	45
LS112	40
LS113	38
LS114	36
LS122	55
LS123	60
LS124	120
LS125	37
LS126	37
LS132	52
LS133	44
LS135	28
LS136	35
LS138	48
LS139	48
LS145	90
LS147	130
LS148	115
LS151	55
LS153	65
LS154	120
LS155	55
LS156	55
LS157	47
LS158	48
LS160	60
LS161	60
LS162	60
LS163	60
LS164	70
LS165	95
LS166	88
LS168	138
LS169	90
LS170	120
LS173	80
LS174	60
LS175	60
LS181	190
LS183	186
LS190	75
LS191	55
LS192	75
LS193	75
LS194	70
LS195	60
LS196	75
LS197	75
LS221	65
LS240	80
LS241	80
LS242	80
LS243	80
LS244	70
LS245	88
LS247	75

LS248	100
LS249	100
LS251	55
LS253	70
LS256	90
LS257	55
LS258	55
LS259	90
LS260	70
LS261	100
LS266	25
LS273	80
LS275	350
LS279	55
LS280	180
LS283	70
LS290	80
LS292	850
LS293	75
LS294	999
LS295	130
LS297	850
LS298	100
LS299	220
LS320	210
LS322	360
LS323	300
LS324	140
LS325	150
LS326	290
LS327	290
LS347	120
LS348	140
LS352	115
LS353	85
LS355	220
LS356	200
LS363	140
LS364	150
LS365	42
LS366	42
LS367	42
LS368	42
LS373	80
LS374	80
LS375	55
LS377	100
LS378	85
LS379	127
LS380	310
LS382	310
LS384	457
LS385	310
LS386	50
LS390	60
LS393	48
LS395	100
LS396	300
LS398	185
LS399	115
LS445	125
LS447	75
LS465	130
LS467	120
LS490	148
LS540	100
LS541	98
LS624	155
LS629	120
LS640	150
LS641	140
LS645	195
LS668	87
LS669	85
LS670	150
LS673	850
LS674	850
LS682	250
LS684	300
LS687	300

CMOS

4000	20
4001	20
4002	20
4006	70
4007	20
4008	60
4009	40
4010	40
4011	20
4012	20
4013	30

4014	50
4015	40
4016	25
4017	45
4018	55
4019	35
4020	50
4021	55
4022	60
4023	20
4024	35
4025	20
4026	90
4027	30
4028	40
4029	45
4030	20
4031	125
4032	65
4033	130
4034	145
4035	70
4036	250
4037	115
4038	75
4039	270
4040	45
4041	55
4042	45
4043	45
4044	50
4045	110
4046	60
4047	50
4048	50
4049	25
4050	25
4051	50
4052	50
4053	60
4054	70
4055	70
4056	85
4057	£10
4059	400
4060	70
4061	£5
4062	995
4063	80
4066	25
4067	230
4068	20
4069	20
4070	25
4071	20
4072	20
4073	20
4075	25
4076	60
4077	25
4078	25
4081	20
4082	20
4085	60
4086	60
4089	120
4093	25
4094	70
4095	70
4096	100
4097	260
4098	70
4099	75
4160	95
4161	99
4162	99
4163	99
4174	99
4175	105
4194	105
4408	850
4409	850
4410	725
4411	750
4412	805
4415	590
4419	280
4422	770
4433	770
4435	850

4440	999
4450	350
4490	450
4500	395
4501	40
4502	50
4503	45
4504	100
4505	350
4506	100
4507	45
4508	115
4510	50
4511	50
4512	50
4513	150
4514	115
4515	115
4516	50
4517	275
4518	50
4519	35
4520	50
4521	110
4522	125
4526	70
4527	60
4528	45
4529	80
4530	90
4531	120
4532	65
4534	365
4536	250
4538	70
4539	80
4541	95
4543	65
4544	150
4549	390
4553	210
4554	180
4555	50
4556	50
4557	250
4558	120
4559	340
4560	110
4561	104
4562	350
4566	160
4568	250
4569	175
4572	45
4580	255
4581	125
4582	99
4583	100
4584	40
4585	65
4599	155
40097	45
40098	42
40100	215
40101	130
40102	140
40103	412
40104	120
40105	220
40106	40
40107	55
40108	325
40109	100
40110	235
40114	240
40161	194
40163	75
40173	100
40174	75
40175	75
40181	220
40192	75
40193	90
40194	90
40195	80
40244	195
40245	195
40257	198
40373	220
40374	220

SPEAKERS

8Ω, 0·3W, 2", 2·25", 2·5", 3" 80p
0·3W, 2·5" 40Ω; 64Ω or 80Ω 80p

DIODES

AA119	8
AA129	10
AAY30	8
BA100	10
BY100	15
BY126	12
BY127	10
CRO33	198
OA9	10
OA47	10
OA70	9
OA79	10
OA81	10
OA85	10
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	12
1N5404	14
1N5406	15
1N5408	19
1S44	9
1S921	9
6A/100V	40
6A/400V	50
6A/800V	65

BRIDGE RECTIFIERS

(plastic case)

1A/50V	18
1A/100V	20
1A/400V	25
1A/600V	30
2A/50V	26
2A/200V	40
2A/400V	42
2A/600V	50
6A/100V	83
6A/400V	95
6A/600V	125
10A/200V	215
10A/600V	298
25A/200V	240
25A/600V	395
BY164	56

ZENERS

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

VARICAPS

BB105B	40
BB106	40

TRIACS

3A/100V	48
3A/400V	56
3A/800V	85
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
25A/400V	185
25A/800V	295
25A/1000V	480
30A/400V	525
T2800D	125

SCR's Thyristors

0·8A-100V	32
5A/300V	38
5A/400V	40
5A/600V	48
8A/300V	60
8A/600V	95
12A/100V	78
12A/400V	95
12A/800V	188
BT106	150
BT116	180
C106D	38
TIC44	24
TIC45	29
TIC47	35
2N5064	38
2N4444	130

DIAC

ST2 25

SOLDERCON PINS

100 45p
500 200p

VERO TOOLS

Spot face cutters 150p
Pin insertion tool 185p

OPTO ELECTRONICS

LED

0·125"

TIL209 Red	10p
TIL211 Green	14p
TIL212 Yellow	14p
TIL213 Amber	14p

0·2"

TIL220 Red	12p
TIL222 Green	14p
TIL226 Yellow	14p
Flashing Red	55p
Bi colour R/G	100p
Bi colour G/Y	100p
Tri colour R/G/Y	85p
Hi-Bright Red	95p
Hi-Bright Green	100p
Hi-Bright Yellow	95p
Rectangl. R,G & Y	35p
Rectang. Stackable	
Red Green Yellow	18p
Triangular R & G	18p

Infra Red

LD271 (emit)	46p
TIL32 (emit)	52p
SFH205 (detector)	100p
TIL78 (detector)	55p
TIL38 (emit)	50p
TIL100 (detector)	90p

7 Segment Display

DL704 ·3" C.An	120p
DL707 ·3" c.Cth	120p
FND357 or 500	100p
TIL321 ·5" C.An	140p
TIL322 ·5" C.Cth	140p
·3" Green C.An	140p
3+1" Red or Green	150p
Bargraph 10 Seg.	250p
Bargraph NSM3914	400p

ILCT6	135p
IL74	80p
ILD74	130p
ILQ74	220p
TIL111	70p
TIL112	70p
TIL113	70p
TIL114	70p
TIL116	70p
BPX25	150p
BPX65	320p
BPW21	280p
TIL81	82p
OCP71	120p
ORP12	78p
2N5777	50p
4N33	135p
Pin Diode	720p
Smith Rec.	700p

0·5" LCD DISPLAYS

3½ digit 495
6 digit 625

OPTO SWITCH

Reflective TIL139 225
Slotted similar to RS 186

ALUM.BOXES

4×2½×2"	100
4×2¾×2½"	103
4×4×2½"	120
5×4×2"	105
5×2¾×1½"	90
5×2¾×2½"	130
5×4×1½"	99
5×4×2½"	120
6×4×2"	120
6×4×3"	150
7×5×3"	180
8×6×3"	210
10×4¼×3"	240
10×7×3"	275
12×5×3"	260
12×8×3"	295

FERRIC CHLORIDE

Crystals 1lb 150p + 50p p&p

DALO ETCH RESIST

Pen plus spare tip 100p

COPPER CLAD BOARDS

	single sided	double sided
Fibre Glass 6"×6"	100p	125p
6"×12"	175p	225p

VERO BOARDS 0·1"

2½ × 1	30p
2½ × 3¼	95p
2½ × 5	110p
3¾ × 3¾	110p
3¾ × 5	125p
3¾ × 17	420p
4¾ × 17	590p
VQ Board	195p

DIP Board	395p
Vero Strip	95p

PROTO DECs

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

VERO WIRING

PEN + Spool	380p
Spare Spool	75p
Combs	8p
Pen + Spool + Combs	599p

VERO PINS per 100

Single Ended	55p
Double Ended	60p
Wire Wrape S/E	155p
Wire Wrape D/E	255p

VOLTAGE REGULATORS

1A T0220 Plastic Casing

	+ve		−ve	
5V	7805	45p	7905	50p
12V	7812	45p	7908	55p
15V	7815	45p	7912	55p
18V	7818	45p	7915	55p
24V	7824	45p	7918	50p

100mA T092 Plastic Casing

5V	78L05	30p	79L05	50p
6V	78L62	30p	—	
8V	78L82	30p	—	
12V	78L12	30p	79L12	50p
15V	78L15	30p	79L15	50p

ICL7660	248	LM317K	250
78H05 5V/5A	550	LM317	99
78H12 12V/5A	640	LM323K	500
78HG+5 to +24V 5A	695	LM337T	175
79HG −2.25V to −24V 5A	785	LM723	30
LM309K	120	TBA625B	75
TL497	185	RC4194	375
		RC4195	160
		78S40	225

SWITCHES

SLIDE 250V		TOGGLE 2A 250V	
1A DPDT	14	SPST	35
1A DPDT C/OFF	15	DPDT	48
½A DP on/on/on	40	4 pole on off	54

PUSH BUTTON Spring loaded

Latching or Momentary 6A	
DPDT c/over	200

MINIATURE Non Locking

Push to make	15p
Push break	25p

SUB-MIN TOGGLE 2 amp

SP changeover	64
SPST on off	58
SPDT c/off	85
SPDT Biased	105
DPDT 6 tags	80
DPDT C/OFF	88
DPDT on/on/on	185
DPDT Biased	145
4-pole 2 way	220

ROTARY: (Adjustable Stop Type)
1 pole/2 to 12 way, 2p/2 to 6 way, 3 pole/2 to 4 way, 4 pole/2 to 3 way 48p

ROTARY: Mains 250V AC, 4 Amp 68p

DIP SWITCHES: (SPST) 4 way 65p; 6 way 80p; 8 way 87p; 10 way 100p; (SPDT) 4 way 190p.

AMPHENOL CONNECTORS

	IDC	Solder
24 way IEEE plug	465p	460p
24 way IEEE socket	485p	480p
36 way Centronics plug	395p	390p
36 way Centronics socket	480p	450p

ASTEC UHF MODULATORS

6MHz Standard 375p
8MHz Wideband 450p

ANTEX Soldering Irons

C15W	600p	C517W	620p
G18W	620p	XS25W	650p

DIL SOCKETS

	Low profile	Wire wrap	Turned Pin Low profile
8 pin	8p	25p	20p
14 pin	10p	35p	25p
16 pin	10p	42p	30p
18 pin	16p	52p	35p
20 pin	20p	60p	40p
22 pin	22p	65p	40p
24 pin	25p	70p	45p
28 pin	28p	80p	55p
40 pin	30p	99p	75p

ZIF SOCKET (TEXTOOL)

24 way	550p
28 way	650p
40 way	800p

DIL PLUGS (Headers)

Pins	Solder	IDC
14	40p	95p
16	45p	100p
24	85p	135p
28	150p	195p
40	200p	225p

RIBBON CABLE

(price per foot)

Ways	Grey	Colour
10	15p	25p
16	20p	30p
20	25p	40p
26	40p	65p
34	50p	80p
40	60p	90p
64	90p	125p

'D' CONNECTORS:

Pins	9 way	15 way	25 way	37 way
MALE				
Solder	55p	80p	120p	150p
Angle	110p	175p	225p	300p
Strait	100p	100p	160p	250p
FEMALE				
Solder	90p	125p	180p	275p
Angle	150p	200p	260p	390p
Strait	100p	125p	195p	355p
COVERS	75p	70p	70p	85p

IDC 25 way Plg. 385p, Skt. 450p

SIL Sockets 0.1"

20 way 65p
32 way 95p

EDGE CONNECTORS

	·1"	·156"
2× 6 way	—	75p
2×12 way	—	160p
2×15 way	—	165p
2×18 way	175p	160p
2×22 way	200p	170p
2×23 way	150p	—
2×25 way	250p	245p
2×28 way	180p	—
2×30 way	280p	—
2×36 way	300p	—
2×40 way	320p	—
2×43 way	400p	—
2×75 way	600p	—

SPECTRUM 32K UPGRADE

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

IDC CONNECTORS (Speed block type)

2 rows	PCB Male with latch Strt. Pins	Angle Pins	Female Header Socket	Female Card-Edge Connector
10 way	65p	65p	65p	110p
16 way	75p	75p	80p	185p
20 way	90p	90p	95p	185p
26 way	105p	110p	115p	230p
34 way	115p	130p	135p	320p
40 way	140p	145p	150p	335p
50 way	165p	170p	175p	350p
60 way	195p	210p	225p	495p

SPECIAL OFFER

	1+	10+
2764 – 250ns	200p	195p
27128 – 250ns	300p	295p
6116LP – 300ns	165p	145p
6264LP – 150ns	400p	395p

TRANSFORMERS

3-0-3V; 6-0-6V; 9-0-9V; 12-0-12V; 15-0-15V @100MA...... 130p
PCB mounting; miniature; Split bobbin.
3VA: 2×6V /0·25A; 2×9V /0·15A; 2×12V /0·12A; 2×15V /0·2A 235p
6VA: 2×6V /0·5A; 2×9V /0·3A; 2×12V 0·25A; 2×15V /0·2A 280p
Standard split Bobbin type.
6VA: 2×6V /0·5A; 2×9V /0·4A; 2×12V /0·3A; 2×15V /0·25A 250p
12VA: 2×4V5 /1A3; 2×9V /0A6; 2×12V /0A5; 2×15V /0A4; 2×20V /0A3 ...... 345p (35p p&p)
24VA: 2×6V /1A5; 2×9V /1A2; 2×12V /1A; 2×20V /0A5 ...... 385p (60p p&p)
50VA: 2×6V /4A; 2×9V /2A5; 2×12V /2A; 2×15V /1A5; 2×20V /1A2; 2×25V /1A; 2×30V /0A8 ...... 520p (65p p&p)
50VA multirail: +5V/5A, +12V, +25V, −5V, −12V @ 1A 620p (65p p&p)
100VA: 2×12V /4A; 2×15V /3A; 2×20V /2A5; 2×25V /2A; 2×30V /1A5; 2×50V 1A ...... 955p (75p p&p)
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1·8MHz	545
1·8432M	200
2·0MHz	225
2·4576M	200
2·5MHz	225
2·56250M	220
3·2768M	150
3·57954M	95
3·6864M	300
4·0MHz	140
4·032MHz	290
4·194304M	150
4·433619M	100
4·608MHz	200
4·80MHz	200
5·0MHz	150
5·185MHz	300
5·24288M	390
6·0MHz	140
6·144MHz	140
6·5536MHz	200
7·0MHz	150
7·168MHz	175
7·68MHz	200
8·0MHz	140
8·08333M	395
8·867237M	175
9·00MHz	200
9·375MHz	350
10·0MHz	170
10·5MHz	250
10·7MHz	150
10·24MHz	200
12·0MHz	175
12·528MHz	300
14·31818M	155
14·7456M	175
14·765MHz	250
15·0MHz	200
16·0MHz	200
18·0MHz	150
18·432M	150
19·968MHz	150
20·0MHz	150
24·0MHz	150
24·930MHz	325
29·695MHz	150
26·670MHz	325
27·125MHz	295
27·145M	190
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We are unable to offer any advice on the use or purchase of commercial equipment or the incorporation or modification of designs published in PE. All letters requiring a reply should be accompanied by a stamped addressed envelope, or addressed envelope and international reply coupons, and each letter should relate to **one published project only. We are unable to answer letters relating to articles more than five years old.**

Components are usually available from advertisers; where we anticipate difficulties a source will be suggested.

Old Projects

We advise readers to check that all parts are still available before commencing any project in a back-dated issue, as we cannot guarantee the indefinite availability of components used. **We are unable to answer letters relating to articles more than five years old.**

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COMPUTERS FOR EVERYONE

As the general interest in hobby computers as games machines wanes and the mass of computer publications diminishes we find interest in using machines for other applications on the increase. In order to do this it is usually necessary to add some hardware.

This issue of *Practical Electronics* carries an interesting and relatively simple computer addition which can open up a new range of uses and interest; the *Computer Movement Detector*.

The most obvious application of the unit is as a computer based alarm stystem which, with a number of units added, could form a comprehensive and extremely versatile system. However, other areas of activity can also be investigated with such a unit. Some readers following our *Experimenting with Robots* series may well find this ultrasonic unit useful for their experiments and photographers might also see various uses—the nature of the project lends itself to experimentation.

As regular readers will know we now carry a computer based project in every issue and these are often the most popular projects with readers. If you do not own a computer and have no interest in these "games machines" perhaps it is time to think again! Why not look at the micro computer as an extremely versatile control unit for various projects, rather than an arcade machine?

I am sure most hobbyists can find a use for such a controller —which can, of course, be used for a variety of other tasks—especially now the price is so low.

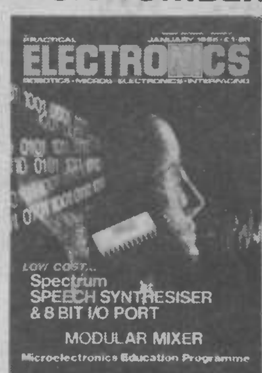
ELECTRONICS FOR ALL

We have had our say on electronics and education, stirred it up a bit and given others the chance to reply. In this issue we take a good look at *Microelectronics For All*. We see what is available to schools (and to others if they are interested), how the products and teaching aids are used in the classroom and how the system builds up to ensure a good understanding of the subject.

We would like to thank Michael Page and Graham Bevis of MEP for their efforts on our behalf. We hope the features have proved interesting, if they have helped to push forward the teaching of technology in schools in any way we will be very pleased.

Mike Kenward

BACK NUMBERS, BINDERS & SUBSCRIPTIONS



Copies of most of our recent issues are available from: Post Sales Department (Practical Electronics), IPC Magazines Ltd., Lavington House, 25 Lavington Street, London SE1 0PF, at £1.25 each including inland or overseas p&p. When ordering please state title, month and/or issue required.

Binders for PE are available from the same address as back numbers at £5.50 each to UK or overseas addresses, including postage, packing and VAT.

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Copies of Practical Electronics are available by post, inland for £14, overseas for £16 per 12 issues, from: Practical Electronics, Subscriptions Department, IPC Magazines Ltd., Oakfield House, 35 Perrymount Road, Haywards Heath, West Sussex RH16 3DH. Tel. 0444 459188. Cheques, postal orders and international money orders should be made payable to Practical Electronics. Payment for subscriptions can also be made using a credit card.

INDUSTRY BACKS YOUTH

New industry backing for the Young Electronic Designer Awards Scheme, announced recently at the House of Commons (with the acknowledgement of the Rt. Hon. Christopher Patten MP, Minister of Education and Kenneth Warren MP, Chairman of the Commons Select Committee for Trade and Industry) is aimed at helping to ease the shortage of suitably skilled graduates and school leavers who are available for recruitment.

The world's largest manufacturer of semiconductors—Texas Instruments, whose substantial British based operations, in common with other employers, have felt these problems for some time—have joined the industry newspaper Electronics Times and component distribution group Cirkit Holdings PLC (originators of the scheme), to provide challenging new incentives. These are designed to encourage the inclusion of "practical electronic projects" in the curriculum and include equipment and materials for educational establishments taking part plus cash and career development opportunities for students.

The YEDA scheme aims to encourage the spirit of innovation in a practical way at the education level, equally imparting a realisation of the true requirements of commerce and industry. Its implementation in the academic sphere is being spearheaded by Professor John Eggleston, Professor of Education at Warwick University.

To enter the scheme, students in full-time attendence at a school, college, polytechnic or university in Great Britain must design and produce an electronic device, which addresses a clearly identified practical need. There are three eligible age groups: under 15, 15–18, 19–25.

Winners and runners-up in each of the categories will receive an impressive range of awards, ranging from straightforward cash sums, through course sponsorships, to computer systems.

In addition to the above mentioned prizes, the sponsors will supply all educational establishments submitting approved projects with a free supply of components to assist in the development of practical work in the science of electronics and each finalist will receive a TI calculator appropriate to his or her age group.

All projects entered will be judged by a carefully appointed panel of experts at a series of regional previews in March this year and the winners announced at a special event in May.

For further information contact, The Department of Education, University of Warwick, Westwood, Coventry. CV4 7AL. (0203 523848).

SURREY SCHOOL TAKES A LEAD

One of the first major diversions from the simple 'micros in schools' scheme is being set up by Surrey County Council.

The project, a micro technology lab for 12–16 year olds, is under development at Heathside School, Weybridge, Surrey. It is being financed by the local authority and the community.

Among the sponsors are Plessey, British Aerospace, Birds Eye/Walls, the Milk Marketing Board and UK information systems consultants BIS Applied Systems.

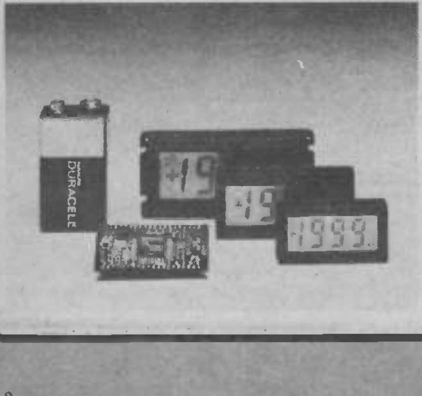
As part of their physics and design lessons, children will now have the opportunity to develop skills in circuit design, control technology, graphics, computer-aided design and robotics.

Says school governor and BIS Applied Systems Principal Consultant Tom Brooks: "The centre will initially teach 12 and 13-year-olds and this is the first time that technological subjects such as these have been made available to children so early in their education. There has been some provision for those over 16, but even that has not been great."

Surrey, however, has responded by offering four schools the opportunity to establish a substantial micro technology centre and to integrate studies into the syllabus. Heathside is leading the project and the Minister of State for Technology Geoffrey Pattie officially opened last November.

Meters made easy

A new range of miniature l.c.d. d.p.m.s designed and manufactured in the UK has been introduced by Lascar Electronics. All types utilise surface mount techniques to vastly reduce the overall size. The d.i.l. format is claimed to make the meters particularly easy to use. Each meter is also supplied with a 'snap-in' bezel for fast fitting.



Standard features include Auto-zero, Auto-polarity, 200mV f.s.d. programmable decimal points and 'Low Battery' indication. A range of useful engineering symbols is incorporated on the l.c.d. Three different versions are available with character heights of 15mm, 12·5mm and 10mm. The DPM 400 with its 10mm character height is the world's smallest off-the-shelf. d.p.m.

Prices as follows: D.P.M. 400 (10mm) £21·79; D.P.M. 500 (12·5mm) £22·94; D.P.M. 2000 (15mm) £24·00. (All prices include VAT and p&p). From Lascar Electronics Ltd., Module House, Whiteparish, Salisbury, Wiltshire, SP5 2SJ. (07948 567).

TAKE A TIP

The 3S–TIP soldering iron bits are specially made as a long lasting alternative tip for Weller TCP and ECP temperature controlled soldering irons.

Now they have been improved further by a new additional surface treatment of the areas wetted by the solder. Various tip designs are available as shown in the photograph.

The supplier, Cobonic Limited, is so confident of these tips that it is offering free samples to all interested persons.

Prices are "extremely competitive". Information and price list is available from Cobonic Limited, 32 Ludlow Road, Guildford, Surrey GU2 5NW. (0483 505260).

MARKET PLACE

SUPERSCOPE FROM SOAR

Now available in the UK exclusively from Advance House of Instruments is the Soar Model 1000, a handheld, battery operated, 3·2MHz digital storage oscilloscope.

Weighing only 2·1kg with dimensions of 264 × 214 × 60mm, the Model 1000 features a dual-trace liquid-crystal display. The display unit comprises a 128 × 160 dot matrix with an effective display area of approximately 76 × 95mm, and a dot size of 0·55 × 0·55mm.

A built-in battery back-up memory allows storage of the waveform for later analysis and a waveform alarm function ensures correct operation.

Features of the Y-axis operation include a scale of four vertical divisions for each channel, a nine-range sensitivity from 10MV/div to 5V/div, and a frequency characteristic of ±3dB or less for d.c. to 200kHz.

The X-axis operation has 10 divisions, a 20-range sweep speed of 5μs/div to 5s/div, continuous-sweep and single-sweep measurement modes, and positive, negative, and switchable trigger slopes.

The Model 1000 also incorporates a separate 7-function 27-range DMM with automatic and manual ranging.

Designed for field service, design engineering and plant maintenance applications, the Soar Model 1000 digital storage oscilloscope operates from rechargeable NiCad batteries with a 6-hour operation or from an a.c. mains adaptor. The good news is that this technology will one day be available to us all, the bad news?—If you want it now it will cost you £990 plus VAT.

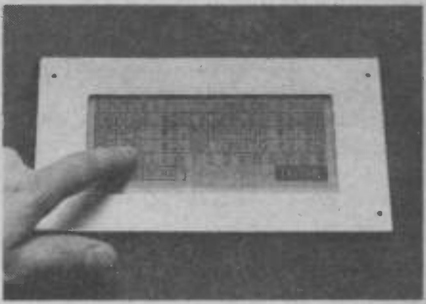
EPSON GO OVER THE TOP

Epson's new Touch Key overlays provide a direct touch entry capability for easy menu selection and data input without resorting to a keyboard. Two variations of Touch Key technology have been developed; X/Y matrix type, which is available now and A/D type which will be available soon.

Touch Key is transparent, allowing it to be accurately positioned directly over an l.c.d. module, allowing designers to build less complicated, thinner and more compact computer and peripheral systems.

Intended for equipment requiring moderate resolution, the X/Y type Touch Key consists of a matrix of transparent electrodes formed on a glass film panel. Finger pressure on the Touch Key panel causes the upper and lower electrodes to make contact, thus entering the required information.

The forthcoming A/D type Touch Key Panel consists of transparent stripe electrodes formed on a glass film transparent board, with a uniform resistor block set at right angles with the electrode stripes. An A/D converter is used to convert the voltage across the panel into positional information.



Applications for Touch Key are seen as keyboards for desk-top calculators, office machinery menu selections, keyboards of facsimile copying machines, data entry terminals for computers, word processors and retail/banking terminals. In the home, Touch Key is suitable as an input device for interactive television sets, acousitic equipment, telephone information entry devices and electronic games.

IN JAPAN

'Success in Japan' is the theme of a new booklet just launched by the British Overseas Trade Board (BOTB). It is compiled from the accounts of some 36 companies who have successfully penetrated the difficult and distant, but rich and expanding, Japanese market. It is also designed to encourage more British firms to emulate the success of those featured.

Norman MacLeod, chairman of the BOTB's Japan Trade Advisory Group in his foreword to the booklet emphasises the need for British companies considering exporting to Japan to be completely professional in this highly competitive market: "Where the products have met the needs of the consumer or industrialist success has come as a result of thorough market research, the right product, commitment and perseverance, competitiveness in price and quality, effective marketing within the Japanese system and consistent, reliable delivery and after-sales service".

Among the companies featured in 'Success in Japan' are Electrosonic Ltd of London SE7 who export specialised audio-visual presentation equipment.

The booklet is available free of charge from the BOTB's Exports to Japan Unit, Room 353, 1 Victoria Street, London SW1H OET. (01-215 5625).

POINTS ARISING...

BYTEBOX
October '85

On the circuit diagram of the Bytebox, page 13, the pin numbers of IC12 to IC28 are incorrect. Pin 14 should read pin 13, 13 should be 12 and 12 should be 11. Also pin 17 of IC10 should read pin 7. The p.c.b. design and layout shown is correct but two through-hole pins have been omitted which connect the power lines to IC21.

Countdown . . .

Please check dates before setting out, as we cannot *guarantee* the accuracy of the information presented below. Note: some exhibitions may be trade only. If you are organising any electrical/electronics, radio or scientific event, big or small, we shall be glad to include it here. Address details to Brian Butler.

Videotex User Show Jan. 29–31. Barbican Centre. D
Electronics in Oil and Gas Feb. 4–6. Barbican Centre. B
Sound Eighty Six Feb. 18–20. Novotel, Hammersmith. F
Electrex '86 Feb. 24–28. NEC, Birmingham. G
Scottish Electronics Technology Show Feb. 25–27. Exbn. Centre, Glasgow. B
Business Telecom '86 Mar. 4–6. Barbican Centre. I
Instrumentation '86 Mar. 5/6. Cresh Hotel, Bristol. J
Electro-Optics/Laser International Mar. 18–20. Metropole, Brighton. B
CAD '86 Apr. 8–10. Metrepole, Brighton. L
Internepcon Production Show Apr. 8–10. NEC, Birmingham. B
British Electronics Week Apr. 29–May 1. Olympia. N

D Emap International ☎ 01-837 3699.
F ASCE Ltd. ☎ 06286 67633.
G Electrex Ltd. ☎ 0483 222888.
J Trident Int. Ex. Ltd. ☎ 0822 4671
L Butterworth Scientific Ltd. ☎ 0483 31261
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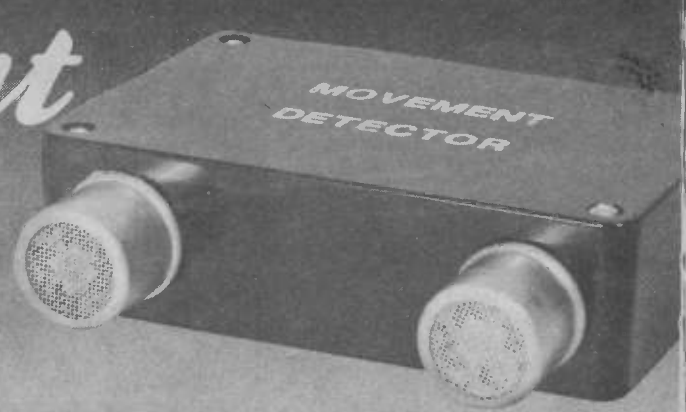
COMPUTER *Movement* DETECTOR



R.A. PENFOLD

COMPUTERS can be used in a vast range of practical applications, but in virtually all cases some extra hardware is required. This can range from mundane items such as printers and joysticks to the more exotic items of equipment such as the movement detector described here. The obvious application for the unit is in a computer based alarm system to detect intruders, but it could also find use in other fields such as in robotics or automatic photography perhaps.

DOPPLER SHIFT

What is almost certainly the most effective type of simple movement detector is the ultrasonic Doppler shift variety, and the system described here is based on this operating principle. Results obtained are to a large extent dependent on the particular transducers used in the unit, and on how the unit is set up. When fitted with large transducers having a fairly broad directional response the prototype could easily be set-up so that it would detect someone moving anywhere in an average size room. When fitted with small and highly directional transducers good sensitivity was only obtained almost directly in front of the transducers, and with only a relatively limited range of about two metres or so.

The unit described here is suitable for use with the popular VIC-20, Commodore 64, and BBC model B computers, It could also be used with any computer that has a 6522 VIA with port B available to the user.

form a 16-bit type. The division rate is simply the total value written to the counters multiplied by two.

ULTRASONIC TRANSDUCERS

Most ultrasonic transducers have a nominal operating frequency of 40kHz, and the computer clock frequencies are such that it is not possible to generate an output at precisely 40kHz. However, this is not too important as practical tests with several types of ultrasonic transducer showed that their frequency response was sufficiently broad to enable good results to be obtained even with quite a large frequency error. The peak to peak output voltage from the 6522 or 6526 is not very great at slightly under 5V when unloaded, and the current drive capability is not very high either. Again, in practice good results were obtained despite this, and it is not necessary to amplify the output signal.

The signal picked up by the receiving transducer is a mixture of direct pick up from the transmitting transducer and signals that have been reflected from the floor, walls, ceiling, and objects in the room. These signals will be randomly phased, and may tend to add together to give a fairly strong signal, or may tend to cancel out one another to give a weak signal. In either case the signals are all at the same frequency and the phasing will consequently remain constant. The received signal level therefore remains constant as well.

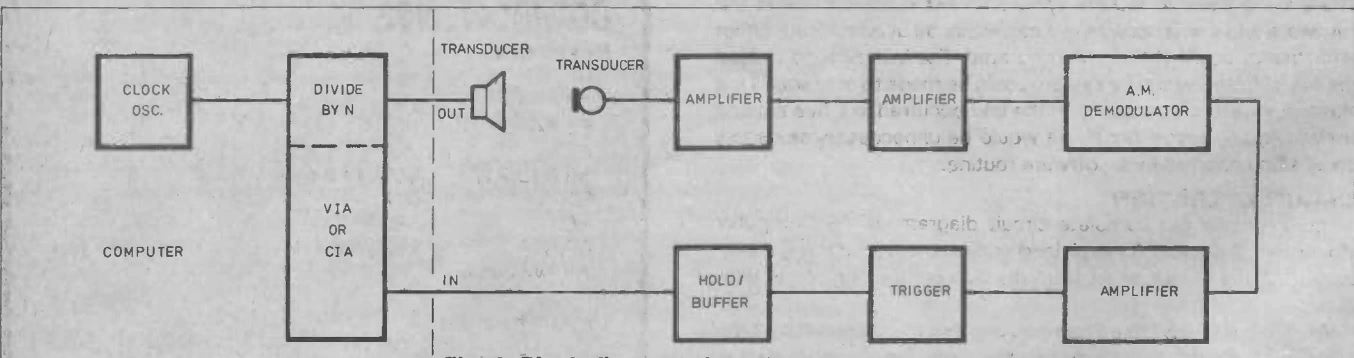


Fig. 1. Block diagram of the Computer Movement Detector

SYSTEM OPERATION

The unit has been made quite simple by using the computer to provide as much of the hardware as possible. As can be seen from the block diagram of Fig. 1, the transmitter section of the device is totally provided by the computer, apart from the transmitting transducer of course. The user port of the three computers mentioned above is provided by port B of a 6522 VIA (versatile interface adaptor). In fact the Commodore 64 has a slightly different device, the 6526 CIA (complex interface adaptor). However, this provides the same basic functions as the 6522, and is equally suitable for the present application.

The feature that is of interest in this case is the ability of the 6522 or 6526 to take the computer's clock signal and divide it by an integer in the range 1 to 65535. A flip-flop at the output provides a further division by two. The division rate is controlled by writing values to two 8-bit counter/registers which together

The situation is different if signals are received via a moving object, as the well known Doppler shift effect then results in an upward shift in the received signal if the object is moving towards the transducers, or a downwards shift if it is moving away from them. In either case the phasing of the shifted signal varies in relation to that of the unshifted signals, so that sometimes the signals add together to give a fairly high amplitude, while at other times the signals have a cancelling effect and give a relatively weak signal. This produces an amplitude modulated signal with the modulation frequency equal to the difference in the frequencies of the received signals (typically a few Hertz to a few hundred Hertz in practice). By detecting this amplitude modulation on the received signal, movement in the room can be detected.

RECEIVING TRANSDUCER

The output signal from the receiving transducer is unlikely to be very large, and could well be less than 1mV. Two amplifiers which each provide about 40dB of voltage gain are therefore used to boost the signal to a more satisfactory level. An ordinary AM detector is then used to obtain the low frequency modulation signal, but the strength of this signal will normally be quite low. Another high gain amplifier is used to boost this signal to a more acceptable level.

collector of TR2 with R4 providing the coupling and C4 decoupling any short term variations in this voltage. The non-inverting input is also fed from the collector of TR2, but via a potential divider circuit (R2–R3). This takes the non-inverting input to a lower potential than the inverting input, and the output of IC1 therefore goes low under quiescent conditions.

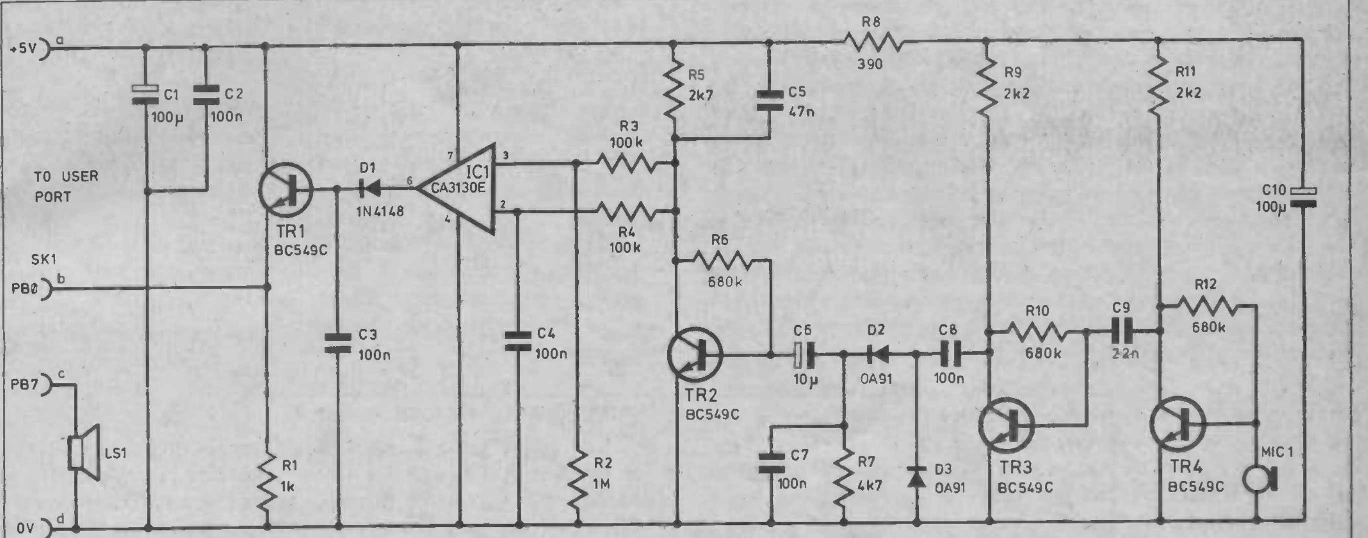


Fig. 2. Complete circuit diagram of the Computer Movement Detector

The boosted signal is fed to a trigger circuit where it is further amplified to give an output at standard 5V logic levels. The output from the trigger is a series of brief pulses, and while these could be detected directly by the computer, in practice they can be missed by a program which uses BASIC and is consequently operating at only a moderate speed. A charge storage and buffer stage is used as a simple form of pulse stretcher to give more reliable results when using the unit with a BASIC program.

There are several digital inputs available at the computer's user port, and the output of the unit is fed into one of these. The way in which the signal is processed and used obviously depends on your particular application. In an alarm application the computer could be used to generate the alarm signal when the unit is activated, or it could operate a relay which would control an alarm bell circuit. There is no need to include entry and exit delay circuits in the hardware since software delays can easily be used instead. Other refinements could also be incorporated. For instance, to reduce the risk of false alarms the system could be made to only sound the alarm if (say) four operations of the unit occurred in a five second period. Again, further hardware would be unnecessary since this could all be handled by a software routine.

CIRCUIT OPERATION

Fig. 2 shows the complete circuit diagram of the Computer Movement Detector. As explained earlier, the transmitting transducer (LS1) is driven direct from the appropriate line of the user port.

MIC1 is the receiving transducer, and like the transmitting type it is a Piezo electric device. In fact the transmitting and receiving transducers are often identical, although in some cases there are minor differences and the correct ones must be used in the transmitter and receiver in order to obtain optimum results. MIC1 is coupled direct to the base of TR4 which is a high gain common emitter amplifier. The output of this stage is coupled by C9 to the input of a second and identical stage.

C8 couples the output of TR3 to a conventional diode AM demodulator circuit, and the output from this stage is then amplified by a third common emitter amplifier which is based on TR2. C5 severely attenuates the response of the amplifier at middle audio frequencies and above, but this does not significantly degrade the sensitivity of the unit since there will be no output from the detector in this frequency range. The lowpass filtering provided by C5 helps to prevent problems due to instability and stray pick up of noise from the computer.

IC1 acts as the trigger, and it is used as a voltage comparator. The inverting input is biased to the quiescent voltage at the

The situation is different when the unit is activated, since the decoupling at the inverting input keeps it at a virtually constant voltage. The voltage at the non-inverting input varies in sympathy with the modulation signal, and on positive peaks goes above the inverting input's potential, giving positive output pulses.

These pulses rapidly charge C3 due to their fairly low source impedance. On the other hand, the only discharge path for C3 is into the relatively high input impedance at the base of TR1. This integrates the pulses to give a continuous output signal while the unit is activated. TR1 is merely an emitter follower buffer stage.

The circuit requires a 5V supply and has a current consumption of only about 5mA. The user port of the computer provides a suitable power supply output.

COMPONENTS . . .

Resistors

R1	1k
R2	1M
R3,R4	100k (2 off)
R5	2k7
R6,R10,R12	680k (3 off)
R7	4k7
R8	390
R9,R11	2k2 (2 off)

All $\frac{1}{4}$W carbon

Capacitors

C1,C10	100u 10V radial elect (2 off)
C2	100n ceramic
C3,C4,C7,C8	100n polyester (4 off)
C5	47n polyester
C6	10u 25V radial elect
C9	22n polyester

Semiconductors

IC1	CA3130E
TR1–TR4	BC549C (4 off)
D1	1N4148
D2,D3	OA91 (2 off)

Miscellaneous

MIC1,LS1	40kHz ultrasonic transducer (2 off)
SK1	5 pin DIN (180 degree) socket

Case 120 by 80 by 35mm; printed circuit board, PE p.c.b. service 509-02; 8-pin d.i.l. i.c. holder; pins; wire; solder, etc.

CONSTRUCTION

A printed circuit board accommodates all the components apart from SK1 and the two transducers. Refer to Fig. 3 for details of the printed circuit board and wiring.

IC1 is a CMOS device, and accordingly it should be fitted in an (8 pin d.i.l.) i.c. holder and the other standard antistatic handling precautions should be observed. D2 and D3 are germanium diodes and not the more familiar silicon type. They are more vulnerable to damage by heat than silicon devices, and care to avoid overheating them should be exercised when soldering them in place. In other respects construction of the board is perfectly straightforward.

A plastic case having approximate outside dimensions of 120 by 80 by 35mm will comfortably accommodate the circuit board and other components. The printed circuit board is mounted on the base panel using M3 or 6BA fixing bolts, and SK1 is mounted at any convenient place on the rear panel. The two transducers are mounted at opposite ends of the front panel, and the method of mounting will depend on the particular make you are using. In most cases it is a matter of drilling a couple of small holes for the terminals at the rear of each transducer and then gluing both components in place using a good general purpose adhesive. The transducers used in the prototype require a single large mounting hole and the connections to be made via phono plugs, but types having terminals for direct soldered connection are far more common these days. Check the retailer's literature to ascertain whether or not the receiving and transmitting transducers are different, and if necessary make sure that they are used in the right positions in the circuit.

SK1 is connected to the user port of the computer via a four-way cable fitted with a 5-way DIN plug and either a 20-way IDC header socket (BBC model B) or a 2 by 12-way 0·156 inch pitch edge connector (VIC-20 and Commodore 64). It is unlikely that an edge connector fitted with a polarising key for a Commodore computer will be available, making it necessary to take care to fit the connector the right way up. Be careful to wire-up the DIN plug to match the method of connection you adopt for SK1.

TESTING AND USE

Taking the VIC-20 and BBC model B first, the user port registers that are needed in this application are the auxiliary control register, the two 8-bit counters of Timer 1, the data direction register, and the peripheral register (which is effectively the eight lines of the user port). These are at addresses indicated in Table 1.

The data direction register is used to set each of the data lines (PB0 to PB7) as an input or an output. PB7 drives the transmitting transducer and must be set as an output, but PB0 is required as an input to monitor the output of the sensor. Setting a bit of the data direction register to 1 designates the corresponding line as an output; setting it to 0 designates the line as an input. A value of 128 therefore sets PB7 as an output and the other lines as inputs.

Timer 1 is controlled by the two most significant bits of the auxiliary control register. These must both be set to 1 in order to give the free running mode with output on PB7 (a value of 192). The following short programs can be used to test the unit with the VIC-20 or BBC model B.

REGISTER	BBC Model B	VIC-20
Peripheral	&FE60	37136
Data Direction	&FE62	37138
Counter (low byte)	&FE64	37140
Counter (high byte)	&FE65	37141
Auxiliary Control	&FE6B	37147

Table 1. User port register addresses

VIC-20

```
10 POKE 37138,128
20 POKE 37147,192
30 POKE 37140,13
40 POKE 37141,0
50 PRINT PEEK(37136) AND 1
60 GOTO 50
```

BBC Model B

```
10 ?&FE62 = 128
20 ?&FE6B = 192
30 ?&FE64 = 13
40 ?&FE65 = 0
50 PRINT ?&FE60 AND 1
60 GOTO 50
```

These print a value of 0 or 1 down the left hand side of the screen (0 under stand-by conditions; 1 when the unit is activated). The value of 13 at line 30 will probably give optimum results, but you can try varying this slightly in an attempt to obtain improved results.

The Commodore 64's 6526 has direct equivalents to most of the 6522 registers, but it has only a rough equivalent to the auxiliary control register in the form of Control Register B.

The important user port register addresses are listed below:

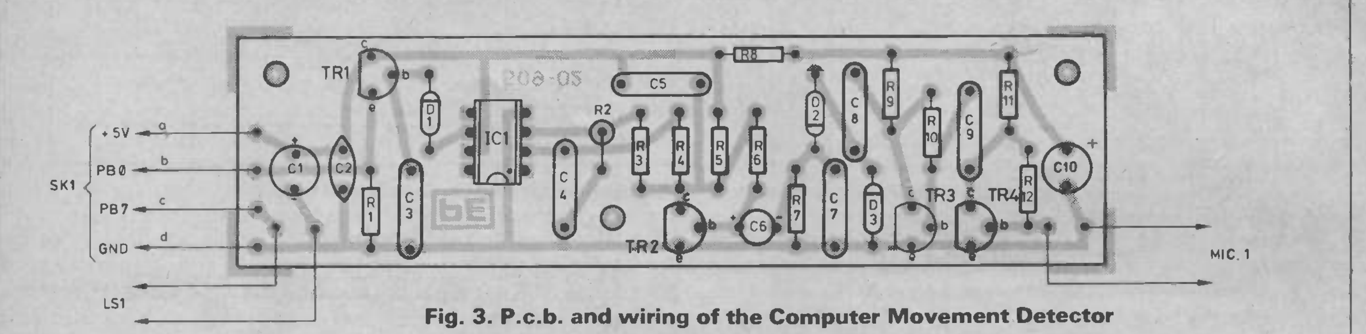


Fig. 3. P.c.b. and wiring of the Computer Movement Detector

Peripheral	56577
Data Direction	56579
Counter B (low byte)	56582
Counter B (high byte)	56583
Control B	56591

Bit 0 of control register B is set high to enable timer B, bit 1 is set high to enable output on PB7 (and automatically set PB7 as an output), and bit 2 is set high to set a squarewave rather than a pulsed output. Bit 3 is set low to give continuous rather than single shot operation, and bit 4 is set high to load the timer. Bits 5 and 6 are set low to set timer B to the mode where it takes its input from the system clock, and bit 7 is irrelevant in this case. This gives a total value of 23 to write to Control register B. The Commodore 64 test program is given below:

```
10 POKE 56582,13
20 POKE 56583,0
30 POKE 56591,23
40 PRINT PEEK(56577) AND 1
50 GOTO 40
```

This program for the VIC-20 below is a basic alarm routine which demonstrates one way in which the unit can be used.

It first sets up the VIA, then an exit delay is provided, after

```
10 POKE 37138,130
20 POKE 37147,192
30 POKE 37140,13
40 POKE 37141,0
50 FOR D = 1 TO 20000:NEXT D
60 IF (PEEK(37136) AND 1) = 0 THEN 60
70 FOR D = 1 TO 20000:NEXT D
80 POKE 37136,2
90 FOR D = 1 TO 600000:NEXT D
100 POKE 37136,0
110 END
```

which the output of the sensor is monitored. If the unit is activated there is a further delay (the entry delay), and PB1 of the user port is then set high. In practice this would be used to switch on an alarm generator. After another delay PB1 is set low again to provide automatic shut off of the alarm generator. ★

Introduction to MICRO SYSTEMS

MICHAEL TOOLEY BA **DAVID WHITFIELD** MA MSc CEng MIEE **PART 5**

THIS MONTH we continue our study of the 6821 by looking at some applications involving the PIA, before moving on to look at the 6502.

I/O CONTROL

There are many situations where micros are involved in applications which require the state of a switch (electronic or mechanical) to be sensed, and action to be taken. After sensing the switch condition (on or off), the micro may take action solely on the basis of the switch setting. More frequently, however, the action taken will also depend on a number of other factors. This type of system behaviour is illustrated diagramatically in Fig. 5.1, and is typical of all but the simplest of control systems.

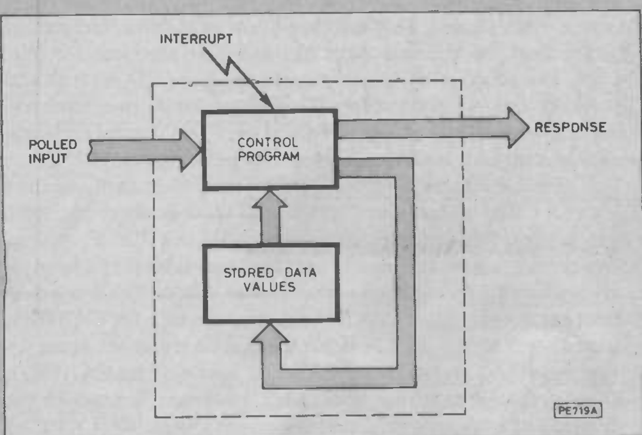


Fig. 5.1. Controller response loop

The factors influencing the response from the system will depend on the nature of the system, but could include such details as the time of day (as indicated by our internal software clock—see last month). For example, if a switch indicating that the cash register drawer has been opened is tripped, the reaction could well depend on the time of day. If the switch is tripped in the early hours of the morning, the action could be to sound an alarm. On the other hand, assuming the system to be installed in a shop, no action would be taken during normal opening hours, or two hours either side.

All this goes to show that, starting from the sensing of a simple switch, the response can either be simply and directly related to the input, or it can be determined by reference to other factors. The system behaviour, as always, will depend on the nature of the micro's control program. For the moment, however, we are concerned with the simple problem of how to sense the switch states, and how to respond by activating a relay to turn on the alarm bell.

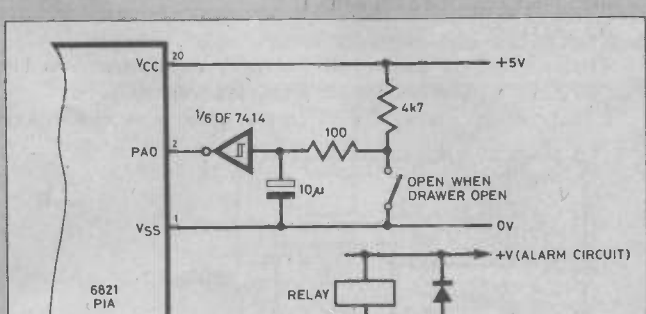


Fig. 5.2. Cash register—peripheral side

CASH REGISTER ALARM

Figs 5.2 and 5.3 combine to show an arrangement which could be used in the cash register situation just described. The peripheral side of the interface is shown in Fig. 5.2, and the CPU side is shown in Fig. 5.3.

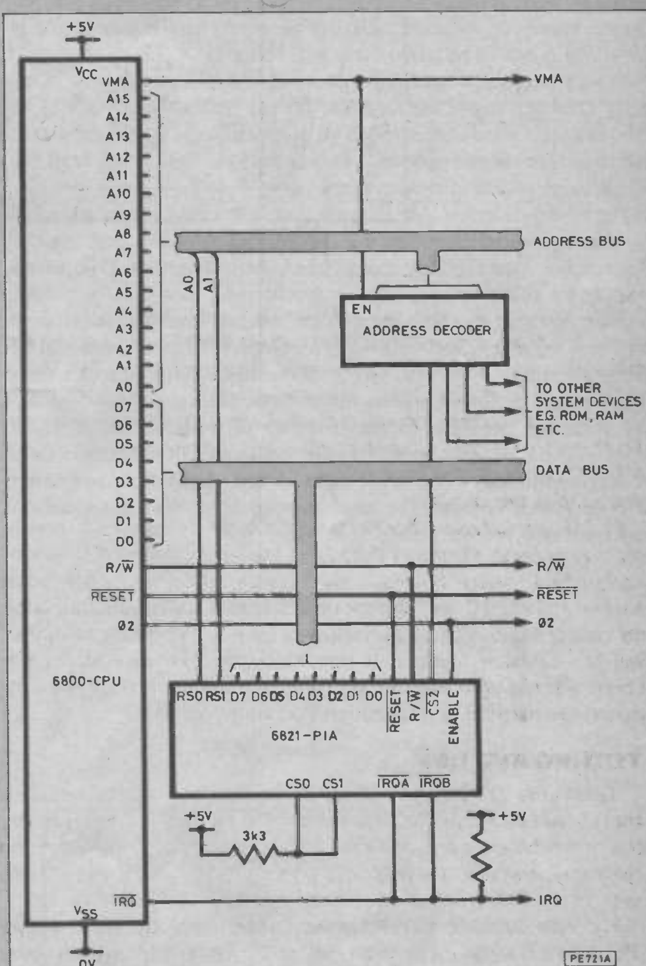


Fig. 5.3. Cash register—CPU side

Peripheral side: The switch and the alarm bell are both connected to the A side of the PIA, using PA0 and PA1 respectively. Because the PIA does not have enough drive capability to be able to drive an alarm bell directly, an interface incorporating an inverter and a VMOS power FET is used to provide the necessary gain. The reason for the inverter will become clear later, but the overall effect of this interface design is that a logic 0 must be output on PA1 to cause the alarm to sound.

On the sensor side, a filter and buffer circuit is used between the switch and PA0. This is frequently a necessary arrangement, and arises because mechanical switches are notorious for their contact "bounce". The input buffer allows the inclusion of a Schmitt-trigger debounce circuit to avoid spurious responses.

CPU side: The PIA is connected to the full width of the data bus. The two least significant address bus lines are connected to RS0 and RS1 to select the required internal register whenever the PIA is selected. Of the control and supervisory signals, the PIA is connected to R/$\overline{W}$ and $\overline{Reset}$ from the CPU, and Ø2 (connected to the "Enable" input). CS0 and CS1 inputs are permanently enabled by being pulled up to +5V. The user interrupt request lines for the two sides of the PIA are tied together (in a wired-OR) and connected to the $\overline{IRQ}$ CPU input.

The $\overline{CS2}$ input is used to support the addressing of the PIA. Whenever an address in the range allocated to the PIA is output on the address bus, the system's external address decoder places a low on this input, thereby enabling the 6821. In our example we shall assume that the addresses allocated to the PIA are 4004 to 4007 inclusive, as for the example system in Part One.

Configuring the PIA: Having established the hardware configuration, the next step is to look at the programming of the PIA to behave as required.

Following a system reset (which also occurs at power-up), the PIA is configured with all PA and PB lines as inputs. At start-up, the peripheral initialisation will therefore need to configure the PIA with PA0 as an input (for the switch), and PA1 as an output (for the alarm). However, we must take care in setting up the output line if the alarm is not to be triggered accidentally.

As we have seen, all of the PA data lines start off configured as inputs. This will cause the inverter on the alarm output (PA1) to behave as if it were connected to an output at logic 1, and the alarm will therefore remain silenced. This avoids the first problem of the alarm being set off at system reset.

The next problem is to make sure that, when PA1 is configured as an output, its output value will be a logic 1 (remember: logic 0 triggers the alarm). This means that, before setting PA1 to an output, we must write a logic 1 to the bit 1 position in output register B. Once this has been done, we are ready to select data direction register A and set PA1 as an output. All other lines will be left configured as inputs. The peripheral data register can then remain selected for all future reads and writes.

Programming the PIA: In the majority of practical cases, much more of the PIA would probably be used, and initialisation would be correspondingly more involved than here. The following section of code could, however, be used to accomplish the initialisation requirements just described:

```
LDAA   4005   ;Select ORA
ORAA   #04
STAA   4005

LDAB   #02    ;Set PA1 O/P to 1
STAB   4004

ANDA   #FB    ;Select DDRA
STAA   4005

STAB   4004   ;Set PA1 to O/P

ORAA   #04    ;Select ORA
STAA   4005
```

The correspondence of addresses to registers is: CRA=4005; ORA/DDRA=4004. The PIA is now ready for use in our application.

The main requirement in the running system is to be able to read the switch setting, decide on its value, and set the alarm if appropriate. The following section of code would probably be included in the overall loop which is polling the state of the cash register. The other activities in the loop are not shown, since these will depend on the detailed design of the application.

```
LDAB   4004   ;Read data

ANDB   #01    ;Test if till open

ASLB          ;Alarm on if till open
STAB   4004
```

In studying the code, we note that the input from the till switch will be a logic 0 when the till drawer is open. Thus, we read the value of the A peripheral data register into accumulator B, and mask out (set to zero) all the other line values except the switch setting (bit 0).

The bit 0 value will be a zero if the till is open, or a 1 if closed. Thus we can move the result in accumulator B one place left, and rewrite the contents of the accumulator to the peripheral data register. Since a 0 will turn on the alarm, this will automatically produce the desired result: the alarm will come on whenever the till is opened.

CLOCK INTERRUPT

Having now looked at a case where the CPU is polling the peripheral, it is time to move on to look at an interrupt-driven application. For this we return to the problem of the real-time clock for the cash register.

Fig. 5.4 shows how the circuit described earlier can be extended to include a real-time clock. The basic 1Hz time tick is generated using a combined oscillator/24-stage frequency divider. This produces a 1Hz signal when used with a 4194·304kHz crystal. The 4521 must be operated from a supply of around 10V for reliable operation at this frequency, and the output level is therefore adjusted by R3/R4. The timing signal is applied to the CB1 input of the PIA. Thereafter all of the time functions are provided in software.

The first problem is clearly to configure the PIA to cause an interrupt every second. This will then allow us to drive the internal software clock. As you may have deduced from the circuit in Fig. 5.4, this can be done by suitably configuring the PIA to treat the CB1 line as a source of interrupts. To see how this is done, however, we need to look a little more carefully at the PIA's control registers, which up until now we have skipped over rather quickly.

The detailed structure of the PIA's A and B control registers (CRA and CRB) is shown in Fig. 5.5, and these really provide the key to interrupt-driven applications involving the PIA. From Fig. 5.5 we can see that, in addition to the DDR access bit (2) we have already been using, there are two other groups of bits. The first group control the action of the CA/CB lines (bits 0 and 1 for CA1/CB1, and bits 3 to 5 for CA2/CB2), while the second group act as the interrupt flags (bit 6 is the flag for CA2/CB2, and bit 7 for CA1/CB1).

Even if special interrupt processing hardware is used in the system, the PIA has only two interrupt outputs, shared by CA1/CA2 and CB1/CB2, respectively. The purpose of the interrupt flags is therefore to identify the source of an interrupt. As can be seen from Fig. 5.5, the flags are automatically cleared whenever the CPU reads the control register. This minimises the work which has to be done in the service routine before interrupts can be re-enabled, and avoids the problem of the same event causing repeated interrupts because the programmer has forgotten to clear the flag. After a reset, the PIA interrupts are all disabled and the flags all cleared.

Setting up the PIA to generate our required clock interrupt is done during system peripheral initialisation. It is a simple matter of setting bits 0 and 1 of the B control register to appropriate values. Bit 0 is set to a 1 to generate an interrupt whenever the selected transition on CB1 occurs. Bit 1 is set to determine whether the transition of the clock on CB1 which causes the interrupt is low-to-high (set to 1) or high-to-low (set to 0).

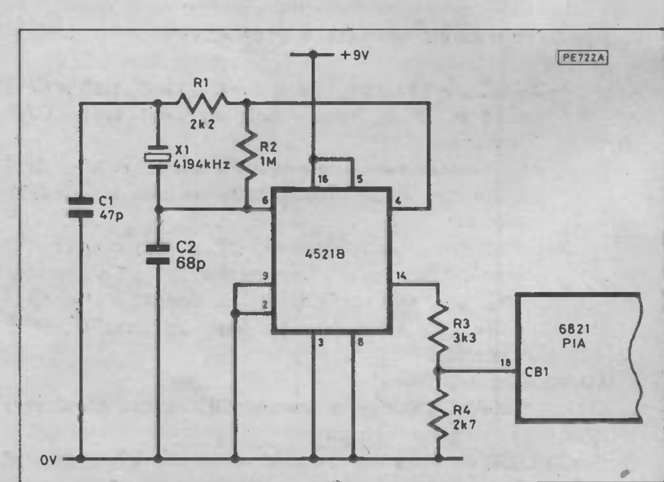


Fig. 5.4. 1Hz time signal generator

IRQA(B)1 interrupt flag:-

b7 goes high on active CA(B) 1 transition. Automatically cleared by CPU read of Control Register.

Determine whether DDR or Output Register addressed:—

b2=0 Data Direction Register selected
b2=1 Output Register selected.

Determine CA(B)1 transition which sets IRQA(B)1 flag:—

b1=0 set by high->low transition.
b1=1 set by low->high transition.

IRQA(B)2 interrupt flag:—

b5=0 b6 goes high on active CA(B) 2 transition. Automatically cleared by CPU read of Control Register.
b5=1 b6 set to 0 and unaffected by CA(B) 2 transitions.

CA(B)1 IRQ enable/disable:—

b0=0 disables IRQA(B) CPU interrupt on CA(B)1 active transition. (Interrupt will occur next time b0 set high by CPU if active transition occurred while interrupt disabled.)
b0=1 enable IRQA(B) interrupt on CA(B) 1 active transition.

b7	b6	b5	b4	b3	b2	b1	b0
IRQA(B)1 Flag	IRQA(B)2 Flag		CA(B)2 Control		DDR Access	CA(B)1 Control	

CA(B)2 Established as Output by b5=1:—

Read/Write strobe operation with b4=0:—

b3=0 CA2 goes low on first H->L E transition after CPU read of ORA; returns high by next active CA1 transition.
CB2 goes low on first L->H E transition after CPU write into ORB; returns high by next active CB1 transition
b3=1 CA2 goes low on first H->L E transition after CPU read of ORA; returns high by next H->L E transition.
CB2 goes low on first L->H E transition after CPU write into ORB; returns high by next L->H E transition.

Data output with b4=1:—

b3=0 CA(B)2 goes low as CPU writes b3=0 into Control Register.
b3=1 CA(B)2 goes high as CPU writes b3=1 into Control Register.

CA(B)2 Established as Input by b5=0:—

CA(B)2 IRQ Enable/Disable:—

b3=0 Disables IRQA(B) CPU interrupt on CA(B)2 active transition. (Interrupt will occur next time b3 set high by CPU if active transition occurred while interrupt disabled.)
b3=1 Enables IRQA(B) CPU interrupt on CA(B)2 active transition.

Determine CA(B)2 transition which sets IRQA(B) 2 flag:—

b4=0 set by high->low transition.
b4=1 set by low->high transition.

Fig. 5.5. PIA control register format. Each bit may be individually set high or low by the programmer: the significance of this is described above

In the following code, the PIA is set up to generate interrupts on a high-to-low transition.

```
LDAB   4007   ;Read CRB
ORAB   #01    ;CB1 interrupt on H->L
STAB   4007   ;Set CRB
```

Another requirement during initialisation will be to initialise the current time, for subsequent maintenance by the interrupt handler. Before interrupts are enabled, it will be necessary (unless the values are already stored in the apropriate locations in ROM) to store the start address of the $\overline{IRQ}$ interrupt handler in locations FFF8 (MS byte of start address) and FFF9 (LS byte of start address).

The final aspect to be considered is the interrupt handler itself. This may well be included in a more complex handler which caters for other interrupts than just that from the clock. Whatever the design, however, the actions taken for the clock interrupt are the same. The handler first of all needs to establish that the interrupt has indeed originated from the clock. If not, the interrupt can either be ignored (in the simple case of it being the only source of interrupts in the system), or passed on to other parts of the handler for processing.

If the interrupt is from the clock, the very act of determining this fact (by reading the value of the bit 7 in CRB) will have reset the flag. If required, interrupts can be re-enabled at this point. The remaining action is then to update the internal software clock, and execute an RTI instruction to return to the interrupted processing.

This concludes our necessarily brief study of the 6800 and its PIA. It is now time to move on and look at a CPU which could reasonably lay claim to having founded low cost personal computing (with the Commodore Pet): the 6502.

THE 6502 CPU

The 6502 was developed from the ideas of the 6800 by MosTek with the object of improving on the original design concept by concentrating on those features considered important to system designers. The bus structure employed by the 6502 is compatible with the interfacing and bus conventions used on the 6800 bus. This allows all of the 6800 peripheral chips to be used in addition to the dedicated 6502 support chips. The 6502 also features a "pipelined" architecture which increases the speed of operation over the 6800 by overlapping the fetch of the next instruction with the interpretation of the previous one.

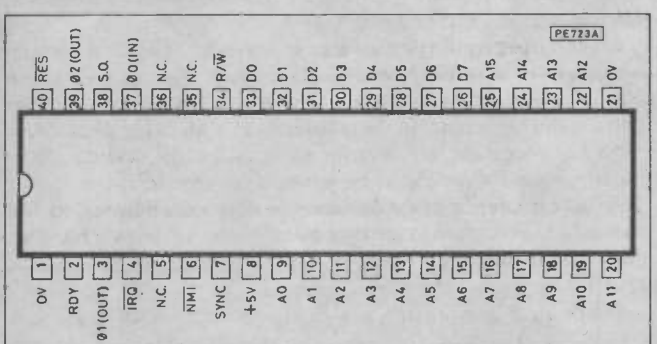


Fig. 5.6. 6502 pin connections

The widely-used BBC microcomputer, based on the 6502 microprocessor

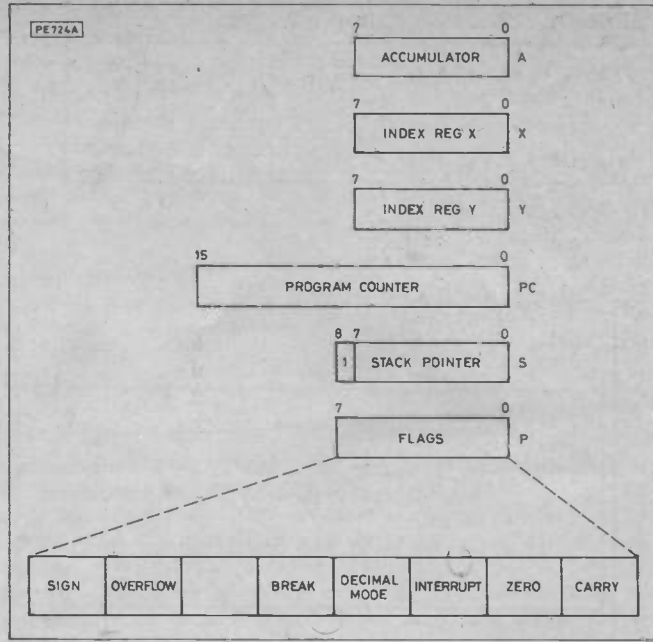


Fig. 5.7. 6502 programming model

The BBC computer with its lid removed, revealing the 6502, its PIA, and associated interfacing circuitry

The pin connections for the 6502 are shown in Fig. 5.6. From this we can see that it is an 8-bit processor with a 16-bit address bus, i.e. the same as the 6800. However, the programming model, shown in Fig. 5.7, indicates some significant differences from the 6800.

The CPU has *two* index registers (X and Y), and only a *single* accumulator. The stack pointer is only eight bits long, rather than the more usual 16 bits, since the designers considered that a stack of 256 bytes would be more than enough for the majority of applications. This allowed them to fix the position of the stack as exending from 01FF down to 0100.

The shortage of general purpose accumulators (only one) is overcome by the fast access provided to the page zero locations (0000 to 00FF), giving an effective 256 registers if required. In addition, the two index registers can be used as general purpose registers. Overall, the designers succeeded in their aims and produced a CPU with a streamlined pipelined architecture and two index registers, which combine to allow the 6502 to perform extremely well, particularly when running languages such as Basic.

In keeping with the approach of a "lean, clean, fast machine", the designers of the 6502 reduced the basic instruction set to just 56 instruction types. To supplement these, however, thirteen addressing modes are provided.

The additional modes over and above those on the 6800 are mainly to take advantage of the increased flexibility afforded by the two index registers. One of the modes, however, is a little different, and emulates the interrupt vectoring approach favoured by both the 6800 and the 6502. The *indirect absolute* mode is only applicable to the JMP instruction, and allows a pair of locations to be defined as holding the address to which the jump should be performed.

NEXT MONTH: A look at some of the 6502's peripherals, and a brief look at the Z80.

INDUSTRY NOTEBOOK

By Nexus

Megabit memories

It's good to hear that British industry is lending a hand in a big European scheme to oppose Japanese domination in microelectronics. A UK manufacturer is providing semiconductor processing equipment for the Mega Project. a co-operative venture to produce competitively-priced 1-megabit and 4-megabit memories using submicron technology.

The principal companies taking part are Philips in the Netherlands, Siemens in West Germany and Valvo, a West German subsidiary of Philips. These partners will invest a total of £370 million over five years. The Dutch and Federal German governments are proposing to jointly subsidise the project to the tune of £M120.

Megabit memories have been chosen for very particular reasons. First of all, memories in general acount for over half the total market for intergrated circuits. So this kind of semiconductor product should have great commercial potential. It's too late to do anything about meeting Japanese competition in 64K and 256K devices. The only hope for Europe is to leap-frog these sizes and go for megabit memories.

The big question now is, can they do it? Will they achieve their target of a 4-Mbit memory by 1989? Japanese semiconductor manufacturers unveiled prototype 1-Mbit memories as long ago as February 1984, and are now well into their stride with both NMOS and CMOS devices

What makes the Japanese such formidable industrial competitors is their unity of purpose on a national level. This comes from a cultural heritage very different from ours. In America and Western Europe individual freedom and self-fulfilment are held to be good in themselves and are encouraged. In Japan they tend to be subordinated to the interests of the group as a whole. The Euro-American way of life certainly produces great entrepreneurs, but because these individuals are competing with each other, within a nation, the general result tends towards fragmentation rather than cohesion.

Individuals and their ways of life set the pattern for society. In turn society's rules control the individuals. So in Japan we see industry, the banks and the government all working together to a common, long-term purpose. The so-called fifth generation of computers, for example, was declared in 1981 as a national goal for the 1990s by the Japanese Ministry of International Trade and Industry and is being sustained as a ten-year investment plan.

In Europe and America much of our energy is dissipated on great battles between commercial and sectional interests. Everybody wants to make a fast buck, not wait ten years for it. Investors are impatient for returns, entrepreneurs come and go with frightening rapidity, and workers and bosses see each other as natural adversaries. The only reason our industry works at all with so many egotistical interests going off in different directions is that we have learnt to balance the forces, more or less, by various forms of bargaining directed at personal acquisitiveness and desire for prestige.

In these conditions I see the Mega Project as a happy sign. Some pretty influential Europeans have realised that, even in a free-market economic system, there is value in co-operation as well as in competition.

Tintinabulation

I suppose integrated circuits must have been responsible to some extent for the recent troubles in the tin industry. Of course the major cause of the fall in demand for tin has been aluminium and plastics food containers taking over from the traditional tin can. But when you think of the number of soldered joints between discreet components that have now been replaced by integrated connections inside chips, the potential loss of solder, and hence tin, consumption is truly enormous.

I say "potential loss" because, if integrated circuits hadn't been invented, I doubt if we would have been soldering together several hundred thousand discrete transistors to form one digital processing unit. Certainly, the market for electronic products has grown tremendously since soldering tags started to take over from screw-terminals and other mechanical connecting devices. But on printed circuits the actual quantity of solder needed to make an electrical connection has been getting smaller all the time.

The tin crisis brings back memories of the great table-salt crisis of some years ago. As a result of a scare that there was going to be a shortage, housewives all over Britain rushed out and bought up every packet of salt they could find on shopkeepers' shelves. This threw the whole salt supplying business into chaos for some time, but quite unecessarily because there was plenty of the stuff to go round and the whole chain of production, distribution and consumption had been running perfectly smoothly and successfully before the scare.

The tin situation was not the same but equally foolish. Producers and traders operated a cartel based on a world buffer stock of tin. When this was used like a reservoir just to smooth out fluctuations in supply and demand it was very useful for stabilization. But it was also exploited as a means of keeping up the price of tin artificially, far beyond that warranted by the actual demand. Whenever the world price dropped due to lack of demand the cartel would buy some more of its own tin to add to the buffer stock, thus creating an artificial shortage and raising the world price again.

It's astonishing that nobody seems to have understood that this game couldn't go on indefinitely. The alarm bells only started their tintinabulation when the cartel suddenly discovered it had run out of money to buy its own tin. The whole financial system collapsed in ruins, and as a result it now looks as if the price of tin will fall to a level that really matches the true economics of production and consumption.

If peace breaks out

We shall never know for sure, but I have been informed that the real reason why the US Army chose the French battlefield communications system Rita in preference to the British system made by Plessey was that the American generals in the Pentagon found it much too difficult to pronounce the name Ptarmigan. In spite of the efforts of our Prime Minister they became fed up, during the preliminary discussions, getting their tongues and teeth in a twist over this awkward bird, while the French bird—socialist or not—gave no problem at all.

There was also, of course, a certain difference in price which may have had something to do with it. The French system offered by Thomson CSF in conjunction with the American GTE Corporation cost about £3 billion, while Plessey, with its American partner Rockwell, was asking about £5 billion for Ptarmigan.

Despite suggestions that the French were charging a loss-leader price for Rita, and the fact that in both cases the US partners would take a large proportion, these figures are a further reminder of the considerable dependence of the British electronics industry on military electronics. The UK Ministry of Defence is in fact the largest single customer of our electronics industry and about a quarter of the industry's output goes into military equipment.

Suppose, though, that the talks between Reagan and Gorbachov in Geneva last November had been so fantastically successfull that East-West tension was reduced to zero and the arms race was brought to an end. It's easy to laugh cynically at this unlikely possibility. But everyone professes to want peaceful coexistence and many individuals and organizations are actively working towards this end—for example Electronics for Peace in the UK.

So we must take it as a serious possibility. If we don't, and continue arming ourselves to the teeth while paying lip-service to peace, we might as well adopt the Groucho Marks line: *"I don't want to take part in any peace talks that would accept me as a participant."*

Modular Mixer

Part 2

John M.H. Becker

Clever connections allow countless combinations of mono or stereo signal controllers—selective filtering and panning facilities

LAST month, in Part One of this article, we took a close look at the individual circuits and p.c.b.s for the modular mixer. In this part, the final part, we will look at the constructional details of two complete systems.

Fig. 5 shows a block layout of the p.c.b. plan configurations needed, and Fig. 6 shows the interwiring. R4 as shown gives a switched high gain of around 50, though other values could be used to suit individual needs. A high value of R4 will give a lower gain, and vice-versa.

FOUR INPUT STEREO MIXER

Fig. 7 shows the block diagram of a versatile four input stereo mixer, in which pre-fade-listen, and echo-send outputs are also included. Four variable gain input stages (Fig. 2a) are used, the outputs of which can be switched by S5 to separate pan and level controls, or to an echo send mixer around circuits in Fig. 2f and Fig. 2g. This enables any one or more input signals to be brought up to a suitable level as set by VR1, combined and distributed to an effects unit such as echo, flange, chorus etc., with an output controlled by VR5.

After processing, the signal comes back in through the echo return socket and thence to the relevant pan and level controls. The wiring of S5 is such that the echo return signal will be delivered equally to each pan and level control stage associated with the original input stages. If this is not necessarily desirable, the echo return signal can be brought back into an unused input channel. Channels 1 and 2 are fed from a stereo jack socket, though the gain, level and pan controls are separate and the socket could equally well be replaced by two mono ones.

Any or all of the input signals may be switched by S6 to the pre-fade-listen mixer. This switching occurs after S5 so that the echo return signal can also be monitored prior to the pan and level

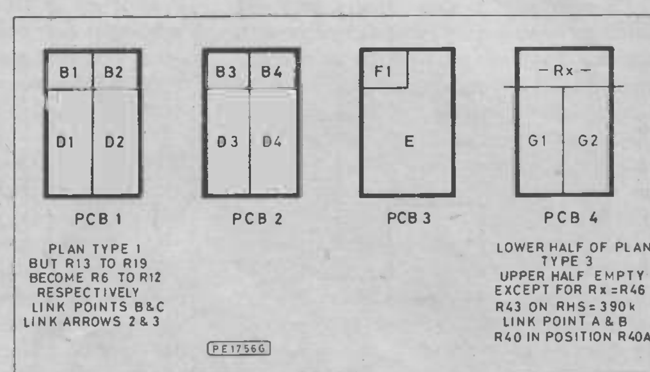


Fig. 5. The Mono VC4-1 p.c.b. plans

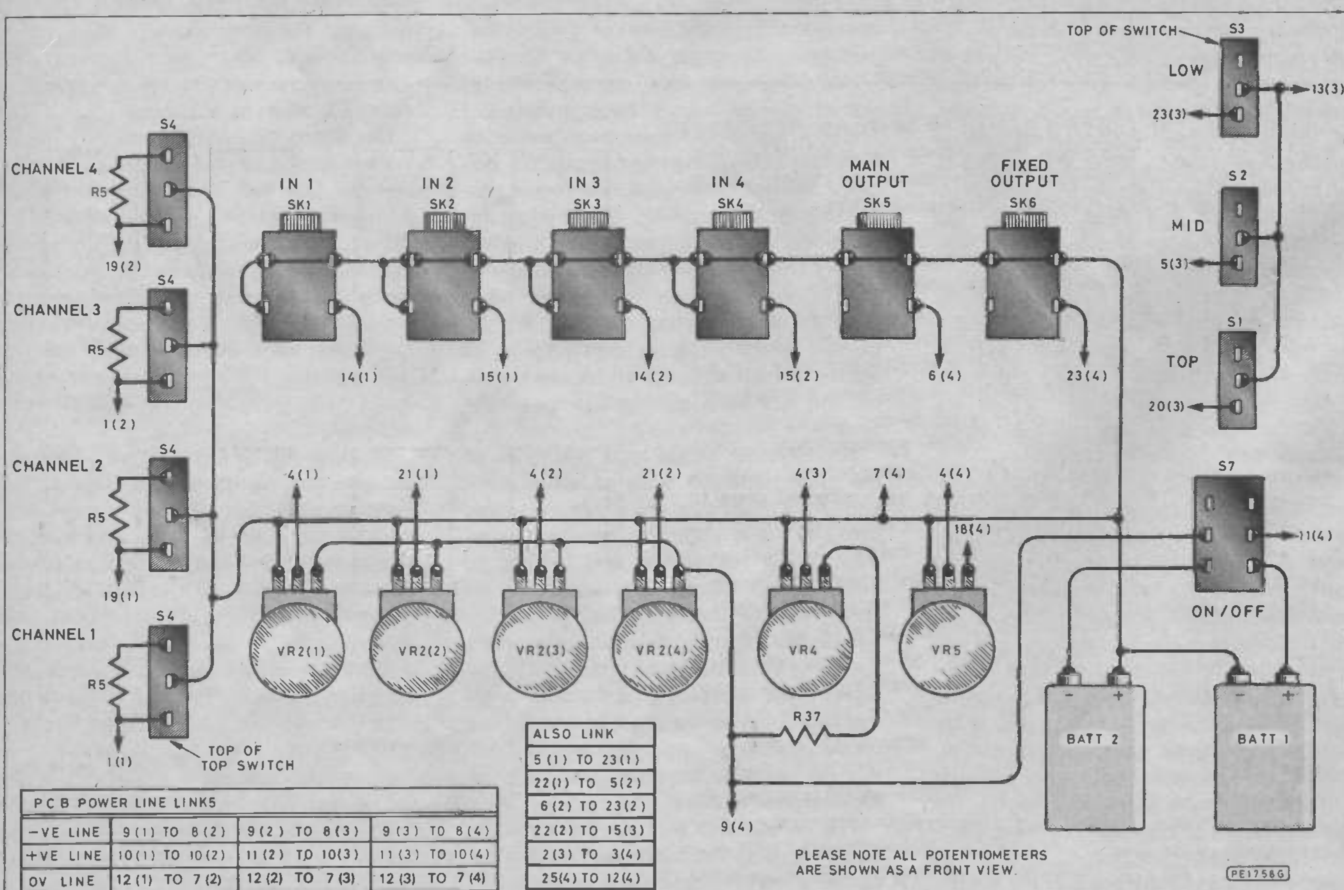


Fig. 6. Wiring diagrams of the Mono VC4-1 systems

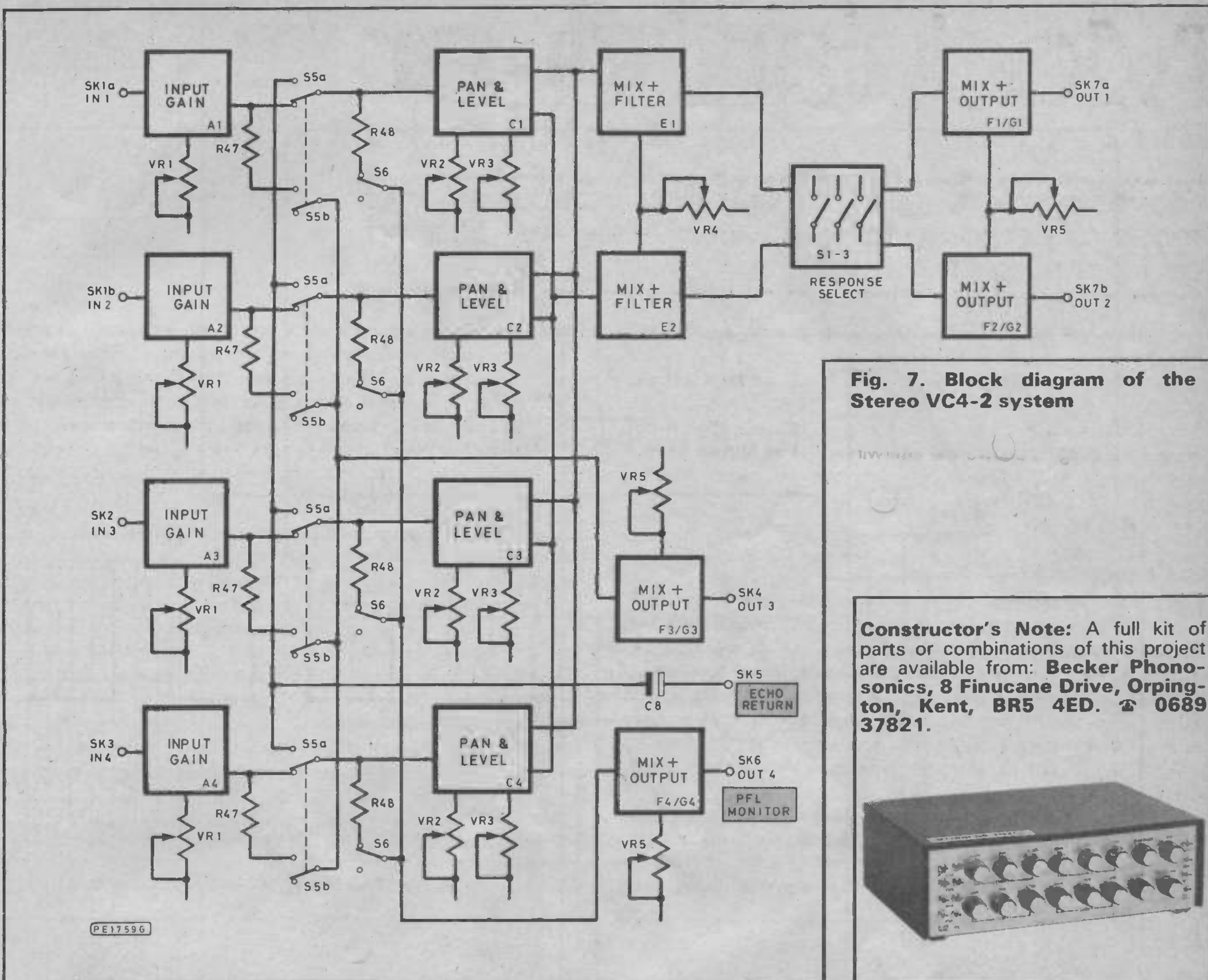


Fig. 7. Block diagram of the Stereo VC4-2 system

Constructor's Note: A full kit of parts or combinations of this project are available from: **Becker Phonosonics, 8 Finucane Drive, Orpington, Kent, BR5 4ED. ☎ 0689 37821.**

control. The circuit is identical to the echo send mixer. The output may be monitored directly if high impedance headphones are used, alternatively it can be fed to a monitor amplifier. Each channel has its own separate pan and level controls, using four circuits of Fig. 2c.

The twin outputs are connected to separate left and right bus lines each feeding to a separate mixer and filter stage around the circuit of Fig. 2e. Any signal can thus be routed totally to one or other of the left or right channels, or equally to both. As shown, the controls of the filters are ganged, so that although they retain their channel separation independence, any filter changes are simultaneously applied to both channels.

There is no reason though why each filter should not be given separate variable response controls VR4, and separate frequency pass switches S1 to S3. After filtering, each channel goes to separate mix and output stages, using the circuits Fig. 2f and Fig. 2g. A single output level control VR5 is coupled to the control nodes of both channels, so that both are controlled simultaneously. Separate level controls could be used instead if preferred. The final stereo mix can be taken to any normal amplifier system or recorder. Fig. 8 shows the p.c.b. block requirements, and Fig. 9 shows the control wiring and inter p.c.b. links.

ASSEMBLY

Full details of the component positions and interwiring are shown in the relevant diagrams. In some instances, values may vary between the stereo and mono versions, these are stated in the parts list and assembly diagrams. The short wire lines on the p.c.b.s can be made from resistor cut off leads. Box drilling sizes and positions will depend upon the component make used. As a

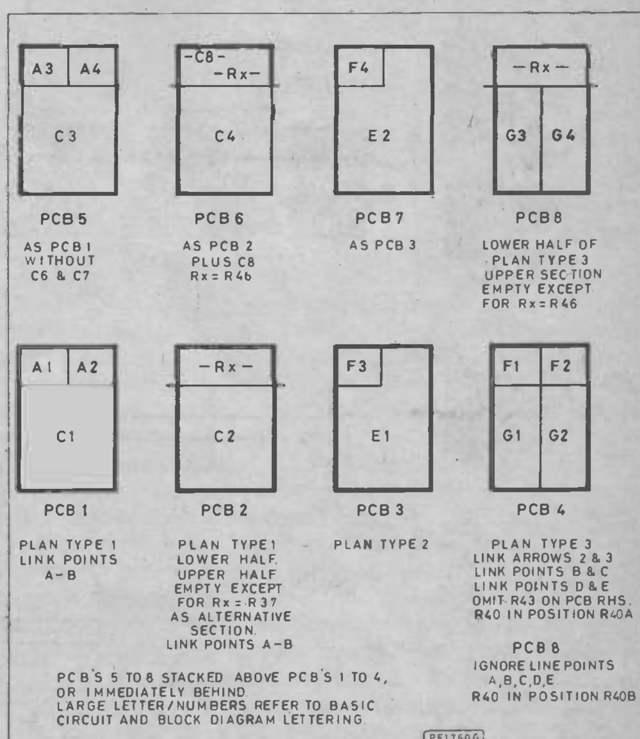
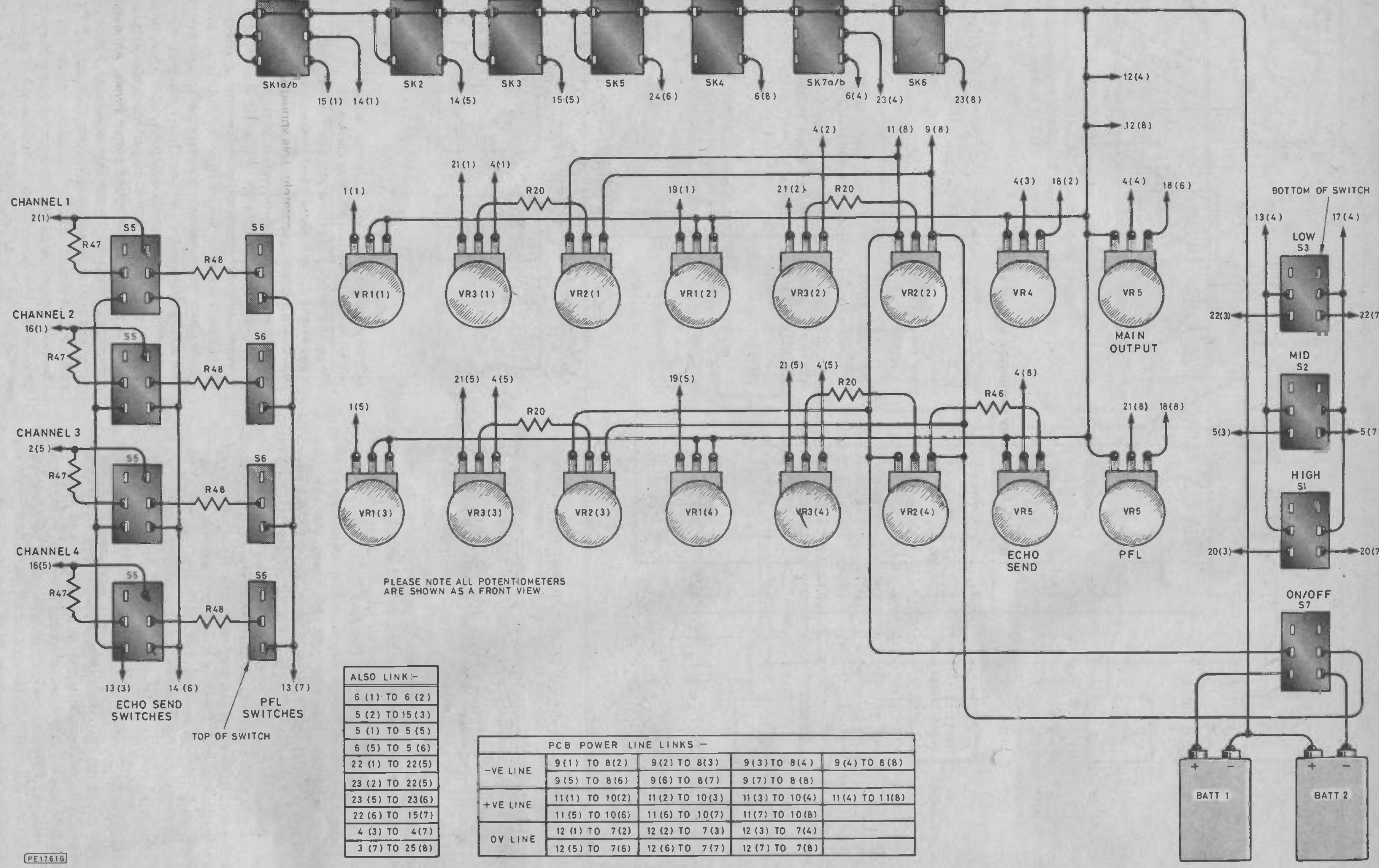


Fig. 8. The Stereo VC4-2 p.c.b. plans

Fig. 9. Wiring diagram of the Stereo VC4-2 system



ALSO LINK:-
6 (1) TO 6 (2)
5 (2) TO 15 (3)
5 (1) TO 5 (5)
6 (5) TO 5 (6)
22 (1) TO 22 (5)
23 (2) TO 22 (5)
23 (5) TO 23 (6)
22 (6) TO 15 (7)
4 (3) TO 4 (7)
3 (7) TO 25 (8)

PCB POWER LINE LINKS:-				
−VE LINE	9 (1) TO 8 (2)	9 (2) TO 8 (3)	9 (3) TO 8 (4)	9 (4) TO 8 (8)
	9 (5) TO 8 (6)	9 (6) TO 8 (7)	9 (7) TO 8 (8)	
+VE LINE	11 (1) TO 10 (2)	11 (2) TO 10 (3)	11 (3) TO 10 (4)	11 (4) TO 11 (8)
	11 (5) TO 10 (6)	11 (6) TO 10 (7)	11 (7) TO 10 (8)	
0V LINE	12 (1) TO 7 (2)	12 (2) TO 7 (3)	12 (3) TO 7 (4)	
	12 (5) TO 7 (6)	12 (6) TO 7 (7)	12 (7) TO 7 (8)	

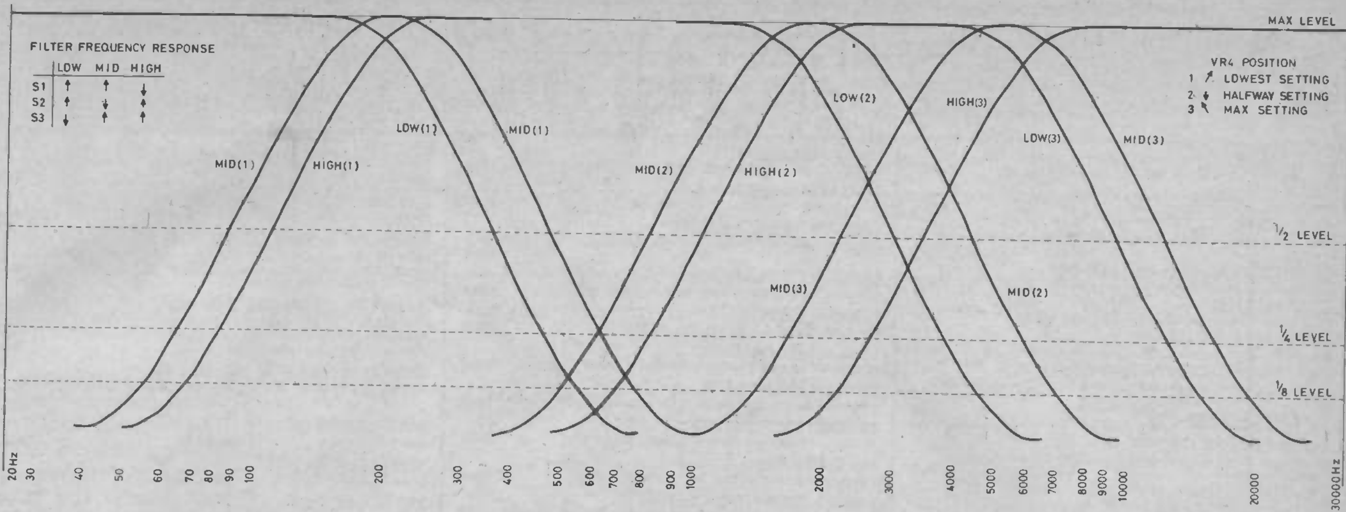


Fig. 10. Frequency response of the VC4.

guide, on the prototypes the horizontal pot spacing is 28mm with 10mm holes. Switch spacing is 13mm with 7mm holes, and the jack socket spacing is 25mm with 12mm holes.

After drilling, the panel may be painted and control legends applied, using a normal rubdown lettering and finishing off with a protective lacquer, all available from most good stationers. For the stereo version there is room in the box for p.c.b.s 5 to 8 to be mounted behind p.c.b.s 1 to 4, or they may alternatively be stacked above them if suitable p.c.b. supports are available.

Perform the wiring methodically, crossing off each connection on the chart as it is made. Diverse colour coding makes subsequent checking easier. Start off with all the wires that are on the front and back panel controls only. Then connect the inter p.c.b. link wires, and finally link the p.c.b.s to the panel controls. Screened wiring should not be necessary, but the case should be grounded as shown in the wiring diagram. Cross check the wiring, and that the i.c.s and electrolytic capacitors are in the correct way round before switching on.

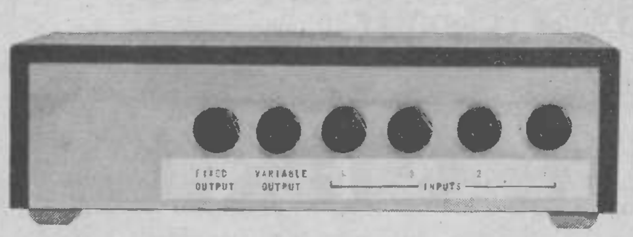


Photo 16. Rear view of the VC4-1

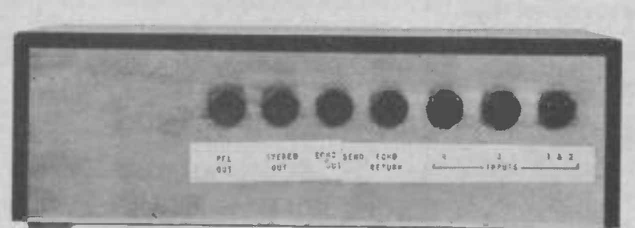


Photo 17. Rear view of the VC4-2

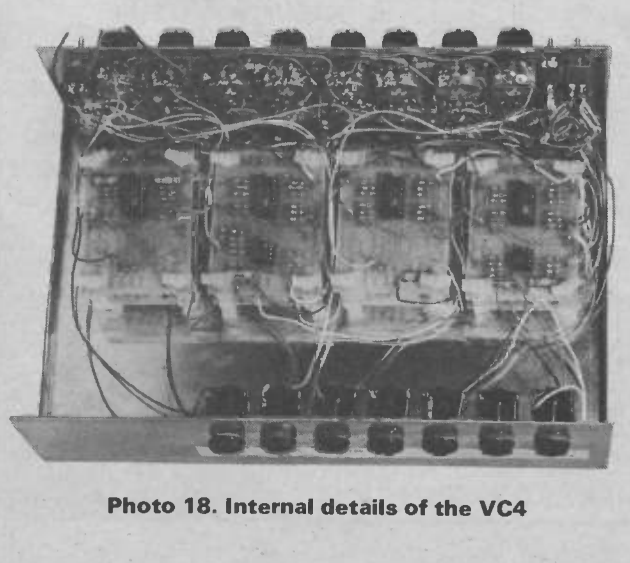


Photo 18. Internal details of the VC4

SETTING UP

There is none to be done! Simply check each channel and each control in turn to make sure that it is performing the function for which it is intended, re-reading the earlier part of this article if you are not fully clear about anything.

USE

There are only two points to make about using the mixers, and these are probably obvious to most people. Firstly, when mixing signals together, although each may be at a reasonable level that

will not overload an individual channel, at the point of mixing, their amplitudes will be summed. This can lead to overload distortion, giving a harsh sound to the signals for the reason shown in Photo 1 and Photo 3. Each signal must, therefore, be kept to a lower level than if it is used separately. This should also be taken into account when feeding two or more signals to the echo send and return paths, for not only will the output to the echo send be summed, but the return signal is distributed equally to each subsequent associated level control channel, the outputs of which are also summed resulting in secondary amplitude enhancement.

Secondly, the intention of providing input gain selection is to enable signals to be more closely matched to each other prior to the level mixing circuit, so that the level controls will be at roughly similar positions for equivalent output levels. Although gain is provided at the inputs, the input signal strength should preferably already be at a reasonable level in order to preserve the signal-to-noise ratio of around −55dB, referred to unity gain of a 1V signal. This ratio will of course degrade if an attempt is made to greatly amplify very low level signals within the unit. If practical, these should ideally thus be raised by a preceding low noise preamplifier. ★

Ingenuity Unlimited

A selection of readers' original circuit ideas.

Why not submit *your* idea? Any idea published will be awarded payment according to its merits.

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Articles submitted for publication should conform to the usual practices of this journal, e.g. with regard to abbreviations and circuit symbols. Diagrams should be on separate sheets, not in the text.

C16 IN-OUT PORT

I WANTED to fit an input/output port to a Commodore C16 and on looking at the computer circuit diagram I noticed that 16 addresses were decoded by the computer's U16 i.c. but some seemed not to be used. An examination of the p.c.b. confirmed this, pin 15 was unused, this pin enables the addresses Hex FD00 to FD0F.

I only needed two 8-bit ports, so I used a 74LS138 which decodes 8 of the 16 addresses. As the other chip selects were there I used them via the spare inverters in the 74LS04 as strobe outputs; perhaps a transistor could replace the inverter if required.

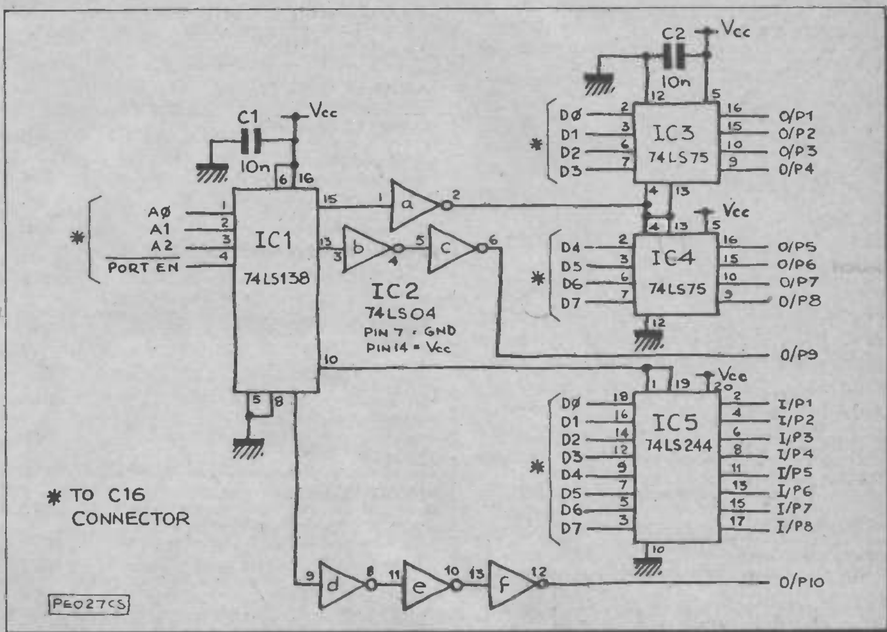


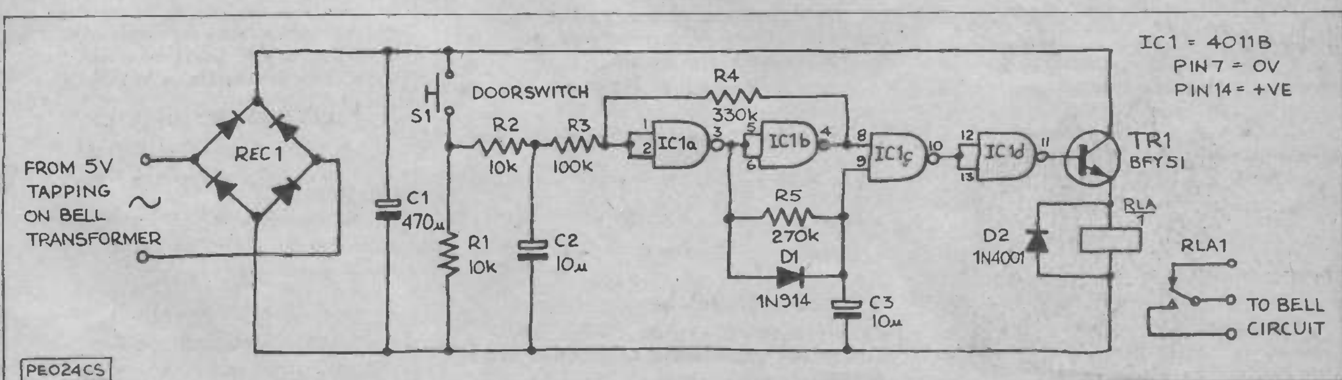
Table 1. C16 Signals

Signal	C16 IC Pin No.
D0	U5–2
D1	U5–3
D2	U5–15
D3	U5–17
D4	U6–2
D5	U6–3
D6	U6–15
D7	U6–17
A0	U15–4
A1	U15–13
A2	U15–5
Port En.	U16–15
Vcc (+5V)	VR1 (voltage reg.)
Earth (0V)	Ground rail on p.c.b.

The output port is at address 64768, o/p 9 is normally high and o/p 10 is normally low. The input port is on 64793; all of these could be changed if required. The Port En. signal comes from U16 and the data bits from the ram i.c.s U5 and U6. Three address lines come from U15 (see Table 1). All wires should be as short as possible. The unit can be built into the C16 as there is an area on the left of the main p.c.b. which will take a 6·75in by 2·6in board; it has 2 pillars 6in. apart so 2 self-tapping screws will hold the extra board in place.

I fitted a 25-way D-type connector near this board at the rear of the computer and an edge socket would also be suitable for the inputs and outputs.

A. R. Knight,
Farmoor,
Oxford.



DOORBELL TIMER CIRCUIT

THIS circuit was designed in response to a request from a friend who works in the repair department of a local shop. Customers frequently leave the door slightly ajar, and the resulting constant ringing of the bell was driving him mad! The circuit shuts the bell off when the door is closed, or after about five seconds, whichever occurs first. The timer principle could be adapted for other applications.

In the quiescent state, the door switch S1 is open, so the input to IC1a is low and its output is high. This charges C3 but holds IC1b output low, so ultimately IC1d output is also low and the transistor and relay are 'off'.

When the switch is closed, the input is taken high. IC1a's output goes low, so IC1b goes high; with this and the charge stored on C3, IC1c has two high inputs so its output goes low and IC1d's output goes high. This turns on TR1 and closes the relay, which rings the bell. However, C3 is discharged slowly through R5. When its voltage becomes low enough IC1c and IC1d change state and the relay opens again.

When the switch is opened, C3 is recharged through D1, providing a rapid resetting action. R2 and C2 prevent any possibility of spurious operation caused by stray pick-up on the long leads to the switch.

For convenience, power for the unit was taken from a 5V supply tapping on the bell transformer, which actually gave about 10 volts after a conventional bridge rectifier circuit. As the quiescent drain is zero, it could just as easily be used with a battery circuit.

The relay is a thumbnail-sized miniature device, but has given constant trouble-free service in a busy shop for well over a year.

Andy Flind,
Taunton,
Somerset.

THE LEADING EDGE

MUSEUM PIECE

The Museum of Science and Industry in Chicago isn't the same as other museums. Like a large version of the Science Museum in London or the Philips Evoluon in Eindhoven, Holland, it is very much a hands-on show of working science, electronics and technology. But to cut running costs the museum managers make over space to large American firms and industries which then stage their own displays.

The most famous MSI exhibit is the hall run by Bell Labs, which is roughly equivalent to British Telecom. In the thirties the Bell display centred on Oscar, a dummy head microphone system. Visitors wore headphones while a demonstrator whispered into Oscar's ears. The result, according to one audio buff who went there as a child, was unnerving. The dummy head and microphone system, usually called binaural, recreates the original sound with uncanny accuracy.

Oscar is no longer there, but the current Bell exhibit explains the principles of sound and electromagnetic waves with working models. One of these would make a nice d.i.y. electronics project.

The visitor is asked to pick up a telephone handset. The earpiece emits a musical tone. The listener must try to memorise its pitch. Then the tone stops and another different tone begins. A rotary hand control raises or lowers this second tone in pitch. The aim is to try and match one against the other.

When the listener thinks there is a match, he or she presses a button. A digital display then reads out the frequency of both the original and adjusted tones. A sign flashes "fair match", "good match" or "excellent match", depending on how close the frequencies are. Apart from making a good game it offers valuable ear training for musicians and electronics engineers who benefit from recognising sine wave frequencies.

HISTORY OF DATA STORAGE

One of the newest exhibits at the Chicago MSI is sponsored by IBM. It traces the history of data storage and processing. Personally I have always found IBM an aloof and distant company, with no apparent interest in communicating this kind of non-commercial information. So some of the facts from the Chicago display are well worth passing on.

The first "computers" used mechanical punched card technology. The IBM Tabulator of 1934 worked in this way. It looked like a clumsy printing press and could add, subtract and compare numbers, by flipping through 150 cards a minute.

In 1942 IBM made an electronic version which worked at a thousand times the speed. Vacuum tube valves replaced cards. The snag was that it had to be rewired for each new task. The big breakthrough came with "stored program" computing in 1947.

The idea originated in two places at much the same time. At the University of Pennsylvania, Presper Eckert and John Mauchly were working on the famous ENIAC computer. IBM was covering the same ground. The computer stored program instructions as well as data.

IBM's 1947 stored program machine was called the SSEC (Stored Sequence Electronic Calculator). The store was punched paper tape. The machine had 12,500 valves and 21,400 relays. One sceptical engineer did some sums, and pronounced it would never do any useful work.

The average life of a vacuum tube valve at that time was 3000 hours. With over 12,000 tubes that meant one tube failure every 15 minutes. It would take at least 15 minutes to find a dud valve and replace it. Ergo, no useful work.

The gloomy prediction turned out to be wrong simply because the reliability of valves greatly improved—to one failure amongst 2000 valves in a year. The SSEC beast ran for five years with acceptable failure rates.

Valves were still being used in the fifties, long after invention of the transistor by Bell Labs in 1947. In those early days of solid state technology valves were far more reliable.

The largest ever valve computer was SAGE (Semi-Automatic Ground Environment) built for the US Air defence system in the early fifties. It had 58,000 valves, weighed 113 tons and drew as much power as a town with a population of 15,000 people.

MAGNETIC MEMORY

In 1952 IBM started to use magnetic tape as a storage medium instead of punched paper. One reel stored 1·4 million text characters, or 1·4 Megabytes of data, equivalent to 12,500 punched cards. The same machine, the 701, used a cathode ray tube for short term storage. The tube screen pictured 1024 bits of data as ones or zeros.

Magnetic core memory was also used. A 10 inch web of wires supported 4000 iron oxide pellets, made in a modified pill-compressing machine. Each core could be separately magnetised to store a one or zero data bit. The webs were stacked in a vertical pile to build up a three-dimensional memory bank of 140,000 bit capacity.

Another memory store of the fifties relied on a metal drum, like a thick rolling pin a foot or so long. It rotated at 12,500 rpm past magnetic heads which recorded data in 40 parallel tracks along the drum length. This stored 10 kilobytes of data, i.e. ten thousand text characters.

The first disc stores appeared in the mid fifties. They were fearsome beasts. RAMAC, Random Access Method of Accounting and Control, was a vertical stack of aluminium discs coated with brown magnetic oxide, each nearly a yard in diameter, and spinning at 1200 rpm. These rotational speeds were of course convenient multiples of the US mains frequency, 60 Hz.

Each RAMAC disc stored 50,000 text characters on each side. Modern hard discs store six thousand times as much data per square inch of disc surface area.

By 1956 RAMAC storage capacity had risen to 5 Megabytes with a read/write data rate of 9700 bytes a second. The discs were fixed in place inside the stack, like a clumsy washing machine. The first removable discs appeared in 1962. Each had a capacity of 2 Megabytes or two million text characters.

By 1966, when banks and big businesses were switching to computers for their data storage and processing (and suffering those teething problems some of us remember so well), it was not unusual for one user to have a hundred disc packs. Each had around a dozen discs and each pack had a capacity of 25 Megabytes.

By 1971 the data transfer rate was 806 kilobytes a second and disc capacity was 100 Megabytes. Today disc capacity is 2·5 billion or gigabytes (2,500 megabytes) with read/write at 3 Megabytes/second.

The first floppy came in 1971. The first small hard disc, now called Winchester because that was IBM's laboratory code name for the project, appeared in 1973. The Winchester was special because the recording head does not contact the surface of the disc, as in early hard discs or the later floppies. The Winchester head floats on a very thin cushion of air generated as the disc rotates.

The trick with tape storage was to move the tape fast enough to achieve a high read/write transfer rate but still give rapid access to chosen sectors. This means almost instant stop, start and reverse; and that in turn means the risk of breaking or stretching the tape.

In the early sixties the IBM 729 tape reader achieved a read/write speed of 90 kilobytes/second by running the tape at 112 inches a second. it could start, and stop, and reverse the tape in 0·005 second.

This was done by running the tape slack between spools through a glass vacuum column. One tape spool held around 17 Megabytes, equivalent to a pile of punched cards as tall as a twenty storey building.

By the early seventies, data read/write rate was 1250 kilobytes a second or 1·25 megabytes. At this rate a single volume dictionary could transfer from tape in 13 seconds.

Without this kind of background information, it is easy to take today's computer storage technology too easily for granted. I can't help feeling it is a pity that such information only comes as the result of a chance visit to a museum on the other side of the Atlantic.

BARRY FOX

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A.C. Voltage 2V to 500V in four ranges at 1% ±2 digits (45 to 500Hz).
D.C. Current 2mA to 2A in four ranges at 0·75% ±1 digit (2·5% ±2 digits at 2A).
A.C. Current 2mA to 2A in four ranges at 0·75% ±1 digit (3% ±2 digits at 2A).
Resistance 2kΩ to 2MΩ in four ranges at 0·75% ±1 digit.
Diode check, polarity indication, over range indication, low battery indication, automatic decimal point display, overload protection, 2000 hours battery life (typical with alkaline battery). Size 164 × 75 × 24mm, weight 200g (including battery).

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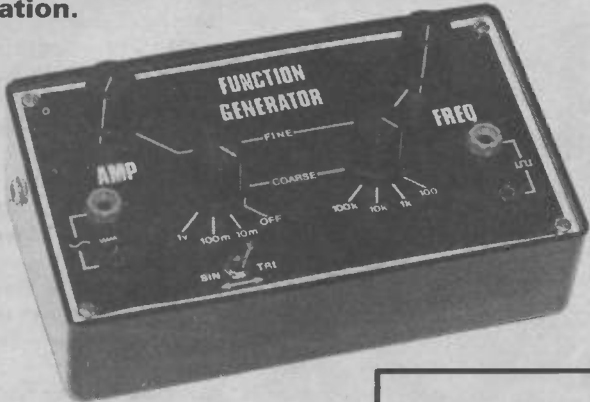
FEBRUARY FEATURES...

FUNCTION GENERATOR

Produces sine, square and triangular waveforms over the range 0·01Hz to 1MHz at up to 1V output, thus forming a very useful piece of test equipment. The article includes a simple battery eliminator for those that require mains operation.



TOUCH CONTROLLER

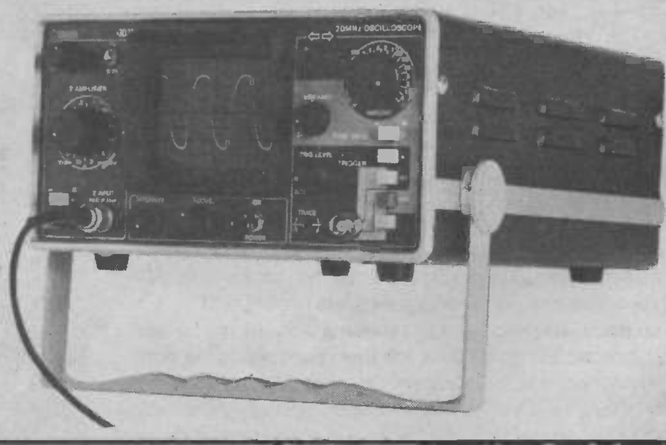
An alternative to a joystick for all computers with a standard Commodore/Atari joystick port. Overcomes the problem of keyboard control where key operation requires unreasonable dexterity.

LIGHT EFFECTS-GAMES UNIT

A fun project which gives the choice of "chasing or chancing"—eight channel lights effect unit or gambling guessing game, from the Building Blocks series, to help you master logic circuits.

Special Offer!

OSCILLOSCOPES



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Burglar Alarm

J.B.Rust

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This control panel has the following features:

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Mains power indicator.
Operates up to 3 passive infra-red detectors.
Immunity to false alarms due to mains "spikes" etc. (due to use of opto-isolators).
Simple to construct, install and operate.

As can be seen from the above specifications, it surpasses the specifications of the majority of domestic burglar alarm control panels on the market.

This system has four types of alarm detection: door loops, pressure pads, passive infra-red detectors and a panic anti-tamper circuit.

INSTANTANEOUS SERIES LOOPS

This circuit consists of a series loop of normally closed switches which are usually in the form of the magnetic reed type, or strips of metallic tape across window panes. These switches are in a normally closed loop so that if the loop is broken by somebody cutting the wires, the loop will go open circuit and the alarm will sound. As there is no limit to the number of switches that can be added to the loop and the reed sensors are not particularly expensive, it is well worthwhile putting them at *all* likely points of entry into the house.

In many cases where it is difficult to conceal a wire leading to a window switch, it may be a good idea to wire the internal door to that room instead, working on the assumption that an intruder will have to open that door to gain access to the rest of the house.

Magnetic reed switches consist of two parts, a magnet and the actual reed switch. The reed switch is mounted on the frame and the magnet is attached in a position such that when either the door or window is closed, the magnet will be adjacent to the reed switch in the frame keeping the reed switch closed. When the door or window is opened to gain entry the magnet will move away from the switch, causing the loop to go open circuit and bells to start ringing. Vulnerable windows and doors with panels of flimsy construction can be protected by strips of metallic tape specially designed for this purpose. This tape can be connected into the series loop using special self-adhesive terminal blocks.

ENTRY/EXIT LOOP

If switches are to be included in doors that have to be opened after the alarm is set, they must be connected into the timed entry/exit loop so that the occupant has time to leave the premises without activating the alarm.

When the occupant sets the alarm, an exit period of around 20 seconds is allowed before the exit loop is switched into circuit. On entry, the occupant will be allowed 30 seconds entry delay after which the alarm sounds if it has not been cancelled within this time period.

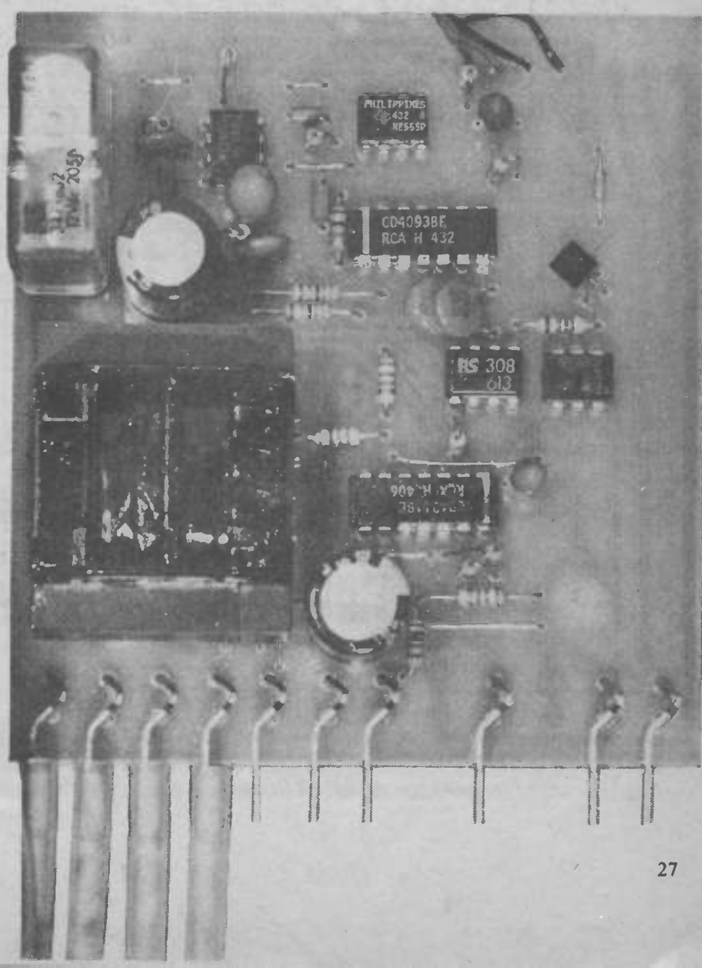
PRESSURE PADS

These pads are usually placed beneath floor coverings such as carpets and mats, and are normally open circuit. They essentially consist of two sheets of aluminium foil separated by a piece of thin foam containing holes. When somebody stands on the pad, the two sheets of aluminium touch and the pad becomes short circuited triggering the alarm. The pads should be placed at areas of the premises where a would-be burglar is likely to tread. These pads are reasonably durable, but they should not be placed in an area where excessive wear will occur, such as the entrance to a busy office, as the foam will eventually break down—causing the pad to go permanently to closed circuit.

Pads could also be used in the instantaneous series loop. If, for example, a television set was placed over a pad under the carpet which was wired to the series loop, the pad would be normally closed circuit. However, if the television were to be removed, the pad would go open circuit and sound the alarm.

PASSIVE INFRA-RED

This unit has the facility to be used in conjunction with up to three passive infra-red detectors. The power for these can be derived from the unit itself and their output can be connected into either the instantaneous loop or the timed entry/exit loop.



Passive infra-red detectors give total protection to the room in which they are used, provided they are installed correctly. These units should be used in rooms that contain valuable items that would be particularly attractive to an intruder. They give a very high level of security and are especially useful in rooms that cannot be adequately protected by means of door sensors and pressure pads.

Passive Infra-red detectors rely on the 100W of infra-red radiation given off by the human body to detect the presence of an intruder. Infra-red detectors consist of a pyro-electric sensor which is mounted at the focal point of a mirror lens. The mirror lens has many flat faces, each of which reflects the infra red radiation from one of many isolated zones in the room. If the pyro-electric sensor detects a change in infra-red radiation from one zone to another, as would happen as a person walked across a room, the signal will be amplified by the internal circuitry of the device and the alarm circuit will be triggered.

This type of infra-red detector has taken over from the now obsolescent ultrasonic type of detector, as it has shown itself to be highly reliable. It only responds to the movement of people, whereas the ultrasonic type responds to the movement of all objects, often giving false alarms if it detects the movement of, say, a pair of curtains as they are moved by a slight draught.

Although these passive infra-red detectors show remarkable immunity to external interference, they should be fitted strictly in accordance with the manufacturer's instructions, so that the optimum level of security can be attained without giving rise to false alarms.

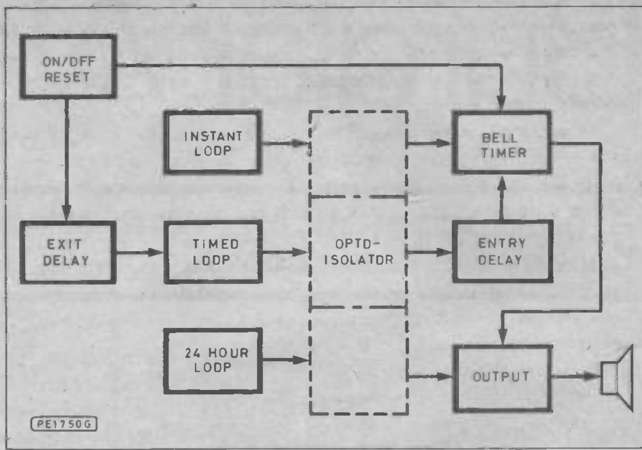


Fig. 1. Block diagram of the Burglar Alarm

These units should not be set up directly facing strong sources of heat such as fires and radiators, and family pets should not be allowed into rooms in which these infra-red detectors are operating.

24 HOUR LOOP

This loop is used mainly for the inclusion of a "Panic" button. A panic button is a special switch that is normally closed but will go open circuit if pressed and can only be reset by means of a key.

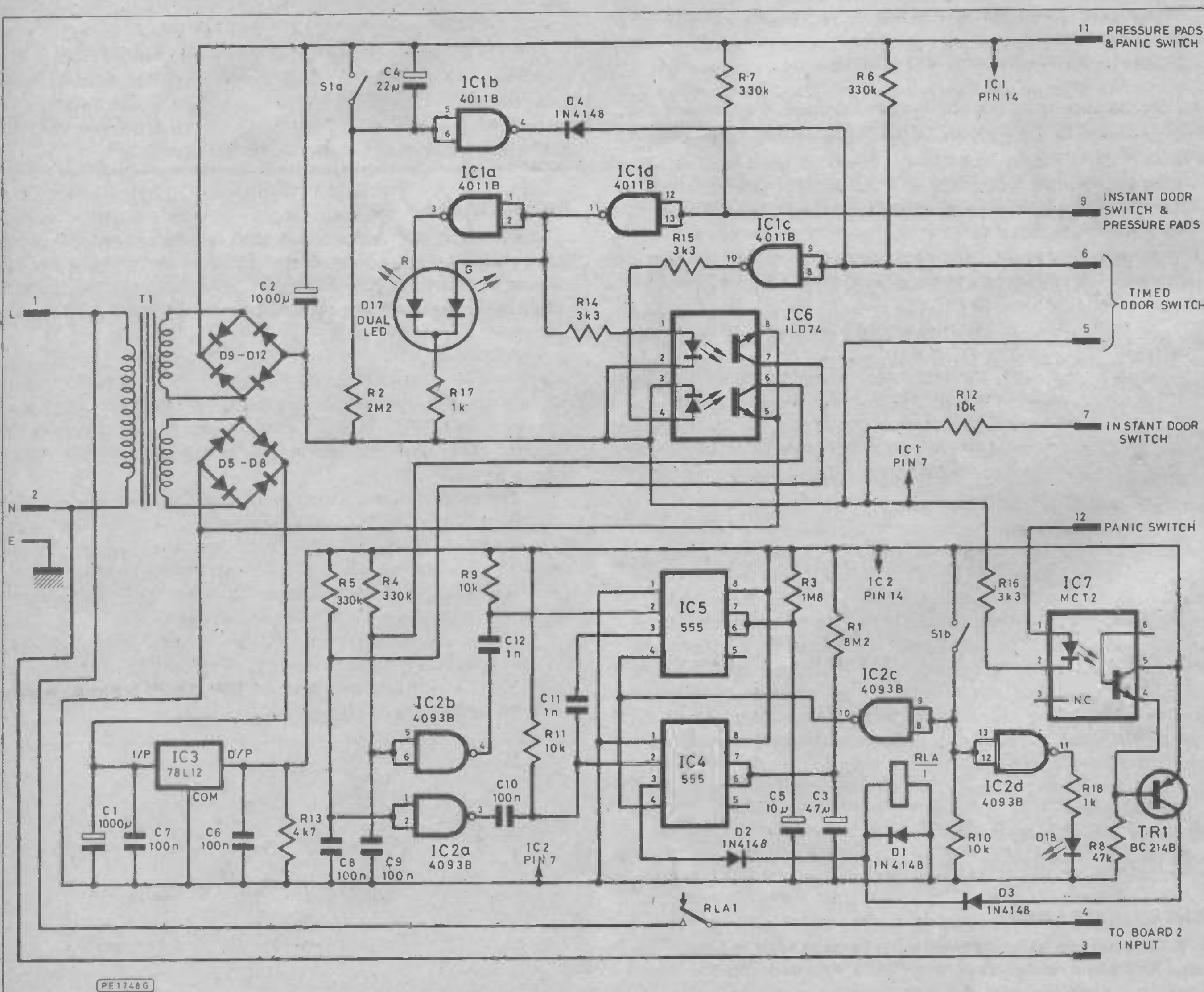


Fig. 2. The logic and control circuitry for the Burglar Alarm. Note that S1a/b is shown open-circuit (alarm armed); also that the +12V supply for passive infra-red detectors should be taken from terminals 11 and 5

This button should ideally be placed by the front door or in the bedroom, and may be operated if the occupant feels threatened in any way; alternatively, it can be used by an elderly person to summon help. This button will operate 24 hours a day, even if the main alarm is not set. The circuit is normally closed so that even if the "Panic" switch were to be ripped off the wall, the alarm would remain sounding.

Most door sensors are fitted with 4 wires, two being wired to the reed switch itself—these are usually identified by their ends being pre-stripped of insulation. There is usually also another pair of wires which simply form a loop of wire which passes through the body of the sensor and can be used in conjunction with the 24 hour loop, providing an alarm if anybody attempts to sabotage the alarm system when the building is occupied and the alarm is not set. A limit switch could be included in the external bell box and connected in series with the 24 hour loop. This would provide an alarm condition if anybody tried to remove the bell cover. Inexpensive smoke detectors are available that could easily be connected directly to the 24 hour loop providing an extra dimension to your security system.

The 24 hour loop circuit is an extremely versatile loop that can be used to maintain constant surveillance of a multitude of peripheral devices, and will sound the alarm continuously until the particular alarm input is reset.

THE BASIC CIRCUIT

When designing an alarm control panel it is essential to incorporate filtering into the system so that it will not be triggered by external interference such as that created by lightning, mains "spikes" caused by the switching of heavy-loads and spurious radio frequency interference.

Most alarm circuit designs attempt to reduce the occurrence of false alarms by incorporating capacitors and coils at various points in the circuit to filter out noise picked up along the wires leading to the sensors. However, this type of filtering is usually only sufficient for relatively small amounts of noise and all too often proves to be ineffective where large mains "spikes" occur or in lightning storms. This control panel uses a radically different solution to provide immunity to false alarms that will still remain effective in even the most violent of thunderstorms. The circuit is split into two parts: the first part is the sensing part, which responds to the inputs from all the sensors and the second part is the output circuit to the alarm controlling the entry and bell cut off delays. Refer to Fig. 1 and Fig. 2.

Both circuits are completely isolated from each other electrically, with their own separate power supply derived from individual secondary windings from the mains transformers. To ensure complete electrical isolation between the sensor circuit and the output circuit they are connected using opto-isolators, making it impossible for any interference that is received along the sensor wires to trigger the alarm output circuit, thus causing a false alarm.

SENSOR CIRCUIT

The instantaneous loop is connected to the input of IC1d. When the door loop is closed, the input to IC1d is held low through R12. If this input is sent high by either a pressure pad becoming short circuit or a door loop becoming open circuit and allowing the input to be pulled high through R7, the output of IC1d will go low, extinguishing the l.e.d. in the corresponding opto-isolator.

IC1b forms the basis of an exit delay timer, utilising the charging time constant of C4 as its reference. When the alarm is not set, C4 is shorted by a set of closed contacts in the key-operated switch, ensuring that the capacitor is kept fully discharged. In this condition, the output of IC1b will remain low keeping the input of IC1c low whatever the condition of the timed loop. When the alarm is set, C4 is allowed to charge through R2; however, during the 30 seconds C4 takes to become fully charged, the output of IC1b will remain low ensuring a high output from IC1c irrespective of the condition of the timed loop circuit, providing a 20 to 30 second exit delay. (For entry delay, see *output circuit*.)

The 24 hour loop circuit consists of a series circuit with an opto-isolator via R16. If this becomes open circuit, the l.e.d. in the corresponding isolator will receive no current: this will be detected by the output circuit.

To set the alarm, it is desirable to determine whether it is "safe" to set (i.e. all the doors and windows are shut and the pressure pads are clear). A single dual-colour l.e.d. is employed in the sensor circuit, which glows red when the alarm is *not* safe to set, and green when all the offending sensors are cleared. As well as a zone condition indicator this l.e.d. will also show that system is supplied with power, as it must glow either red or green, whatever the circumstances—provided power is present.

OUTPUT CIRCUIT

The output circuit is powered separately from the sensor circuit so as to prevent possible noise received from the sensor wires triggering the timers via the supply rails. The supply to this part of the circuit is necessarily regulated with a simple 78L12 monolithic voltage regulator in order to filter out supply transients which could quite easily trigger the inherently sensitive 555 timer chips. This part of the circuit receives relevant sensor information via three opto-couplers.

The transistor in the opto-isolators will allow conduction if it receives photons from its controlling l.e.d. in the sensor circuit, provided that the emitter is at a lower potential than the collector.

The first opto-isolator controls the instantaneous loop. When the input to IC6 is high the output transistor will conduct and maintain a low input to IC2a. If the input to IC6 goes low, the transistor will no longer conduct, causing the input to IC2a to be pulled high through R5 (C8 introduces a delay time of about 10ms to ensure that transients, which usually last only a few micro seconds, and are detected by the sensor circuit, will not trigger the alarm falsely). IC2a, having received a high input, will swing its output low, allowing a negative-going pulse to the input of IC4 via C10. This timer will be triggered and remain "on" for a period of around 10 minutes (governed by the charging of C3 through R1). Timer IC4 acts to latch the alarm on and also provides an alarm output for 10 minutes, after which the alarm will be silenced and automatically be re-armed.

The entry/exit loop is connected to the other half of IC6 which controls the state of IC2b by the same method that IC2a is controlled by IC6. The output of IC2b is directly connected to the input of IC5 via C12. When the timed loop is broken, IC5 will be triggered causing the output to go high. With the stated values of R3 and C5 the high output will remain high for around 20 seconds (providing an entry delay). If the unit is not cancelled within this time period, the output of IC5 will return to its original low state, creating a negative pulse which will trigger the IC4 alarm output timer via C11.

The 24 hour loop is operated by IC7. When this circuit is not broken TR1 is held off by the transistor in IC7. However, if the loop becomes open circuit the transistor in IC7 will no longer conduct, and TR1 will be held on via R8; this will energise the output relay and the alarm will continue until the loop is reconnected.

When the alarm is not set, the pole of the key switch is closed holding IC2d output low, extinguishing the l.e.d. and also holding pin 4 of both timers low via IC2c, ensuring the output is held off whatever the state of the timed or instantaneous loops. When the alarm is off, all the timers are reset. Note that the 24 hour loop will still operate even when the alarm is not set.

The main controlling p.c.b. will give an alarm output of 240V a.c. which is connected to the input of Board 2 as shown in Fig. 2 and Fig. 3: this gives an output of 12V d.c. at 500mA, which is suitable for driving most alarm sounders.

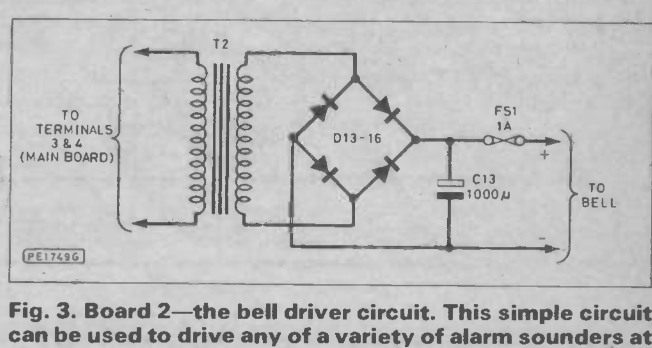


Fig. 3. Board 2—the bell driver circuit. This simple circuit can be used to drive any of a variety of alarm sounders at 500mA, 12V d.c.

CIRCUIT CONSTRUCTION

As this circuit is intended to be mains-powered and a permanent fixture, the unit must be constructed both carefully and to a high quality to ensure safety and long-term reliability. For this reason it is strongly recommended that the components are mounted on a p.c.b. with the layout illustrated below (Figs. 4 and 5) and housed in a *well earthed* vented metal case with similar dimensions to those stated.

As the layout of the p.c.b. is compact in order to save space, care must be taken not to bridge adjacent tracks with solder. The construction of the p.c.b. is very straightforward provided that the components are inserted in the correct order, checking the correct orientation of all polarised components.

First, insert the rectifier diodes D5–D12 and then R17, as these cannot be installed after the insertion of transformer 1. Then, with the exception of the i.c.s and the opto-isolators, all the other components can be inserted. It is advisable to leave C1, C2, the relay and the transformer until the end, as they are bulky and would make it difficult to insert the smaller components if they were inserted earlier.

At this point the opto-isolators and i.c.s must be soldered into place. As with all semiconductors they are susceptible to damage from excessive heat and thus care must be taken when soldering so that the components are not damaged. The simplest way to solder semiconductors without causing damage is to solder each pin individually, ensuring the iron is not applied for more than five seconds and then allowing about 15 seconds between joints in order to prevent a build-up of heat within the chip. Since i.c.s 1 and 2 are CMOS, the usual precautions should be taken when handling these devices. The use of i.c. sockets is *not* recommended, as after a period of time the chips could become loose or their pins may corrode—which will affect the long-term reliability of the circuit.

After inclusion of the i.c.s, the construction of the main p.c.b. can be finalised by soldering the two l.e.d.s to the underside of the p.c.b. First the leads of both l.e.d.s should be cut so that they extend about 8mm from the base of the l.e.d. body. The red/green l.e.d. has three leads. The middle (common) lead should be soldered to the pad labelled "3" as shown on the overlay diagram. The lead next to the "flat" should be soldered to pad "1" and the remaining lead to pad "2". The red l.e.d. must be soldered to the pads numbered "4" and "5" using the same procedure, with the negative lead (lead closest to "flat") going to pad "4". The position of the l.e.d.s, and the length of their leads may have to be manipulated slightly in order to line them up with the holes allocated in the panel.

The construction of the bell driver board is very simple. Sometimes mounting the fuse clips can be a little tricky: a useful tip is to attach the clips to both ends of the fuse when they are being inserted; this ensures that the clips are "square" relative to one another and maintains the correct separation.

When the construction of the p.c.b. has been completed, the key-operated switch can be connected using 4 pieces of flexible wire of about 7cm in length.

If the unit is intended to have two zones then connect the s.p.d.t. zone switch; if the unit is only required to control a single zone, this switch is omitted.

TESTING

When the two p.c.b.s have been constructed, it is necessary to install them into the unit. It cannot be over stressed that any connection to the circuit must be carried out with the mains supply disconnected.

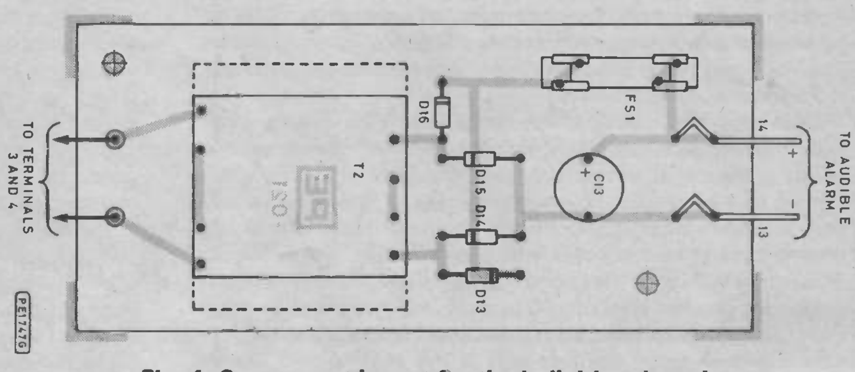


Fig. 4. Component layout for the bell driver board

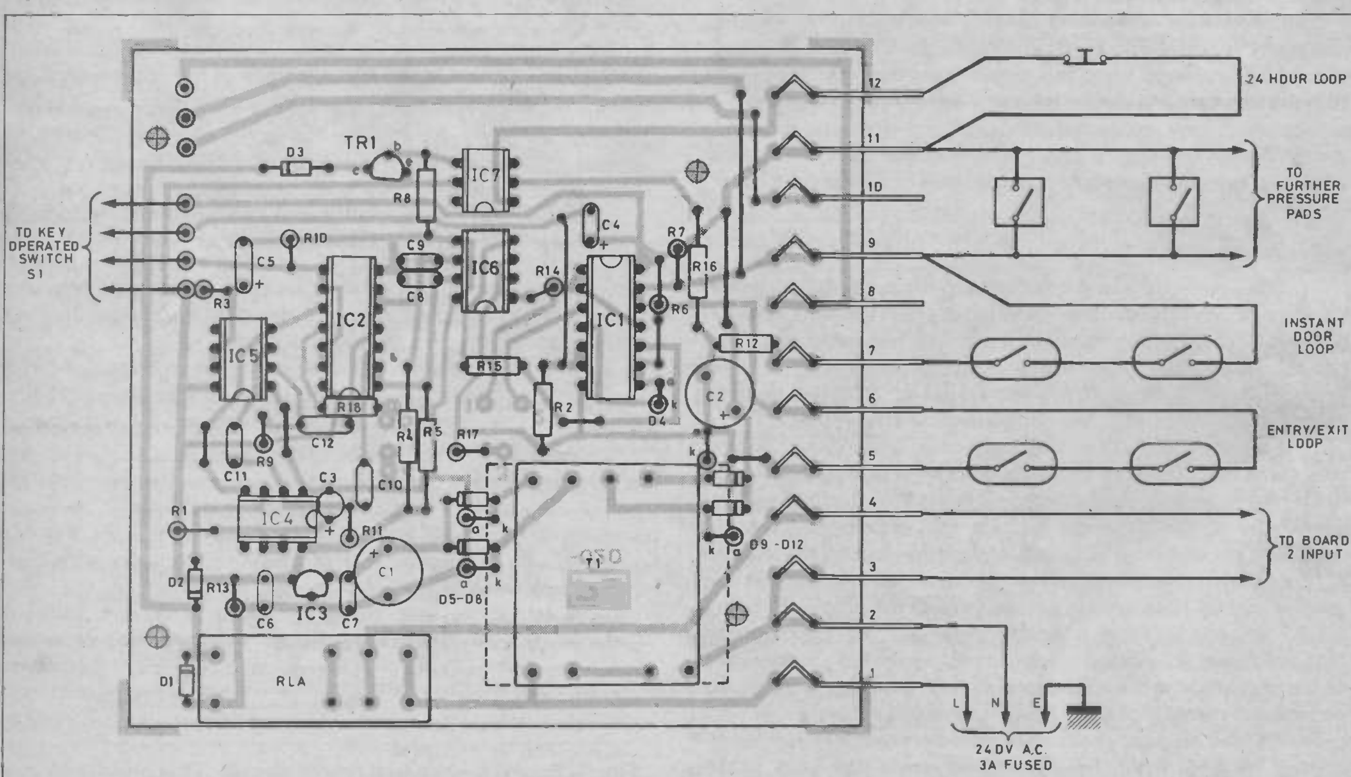


Fig. 5. Component overlay and wiring details for the Burglar Alarm main circuit board

COMPONENTS . . .

Resistors

R1	8M2
R2	2M2
R3	1M8
R4–R7	330k (4 off)
R8	47k
R9–R12	10k (4 off)
R13	4k7
R14–R16	3k3 (3 off)
R17,R18	1k (2 off)
All $\frac{1}{4}$W ±5%	

Capacitors

C1,C2,C13	1000μ elect. (3 off)
C3	47μ elect.
C4	22μ elect.
C5	10μ elect.
C6–C10	100n (5 off)
C11,C12	1n (2 off)

Semiconductors

D1–D12	1N4148 (12 off)
D13–D16	1N4001 (4 off)
D17	dual l.e.d.
D18	red l.e.d.
TR1	BC214B
IC1	CD4011BE
IC2	CD4093BE
IC3	78L12 voltage regulator
IC4,IC5	555 timers (2 off)
IC6	ILD74 dual opto-isolator
IC7	MCT2 opto-isolator

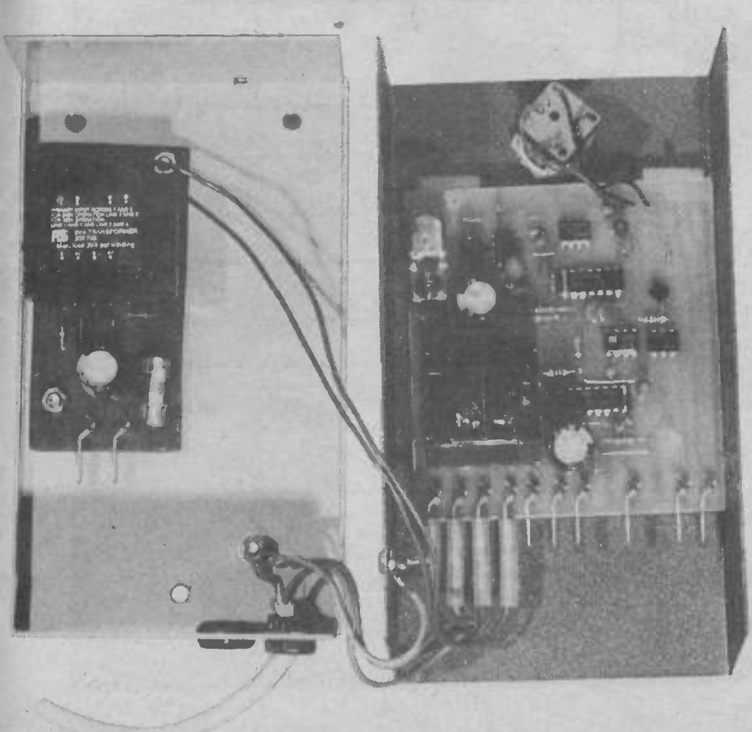
Miscellaneous

FS1	1A 20mm fuse
RLA	12V, 205Ω relay
S1	d.p.d.t. key-operated switch
T1	12V + 12V, 3VA mains transformer
T2	6V+6V, 6VA mains transformer

Case—approx. 167 × 96 × 74mm; main circuit p.c.b., available from the *PE PCB Service*, order code PE–020; bell driver board, order code PE–021; $\frac{1}{4}$in. p.c.b. blade connectors (12 off); $\frac{1}{4}$in. push-on connectors (12 off); insulating covers for blade connectors (12 off); adhesive p.c.b. supports; l.e.d. clips (2 off); cable grommets (2 off); fuse clips (2 off).

TWO-ZONE MODEL ONLY

Toggle switch, changeover; $\frac{1}{4}$in. p.c.b. blade connectors (2 off); $\frac{1}{4}$in. push-on connectors (2 off); insulating connector covers (2 off).



When the circuitry has been properly fitted into the panel, the testing procedure can be carried out. In order to simplify testing, all the terminals from 5 to 14 which have a maximum of 12V supplied to them, can be connected to a 10-way terminal connector, so that the links between the terminals can be connected and disconnected more easily. It is also recommended that the bell output terminals, 3 and 4, are connected to a small 12V bulb to indicate an alarm condition in order to avoid the nuisance caused by bells ringing during testing.

First it is necessary to connect terminals 1 and 2 to the mains supply, fused via a 3A fuse and ensuring that both halves of the case are well earthed; then the bell driver board should be connected to the main board via terminals 3 and 4.

For the testing of the single zone panel, the following procedure must be undertaken. First it is required that the entry/exit loop is made by connecting terminals 5 and 6, the instantaneous loop is made by connecting terminals 7 and 9, and the series loop of the 24 hour circuit is completed by linking terminals 11 and 12. If the mains supply is connected and the key is in the off position, the dual colour l.e.d. will indicate green, showing that a condition where all the doors in the instantaneous loop have been closed and all the pressure pads are clear has been simulated. If the key is now turned to the on position the dual colour l.e.d. will remain green, but in addition the second red l.e.d. will light to indicate that the alarm is set. If the 24 hour loop between terminals 11 and 12 is made open circuit an alarm output will be indicated by the 12V bulb and this condition will remain until terminals 11 and 12 are re-connected.

Then the same procedure should be repeated to check that the 24 hour loop operates with the key switch in the off position. With terminals 11 and 12 re-connected and the key being turned off and on again to make sure the alarm has been reset, the instantaneous loop can now be checked. To check this loop the dual colour l.e.d. will first indicate green, but when the link between terminals 7 and 9 is removed this l.e.d. will go red and an alarm output will be triggerred; when this link is re-inserted the alarm output should remain and can only be cancelled by turning the key to the off position.

So that the pad circuit can be verified the link between terminals 7 and 9 must remain connected and the key switch turned on after the panel has been reset. When a link is shorted between terminals 11 and 9 (simulating input from a pressure pad) the dual colour l.e.d. should change from green to red and the alarm should be triggered as indicated by the illumination of the 12V bulb. Now disconnect the link between 9 and 11 and, as with the door loop circuit, the alarm will remain on until it is cancelled by turning the key to the off position.

The entry/exit loop is the final loop that is to be tested. With a "green" condition present, reset the alarm by turning the key off and then on again. As soon as the alarm has been turned on, remove the link between terminals 5 and 6 (simulating the opening of a door in the entry/exit loop), leave this link disconnected for between 17 and 23 seconds only and then reconnect it. If an alarm condition is not realised within a minute of this operation the exit delay has been verified. After the verification of the exit delay remove the link between terminals 5 and 6 once again; after a period of between 20 and 25 seconds an alarm output should appear, proving the correct operation of the entry delay.

When the operation of all the sensor loops has been checked, the only other test is to check that the 10 minute bell cut-off is working correctly. Reset the alarm and trigger an alarm output by shorting terminals 11 and 9 together; do not cancel the alarm. If the bell cut-off is working correctly, the alarm will automatically cancel itself after about 10 minutes (allow up to a maximum of 15 minutes). Note that the bell cut-off timer is not operational when the alarm has been triggered by the 24 hour loop.

Testing of the two-zone panel is carried out in the same manner as the single zone panel, but remember that there are two series door loops and two pressure pad circuits that are in operation when the zone switch is in position "A". When the zone switch is in position "B", the pressure pads and door loop circuits in zone two are inactive (cancelled)—see Fig. 6.

Left, the photograph shows the completed unit, opened up to show p.c.b.s and interwiring

MECHANICAL CONSTRUCTION

When the building of the circuitry has been completed, it is necessary for it to be housed in a suitable box. This should be both pleasing to the eye and must be manufactured out of metal so that it will be resistant to attack. If a case of the same type and dimensions to that which is supplied with the kit is employed, the mechanical construction is very straightforward, provided that the instructions are followed carefully.

First it is important to cover all the drilled surfaces with masking tape to prevent the finish getting scratched, then mark out the position of all the holes. These holes must be positioned with a high degree of accuracy and centre punched prior to drilling. Failure to do this could easily result in circuit boards not fitting into the panel or possibly the final appearance being marred. To make the hole for the key switch use the largest drill available and enlarge with additional filing (pre-punched in kit form).

Now fit the key switch, fastening it tightly so that the body will not rotate when the key is turned. There are 2 holes drilled in the front of the panel for the l.e.d.s into which the 2 bezels from the l.e.d. clips should be inserted (the ring part of the clip is not used). The main p.c.b. should be placed so that the l.e.d.s soldered to it line up with the bezels; bending of the l.e.d. leads may be required to enable exact alignment. When the exact placing of the main circuit board has been established, the self-adhesive p.c.b. supports should be inserted into the board. When you are confident of the exact positioning, peel the back from the adhesive fixing and press the p.c.b. firmly into place, ensuring each support is well stuck down and the l.e.d.s fit correctly into the bezels. These p.c.b. supports space the circuit board 13mm from the front of the panel and, being adhesive backed, avoid unsightly holes having to be drilled into the front of the panel. At this point the appropriate wires from the p.c.b. should be soldered to the key switch.

Next, the bell driver board should be fixed to the base using 4mm bolts. A sheet of insulating material such as a piece of blank p.c.b. *must* be sandwiched between this board and the metal base, to prevent shorting of the tracks, especially when one considers that this board is ***live.***

Next, earth tags should be attached to both the base and the front half of the panel using 4mm bolts, scraping away the paint from where the tags are to be mounted. Both of these terminals should be connected to mains earth.

Once the cable grommets have been inserted, the construction of the panel has been completely finished. When the panel has been installed, make sure all the wires leading to the panel are well clamped, and if possible, they should be run in conduit for protection.

OPERATION

Once the panel has been installed in accordance with the wiring diagrams shown, make sure that any unused series loop is short circuited and that any unused parallel circuit is left open circuit.

The presence of power is indicated by the illumination of the dual colour l.e.d.; this will normally be red when the premises are occupied. When you wish to set the alarm all the doors protected by the instantaneous loop must be closed and all the pressure pads must be "clear", so that a green condition will be indicated. The alarm must not be set if a green condition does not exist. When the l.e.d. is green the alarm is set by turning the key 90° in a clockwise direction, this will be confirmed by the illumination of the second l.e.d. The building must then be vacated within the exit period of 20 seconds after the alarm has been set, via a door protected by the entry/exit circuit. This exit time can be reset by turning the alarm off and then on again.

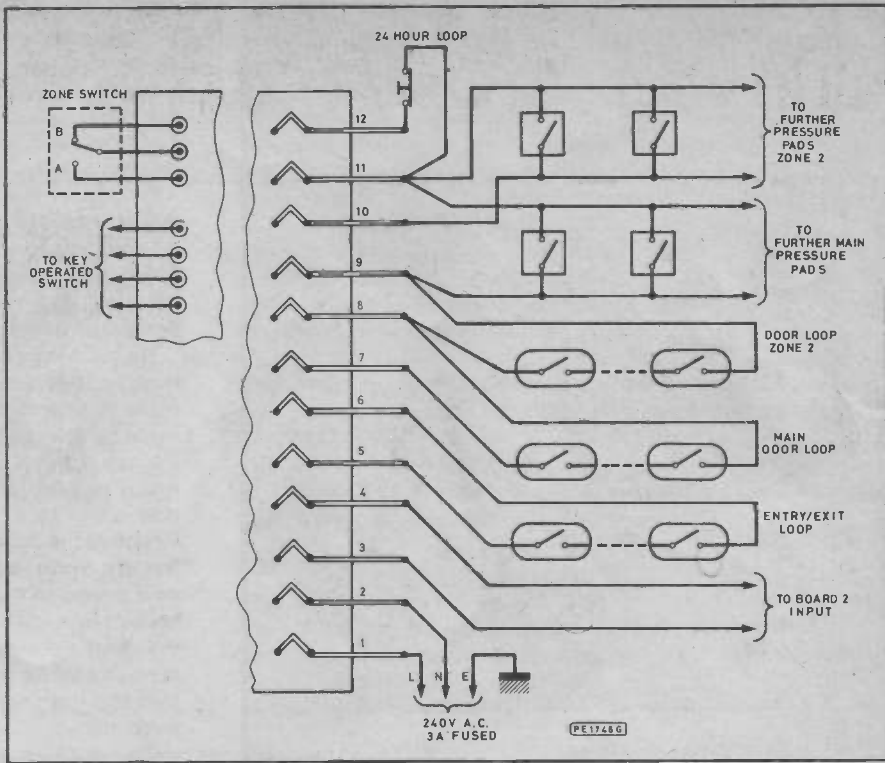
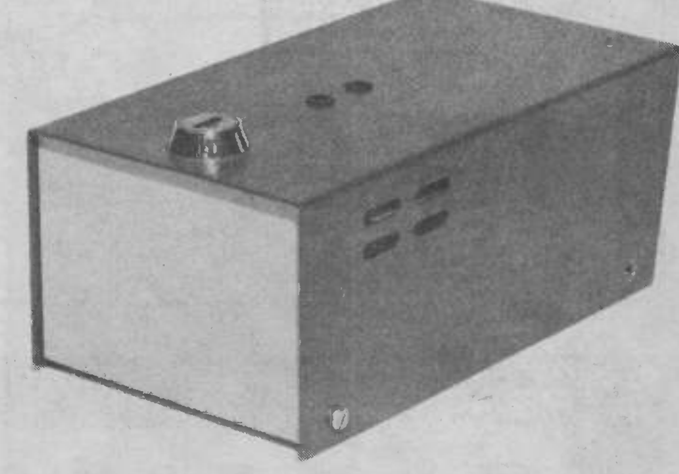


Fig. 6. Wiring details for two-zone operation of the Alarm

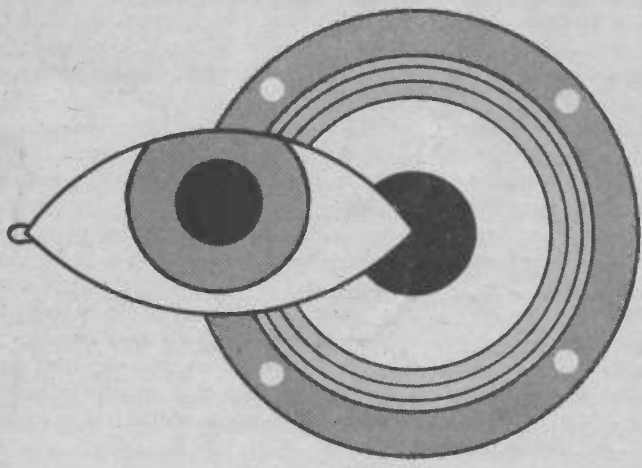
When returning to the premises the key must be turned to the off position within the entry time of 30 seconds, otherwise the alarm will be activated. Note that a door in the entry/exit circuit being left open *will not* prevent a green condition being indicated on entry.

The 24 hour Panic circuit will operate even when the rest of the alarm is not set. This circuit is the only one that will not allow the alarm to be silenced after the normal 10 minute cut-off time. The only way that the alarm can be silenced when a panic button has been operated is to reset the particular button with the key provided. With the 2-zone panel, a second set of parallel and series circuits is provided that will only be operational when the zone switch is in position "A": in this case, there are two parallel pressure-pad circuits between connectors 9, 10 and 11, and two series door loops between connectors 7, 8 and 9. In position "A", connector 10 is common to 9, while in position "B" (single zone), connector 9 is common to 8. ★



Constructors' Note:
A complete kit of parts is available, or p.c.b.s only, for single or dual zone models from **J. R. Alarms**. Also available: the unit ready-built and tested; and a system which includes eight door switches, one panic button and two pressure pads.

all in your MARCH issue!



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MARCH 1986 ISSUE ON SALE FRIDAY, FEBRUARY 7

Interesting results with regard to the atmosphere of Mercury have been obtained by two American astronomers, A. Potter and T. Morgan, from the McDonald Observatory in Texas. Apparently sodium is a major constituent of this excessively tenuous atmosphere.

Potter and Morgan even suspect that Mercury has a "tail" not unlike the ion tail of a comet. The origin of the sodium is uncertain; it may be produced internally, but is more likely to be sputtered off surface minerals by the solar wind.

The Sun itself remains decidedly inactive, with very few spot-groups. This may indicate that there will be no major short-term changes in the tail of Halley's Comet, at least on the scale of those observed at the 1910 return.

Plans for the launching of the Hubble Space Telescope, a 94-inch reflector, seem to be going well, and there is every hope that the telescope will be in orbit during 1986, though not, unfortunately, in time to make the best use of the return of Halley's Comet.

VOYAGE TO URANUS

The main "space news" this month is, of course, the rendezvous of the *Voyager 2* probe with Uranus, which is due on the 24th.

Uranus is in many respects a most peculiar planet. It is now known to be slightly larger than Neptune, though not so massive; it has a unique axial tilt—98 degrees to the perpendicular of its orbital plane—so that at present it is almost pole-on to the Sun.

The rotation period is now thought to be about 16.2 hours, considerably longer than was believed a few years ago, but the Uranian "calendar" must be very strange, with each pole having a "night" equal to 21 Earth-years, with corresponding "midnight sun" at the opposite pole. The Uranian atmosphere is clear and transparent to great depths (unlike Neptune's, which contains obvious aerosols), and there is less ammonia than with Jupiter, Saturn or Neptune. There seems to be a rocky core, surrounded by a deep shell of water ice and an outer "atmosphere" made up largely of hydrogen, together with some methane.

Uranus also differs from the other giant planets inasmuch as it appears to lack an internal heat-source, so that it is no warmer

The Sky This Month

The coming year will be of special importance for astronomers—particularly, perhaps, for those who are interested in the Solar System. But for the planetary observer, 1986 starts off on a rather dull note.

Mercury and Venus are to all intents and purposes out of view (Venus passes through superior conjunction on the 19th of January); Jupiter, in Capricornus, sets not long after the Sun. Saturn is visible low in the south-east just before sunrise; Mars, in Libra, is also a morning object, but its magnitude is only 1.4, and even large telescopes will show little upon its disk. Even the outer planets are poorly placed; Uranus is in Ophiuchus, Neptune in Sagittarius and Pluto in Virgo.

To make up for this, we have the usual splendid display of winter constellations—dominated by Orion, which is high in the south after dark. As all star-gazers know, the three stars of the Hunter's Belt point downward to Sirius, which is much the most brilliant star in the sky.

Though, admittedly, it owes its pre-eminence mainly to the fact that it is comparatively close to us, Sirius is "only" 26 times as powerful as the Sun, whereas Rigel in Orion can match at least 60,000 Suns. The distance of Sirius is a mere 8.6 light-years; and of the first-magnitude stars, only the southern Alpha Centauri is closer than that.

Note, too, that although Sirius is a pure white star, it twinkles violently, and flashes various colours. This is because it is so bright, and is always fairly low down as seen from England.

Surprisingly, many of the old astronomers (including Ptolemy, who died around A.D.180) described Sirius as red. Certainly it is not red now, and there seems to be no chance that it has genuinely altered since ancient times, so that there must be some error in interpretation; all the same, it is decidedly curious.

Capella is now almost at the zenith during evenings (the position occupied during summer evenings by Vega). Capella is yellow, like the Sun, but is much more luminous, and is actually a very close binary. Close beside it is the little triangle of stars making up the 'Hædi', or Kids; at the apex of the triangle is the remarkable Epsilon Aurigæ, an eclipsing binary with a period of 27 years.

The eclipsing secondary has never been seen, and its nature is uncertain. The last eclipse ended in 1984, and by now Epsilon is back at maximum, slightly brighter than the second 'Kid', Eta Aurigæ; but there are suspicions that it is never quite steady in light, and it is worth watching.

The prototype eclipsing binary, Algol (Beta Persei) is high up. Its usual magnitude is 2.1, about equal to the Pole Star, but at minimum it falls to 3.4. During January, suitable minima occur on the 8th (3.4 hours G.M.T.), 11th (0.2 hours), 13th (21 hours) and 31st (01.9 hours). The most famous of the intrinsic variables is Mira in Cetus (the Whale), which has been known to exceed magnitude 2; the period is 331 days, but during this month it is far too faint to be seen with the naked eye.

HALLEY'S COMET

The first part of January is the vary last time that Halley's Comet will be a naked-eye object from Britain—that is to say until the next return, that of the year 2061. The comet moves through Aquarius; the positions are as follows:

January 1, R.A. 22h 15m, declination S. 2° 34′
January 5, R.A. 22h 06m, declination S. 3° 28′
January 10, R.A. 21h 56m, declination S. 4° 28′
January 15, R.A. 21h 47m, declination S. 5° 23′

After the 15th, the comet will set so soon after the Sun that it will be lost in the evening twilight. Look, however, on the 13th, when the comet will be close to Jupiter and the crescent moon. The Moon itself will not interfere badly, as it is new on January 10; by the time of full moon (January 26) the comet will have been lost. Perihelion occurs on February 9, but will be unobservable from Earth; the only hope of recording it at this time will be from the Pioneer *probe now in orbit round Venus.*

Generally speaking, Halley's Comet develops its tail to the maximum extent well after perihelion. It will be at its closest to the Earth next April (about 39,000,000 miles), but will be too far south to be visible from Britain, and by the time it returns to our skies it will have faded below naked-eye visibility. So make the most of your opportunities this month, and by all means try some photography.

At the time when I write these words (November 8) it is uncertain whether or not the comet will be easily visible without optical aid; we must hope for the best. The coma is already very large, with a diameter of over 600,000 miles (more than half that of the Sun), but the comet is decidedly diffuse.

than Neptune even though it is much closer to the Sun. Its revolution period is 84 years.

Vague bands and spots have been reported on the pale, greenish disk, but photographs taken in 1970 from the Stratoscope balloon telescope showed no cloud features.

The outlook for *Voyager 2* appears to be fairly good. Following the pass of Saturn the scan platform carrying the cameras gave trouble, and some valuable data were lost; it was originally believed that the probe had been damaged by collision with a piece of ice, but it now seems that it seized up because of several hours' use of the high-rate motion in azimuth. Subsequently, lubricant seeped back into the mechanism, but it was a salutary warning, and the high-rate slew will not be used again.

Preliminary results have shown that, surprisingly, no "weather patterns" are obvious. It is still too early to come to any definite conclusions, but all the planets so far studied from space-probes have provided their quota of shocks, and no doubt Uranus will continue the trend!

SEQUENCE OF EVENTS

The time-table for this month is as follows:

January 10: the "far-encounter" sequence begins.

January 23: *Voyager* may enter Uranus' magnetosphere. Of course, we will have no definite proof that a magnetosphere exists, but all the indications are that it does, even though the extra-ordinary axial tilt may show that the conditions are quite different from those of Jupiter or Saturn.

January 24: the main encounter sequence. Minimum distance from Uranus will be at 18h, 50,700 miles from the cloud-tops. All five satellites will also be surveyed, between 15h 11m and 20h 53m.

January 25: Search for ayroræ on the night-side of the planet.

Further observations will be made until 25 February, when the Uranus encounter will be regarded as complete.

Uranus has its own satellite family, about which very little is known at the moment. The smallest satellite, Miranda, will be examined in the greatest detail, since *Voyager* will by-pass it at a mere 18,000 miles. The minimum encounter distances for the other satellites are 231,000 miles for Titania, 293,000 miles for Oberon, 79,000 miles for Ariel and 202,000 miles for Umbriel.

It is reasonable to assume that all five satellites will be icy, similar to the icy satellites of Saturn, and that they will be cratered; but we cannot be sure. Remember that two other planetary satellites, Europa in Jupiter and Enceladus in Saturns, are very smooth.

Obviously the ring-system will also be examined, and a search will be conducted for any extra satellites. The whole encounter will be of absorbing interest, and I will report upon it when results come to hand.

Let us hope that *Voyager 2* continues to perform well. If not, we must resign ourselves to a long wait before collecting any further close-range data from this strange, remote world.

Ingenuity Unlimited

A selection of readers' original circuit ideas.

Why not submit *your* idea? Any idea published will be awarded payment according to its merits.

Each idea submitted must be accompanied by a declaration to the effect that it has been tried and tested, is the original work of the undersigned, and that it has not been offered or accepted for publication elsewhere. It should be emphasised that these designs have not been proven by us. They will at any rate stimulate further thought.

Articles submitted for publication should conform to the usual practices of this journal, e.g. with regard to abbreviations and circuit symbols. Diagrams should be on separate sheets, not in the text.

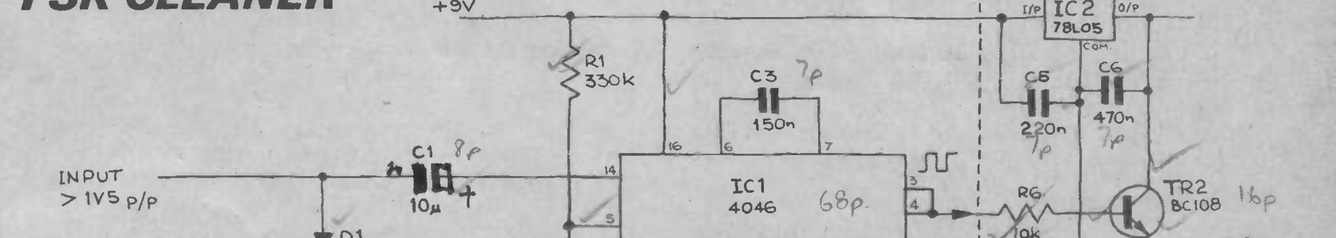
This circuit was primarily designed for interfacing satellite transmitted data with the tape input port of a microcomputer but can be used to clean up any serial frequency shift keyed (FSK) data. Poorly taped software can be cleaned up tape to tape, without having to load into memory and then punch a new tape. (I can't think why anyone should want to do that!)

The circuit is designed to accept high/low frequencies of 2400 and 1200Hz and will operate at up to 1200 Baud.

The system being a phase locked loop, has the advantage of being frequency conscious rather than level conscious as in similar systems using Schmitt triggers. This gives good noise rejection and by using a limited capture range the loop will automatically act as a band pass filter. The circuit will lock onto inputs as low as 1·5V peak to peak and the output at pins 3 and 4 will be a 9V "squared-up" copy of the input. (CMOS compatible.) In the absence of any input, TR1 switches off allowing pin 5 to go high and thus inhibiting the free running oscillator from appearing at the output. IC2 and TR2 form a TTL compatible buffer if needed.

S. Grosvenor,
Stranraer.

FSK CLEANER



Logic Probe

Tim Watson

TTL and CMOS compatible logic test aid with advanced features including waveform indicator

For anyone dealing with digital circuitry, a logic probe is an invaluable if not essential instrument for proving and testing circuits and projects. There are many types around, offering facilities varying from the basic high/low indication to advanced logic analysis.

SPECIFICATIONS

The probe described in this article offers a compromise between great expense and high specification. It features; high/low indication, switchable test for TTL and CMOS, tone indication, pulse catcher and pulse waveform indicator.

Unlike some "hobby" logic probes, the input impedance is around 5M which is sufficient to avoid undue loading of the circuit under test. Because of the high input impedance, a screened probe is used as stray noise pick-up on the input would, otherwise, give rise to false readings.

CIRCUIT DESCRIPTION

Fig. 1 shows the full circuit diagram of the logic probe, and the circuit operation is as follows. Starting from the input, R4 to R8 form a resistor ladder to produce the switching levels of TTL or CMOS circuits, depending on the setting of S1. These levels are compared by IC1 and IC2 with the probe voltage. IC1 and IC2 need to be true comparators, since op-amps are generally too slow and would stop the probe's ability to "catch" short pulses. D1, D2 and R1 give protection against the probe voltage being outside the supply levels. R2 and R3 bias the probe into the middle of the float region, so that when the probe is open circuit a reading of "float" is given.

Table 1. Comparator output truth table

Comparator outputs		Meaning
IC1	IC2	
0	0	Float
0	1	Low
1	0	High
1	1	Not possible

Table 1 gives the meanings of the comparator output combinations. These outputs drive the high and low l.e.d.s directly. IC3a and IC3b form an EX-NOR gate, the output of which is buffered by IC4a to drive the float l.e.d. The comparator outputs are cleaned up by IC3c and IC4b, and the rest of the circuit operates from these signals.

R12, D6, C1 and IC3d detect a change from the float state to another state. If this happens then the flip-flop formed by IC5a and IC5b is set. Thus if the change is of short duration it is not lost. S2 resets the flip-flop but note that the flip-flop cannot be reset when the probe is in the float state. Thus, the circuit counts a change as a change from high or low to either of the other possible states. The logic to detect a pulsing waveform, which is counted as being about 10Hz or greater is formed by R16, R17, C3, C4, D8, D9 and IC5c.

The oscillator for the tone is based around IC5d. If the probe input is high then C5 is charged via R18 and if it is low then C5 is charged via R19. In both cases the discharge path is R21 and, thus, the two different tones are generated.

COMPONENTS . . .

Resistors

R1	1k
R2, R3	10M (2 off)
R4	12k 1%
R5	4k7 1%
R6	3k3 1%
R7, R8	3k6 1% (2 off)
R9–R13, R15, R20	510 (7 off)
R14, R16, R17, R19	1M (4 off)
R18	220k
R21	10k

Capacitors

C1	47p
C2–C4	100n disc ceramic (3 off)
C5	10n miniature dipped case

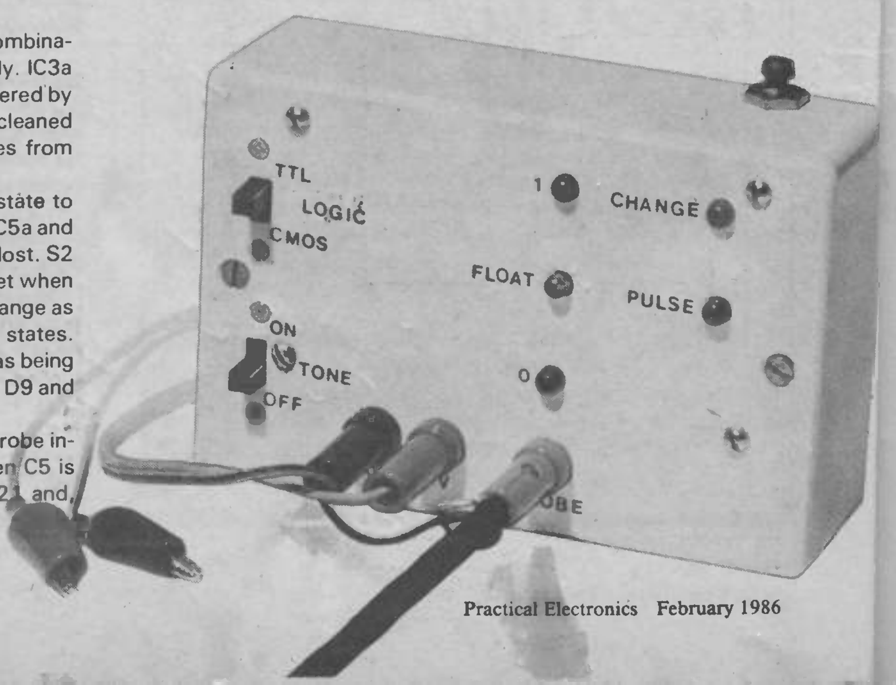
Semiconductors

D1, D2, D8–D11	1N4148 (7 off)
D3	0·2in l.e.d. green
D4, D12	0·2in l.e.d. red (2 off)
D5	0·2in l.e.d. orange
D7	0·2in l.e.d. yellow
IC1, IC2	LM311N (2 off)
IC3	4070
IC4	4041
IC5	4093

Miscellaneous

8 pin d.i.l. socket (2 off); 14 pin d.i.l. socket (3 off); S1 d.p.d.t. switch; S2 push to make; S3 S.P.S.T. switch; Piezo transducer wire; cable; sockets, etc.

Constructors' Note: Please note it was found that in practice, the Logic Probe functions better if D6 is replaced by a link. The p.c.b. for the Logic Probe is available from the **PE PCB** Service, order number 024



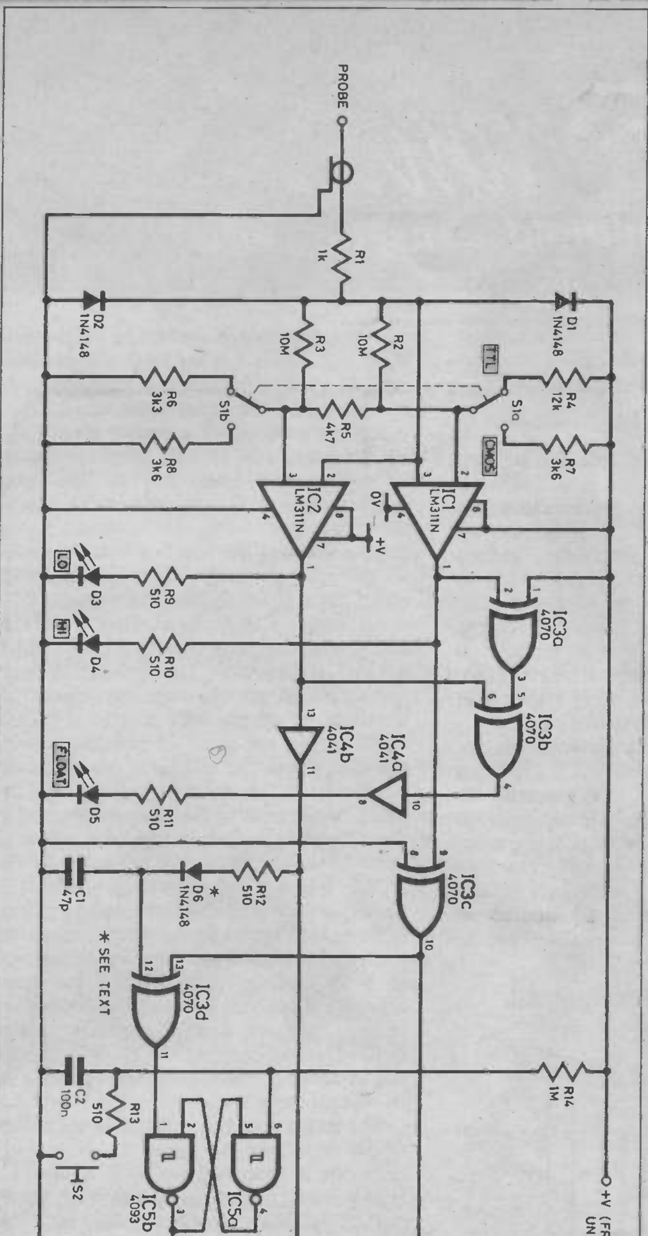


Fig. 1. Complete circuit diagram of the Logic Probe

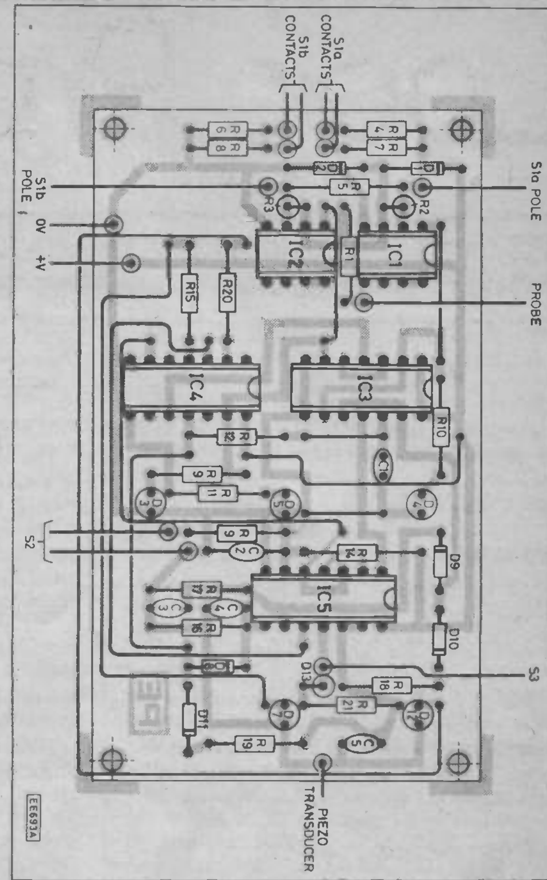
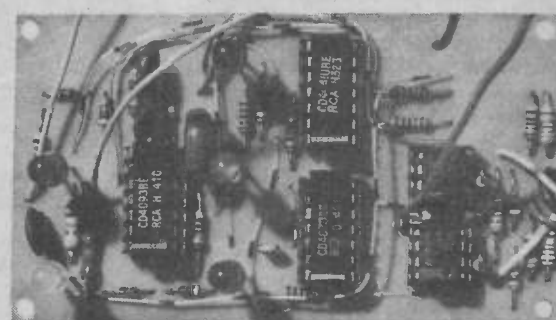


Fig. 2. P.c.b. design, component layout and wiring diagram of the Logic Probe



CONSTRUCTION

The prototype for this project was built to fit into a small case measuring 110 × 75 × 35mm. All the l.e.d.s, switches and probe sockets can be neatly mounted on the front of the case.

Construction starts with the p.c.b., shown in Fig. 2. The smaller components such as the resistors and capacitors should be mounted first, leaving plenty of working space for the larger components. These are followed by the i.c. sockets, l.e.d.s and interconnecting wires. The p.c.b. is quite compact, so care must be taken to avoid solder splashes and bad joints.

Once the board has been carefully examined for good workmanship, the interconnections to the switches and sockets may be made, then after a final check, the i.c.s can be inserted. It would be wise at this point, to connect up and test, before finally mounting the board in the case.

TESTING

There should be little problem testing the logic probe, and providing care has been taken during assembly, it should work first time. Connect the supply leads to a suitable logic supply and make sure that the level (TTL or CMOS) switch is set to the correct type. Touching the probe onto a high level should cause the high indicator to glow, and a similar result should be apparent for a low test. To test for correct pulse and change indications, the probe may be very quickly touched onto a high level and then a low level. When the probe is not connected, the float l.e.d. should light. ★

BBC Micro Forum...

David Whitfield MA MSc CEng MIEE

THE *BBC Micro's* sideways ROM facility is a much vaunted and extremely useful feature of the machine. This month we take the lid off the sideways ROM system, and look at how the ROMs are organised and controlled within the micro.

SIDEWAYS ROMS

The idea of using ROMs for storing software is now well established in all areas of computing and control applications. However, and as you might well have guessed from previous encounters, the structure of the bytes inside a sideways ROMs in the *BBC Micro* is a little more complex than simply starting the code in the first available byte, and continuing from there. Before looking at this structure, however, it is worth reviewing the overall concept of the sideways ROM system.

Essentially the sideways ROM system in the *BBC Micro* is an ingenious method of overcoming the address range limitations of the 6502, but without resorting to loading programs from tape or disc. Since it has become the norm for a home computer to be ready to run BASIC immediately after switch on, this really requires the language to be provided in ROM. The *BBC Micro* has an addressing range of only 65536 (64K) memory locations. The BASIC language ROM uses a quarter of this address range on its own, and this does not leave much spare for other uses. What is done, therefore, is to provide a means of switching out the Basic ROM when not required, and switching in another language. This other language may be a 'real' language (e.g. Forth, BCPL), or an application such as a word processor. The hardware and OS 1.20 software in the micro allow up to sixteen such ROMs to be used (with a suitable ROM expansion card).

The memory map for the *BBC Micro* is shown in Fig. 1. From this we can see that the sideways ROMs occupy memory addresses 8000 to BFFF, i.e. 16K of address space. In practice, sideways ROMs are usually either 8K or 16K ePROMs (erasible by ultra-violet light). The actual ROM selected at any time is determined by a hardware register located at FE30. However, this is a write-only register, so the MOS keeps its own record of the currently selected ROM in RAM location 00F4 (for OS 1.20). Issuing the following command from the keyboard while BASIC is active should therefore indicate the socket occupied by the BASIC ROM:

PRINT "Current ROM = ";?&F4

When looking at the result, it is worth remembering that the four sockets on the standard machine are numbered 12 to 15. The OS maintains the contents of location 00F4 so that it always reflects the setting of the hardware latch. Changing the currently selected ROM via the various OS calls provided will ensure that the system continues to operate correctly. It is *not* advisable, however, to manipulate the hardware select register directly from BASIC, since this may crash the machine by de-selecting BASIC.

FINDING BASIC

The MOS treats BASIC as a special case of a sideways ROM. As we shall see later, BASIC is recognised by being a language ROM without a service entry (all will be explained!). The MOS provides, among other facilities, an OSBYTE call (187) to allow the current location of the BASIC ROM to be determined. This call returns the socket number in the X register; if BASIC is absent, the value will be FF. Thus, if we run the program in Listing 1, the result should be the same as obtained earlier.

This OSBYTE call is very useful for diagnostic programs which mix BASIC and assembler. It allows us, for example, to write programs which have machine code sections for analysing ROMs, safe in the knowledge that we can always return to BASIC at the end. The control, set up and display sections can thus be written in BASIC, leaving the data collections to machine code procedures.

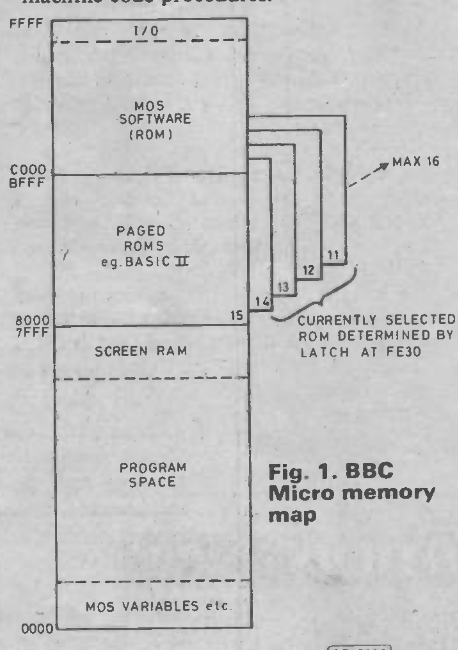


Fig. 1. BBC Micro memory map

ROM STRUCTURE

The ROMs in the *BBC Micro* are required to have a defined structure in order to operate correctly in the machine. This structure affects the use of the first few bytes in the ROM, i.e. the twenty or so bytes starting at address 8000. The format required of a sideways ROM is summarised in Table 1. This table identifies the offset in bytes from the start of the ROM. 8000 must thus be added to get the effective address when the ROM is located within the machine. Thus, for example, the binary version number will be found in location 8000 + 8. Table 1 is far from self explanatory, so a few words are probably appropriate on each of the items in the table.

Any program which is written such that it is independent of another language should be written as a language. The first three bytes in the ROM contain an instruction of the form JMP nnnn, where nnnn is the jump address. Thus the first byte is always 4C (the JMP opcode). If there is no language entry, these bytes should all contain 00.

All paged ROMs must have a service entry, with the exception of BASIC (which is how it is detected!). This is the entry point to the ROM which must be capable of handling all of the calls sent to it by the MOS. There are in all 21 possible service call codes, and the call ID is passed in the accumulator. For example, call type 9 is the *HELP call, and the ROM must respond at once. Service call 4 is used for allowing "new" *commands to be provided by the ROM. When a service call is made it is passed to each ROM in turn (highest priority first) until one is found which recognises the call. This ROM will then set the call type to 0 to indicate that the call has been serviced. The three bytes in the header are in the form of a JMP mmmm, where mmmm is the start of the ROM's service call processing routine. BASIC contains 00 in each of these bytes.

The ROM type byte identifies the nature of the ROM. In the main, this byte takes only one of three values: &C2 indicates a ROM with language and service entry points, e.g. View, Wordwise; &82 indicates a ROM with only a service entry, e.g. the Acorn DFS; while Basic has a type number of &60.

The copyright offset identifies the number of bytes from the start of the ROM to the 00 byte immediately preceding the copyright string's opening bracket. Thus 8000 plus the contents of the offset byte gives the address of the null byte. The format of this string is vitally important, and must start with a 00 byte, and then "(C)", since this is what the MOS checks for in detecting the presence of a ROM during initialisation.

The binary version number is a single byte provided solely for the programmer, and it is never used or read by the MOS. The version string is optional, and is not output by the MOS, although it can be output by the programmer during the processing of *HELP.

The title string is output by the MOS when the ROM is initiated if it is a language. Thus typing *BASIC will cause the title string to be printed. The ASCII string is terminated by a 00 byte. This string is also usually the one printed during the processing of *HELP, followed by the version string.

The final item in the header is the tube relocation address. This four-byte value gives the address in the second processor's memory to which the contents of the ROM will be copied. A tube relocaion address is expected by the MOS if bit 5 of the ROM type is set. The ROM must, however, be written with this relocation in mind if second processor operation is required, since no address conversion in the code will occur.

```
Addr        Bytes                     ASCII

8000  4C 96 80 4C 30 80 C2 16  L..LO...
8008  10 57 4F 52 44 57 49 53  .WORDWIS
8010  45 00 31 2E 32 30 00 28  E.1.20.(
8018  43 29 31 39 38 34 20 43  C)1984 C
8020  4F 4D 50 55 54 45 52 20  OMPUTER
8028  43 4F 4E 43 45 50 54 53  CONCEPTS
8030  08 48 C9 04 F0 07 C9 09  .H......
8038  D0 1E 4C EA 81 98 48 8A  ..L...H.
8040  48 A2 00 B1 F2 29 DF DD  H....)..
8048  09 80 D0 3E C8 E8 E0 08  ...>....
8050  90 F1 B0 3A 68 AA 68 A8  ...:h.h.
8058  68 28 60 68 AA 68 A8 68  h(£h.h.h
8060  A9 00 28 60 A9 7B 85 51  ..(£.{.Q
```

Fig. 2. ROM header example

```
 10 REM Basic ROM Socket Number
 20 REM ----------------------
 30 REM
 40 OSBYTE=&FFF4
 50 Temp%=@%
 60 DIM P% 10
 70 [OPT 0
 80 .basic: LDA #187: LDY #&FF
 90 LDX #0: JSR OSBYTE: RTS:]
100 PRINT "Basic ROM in socket ";
110 S=(USR(basic)AND&FF00)DIV256
120 @%=&202: PRINT S: @%=Temp%
```

Listing 1 BASIC ROM position

Offet	Contents
0	Language entry point
3	Service entry point
6	ROM type
7	Copyright offset pointer
8	Binary version number
9	ROM title string
	&00
	Version string
	&00
	"(C)" + Copyright string
	&00
	Tube relocation address
	ROM software

Table 1. Sideways ROM format

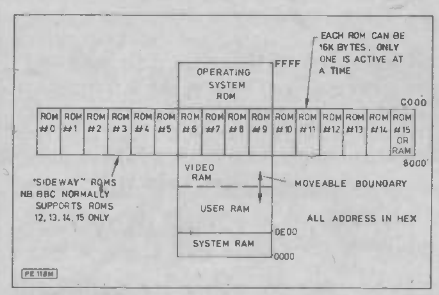


Fig. 3. Another way to view the BBC Micro memory map

INSPECTING ROMS

The description above is a little heavy going to say the least! In truth it is only possible to give a brief flavour of the subject to get you interested in what really is a fascinating area of the *BBC Micro*. A fuller description of the sideways ROM system will be found in the following books (two of which have been reviewed in earlier columns):

Useful Book Reminder

The BBC Micro ROM Book, by *Bruce Smith, Collins*, ISBN 0-00-383075. A very readable step-by-step guide to the working of ROMs, and writing software for them.

The Advanced User Guide, *Bray, Dickens and Holmes*, Cambridge Microcomputer Centre, ISBN 0 946827 00 1. A very complete guide in Chapter 15, but heavy going. Reading one of the other two books first will avoid mental indigestion.

BBC Micro ROM Paging System, *Watford Electronics*. A good introduction which is also useful as a summary in conjunction with either of the other two books.

To bring the description of sideways ROM structure to life, one of the best ways is undoubtedly to look inside a ROM to see how it works. An example of the header of a ROM is shown in Fig. 2.

Finally, it is worth knowing that the MOS provides us with a way to read a byte from a selected ROM. If the routine OSRDRM is CALLed at FFB9 with the ROM number in the Y register, the address in the ROM in locations 00F6 and 00F7, the value in the ROM byte indicated will be returned in the A register.

Microelectronics Education Programme

Part 2 Graham Bevis & Michael Page

In the January issue of *Practical Electronics* we gave an outline of the nature of the activities of MEP (Microelectronics Education Programme) and some more general detail of the thrust of the work of the Electronics and Control Technology (ECT) domain.

The reasoning behind many of the ECT initiatives is that microtechnology is increasingly pervasive in its influence on the world of work, leisure, education, the daily organisation of our individual lives and the way in which society is organised and controlled. Therefore, in a democratic society, all citizens should be well enough educated about the nature and capabilities of this new technology in order to be able to intelligently influence its adoption, application and development.

This article describes in some detail the nature of two separate but integrated resources which are now being used in an increasing number of schools and colleges. They have been designed to enable a process in which all young citizens at school become well enough educated about the nature and capabilities of the new technology.

The two modules are titled Microelectronics For All (MFA) and Control Pathways. The term Microelectronics For all is largely self-explanatory and the work done by the pupils in MFA provides an introduction to programmable control systems. Control Pathways carries on the development of these ideas and associated concepts to a degree of sophistication which is appropriate for the pupils and level of study concerned. For some pupils this might well involve the use of feedback principles in a systems design and associated program. Taken together these two resources provide experiences for pupils which put them well on road to having a comprehensive appreciation of IT Systems and their application.

Fig. 1. How microelectronics technology affects every aspect of our lives

EXPONENTIAL TECHNOLOGY

Human Activity	Was	Is Now
Timekeeping	Sundial	Digital Systems
Entertainment	Stones Percussion	Video Chess Synthesisers
Washing	Stones/Rivers	Programmed Washing Machine
Cooking	Charcoal	Microwave
Communications	Signal Fires Towncrier	Satellite Links Ceefax, Oracle, Prestel, System X
Calculation	Tally Sticks Napier's bones	Microcomputer
Medicine	Thermometers	ECG—Scanners
Transport	Walking	Space
Warfare	Tooth & Claw	Computerised overkill
Education	Mother's Knee	Computer Assisted Learning Databases
Weather Forecasting	Folk Lore	Satellites & Computers
Information Storage	Cave Walls	Microfilm—Video Disk Digital Graphics
Farming	Hand & Hoe	Computerised Milking Parlour & Digital Tractors

THE BACKGROUND TO THE MFA EXPERIENCE

Microtechnology affects every aspect of our lives and Fig. 1 illustrates the extent of this range. Three particularly significant points emerge: the breadth of the application of microtechnology is indeed pervasive in its effect on human existence and activity; the application and effect of microtechnology has been rapid and profound and indicates potential for further application vastly exceeding that so far seen; while the range of microtechnology applications and uses are wide there is a set of common principles and techniques underlying each application.

In general all systems utilising microtechnology may be described in terms of the classical system model (Fig. 2). In fact, this model applies equally well to any system having a controlled output and will be familiar to other students of systems behaviour and processes, e.g. biologists, members of the medical professions, sociologists, etc. Clearly, it would be conceptually quite difficult for most young people to understand all the implications of this model, and the relationship and generality of all the fundamental processes which it embodies. But the MEP/MFA experience sets out to enable pupils to explore practically many of the fundamental processes and techniques used by microelectronic systems and, as a result, to begin to see how they fit together into the overall systems framework.

Some important key words and associated processes to be explored are:

SENSE What is electronic information? What can it be used for? How is electronic information sourced? How is the information put into a system and used to control the system to enable it to perform a useful task?

DECIDE What are the processes through which the sensed information and the required system response produce the signals to implement the 'useful tasks' performed by the system?

ACTION What are the devices and associated processes which produce the output or function of the system control?

Among other key words and associated concepts incorporated in the MFA experience are: count, remember, sequence, address, binary, digital, pattern, analogue. The words, and their associated concepts and techniques, apply universally to microtechnology systems. The development and appreciation of these terms is built into the pupils' learning process through the use of the MFA modular course.

It is perhaps worth noting here, as an aside, that one effect on pupils of the MFA experience, and noticed generally by teachers, is the significant effect on pupils' development, vocabulary and use of language. The work scheme requires pupils to work in groups to work out problems which they find meaningful, challenging and satisfying to solve. This approach directly requires pupils to formulate concepts and to be able to express them. What better way to develop a capability in language and communication that the current education process is reputed to be less than effective in? Furthermore, many pupils—previously not motivated by traditional study—find a sense of purpose which creates a willingness to learn, with some results which are frequently surprising to their teachers.

GENERAL DESIGN CONSIDERATIONS FOR MFA HARDWARE

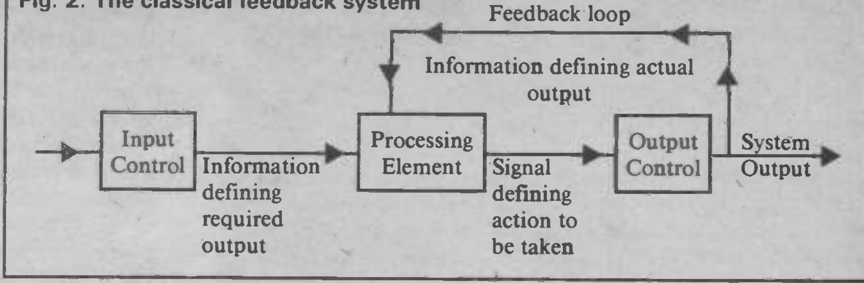


Fig. 2. The classical feedback system

The work in which the pupils engage is aimed at developing an understanding of the processes of the technology and their use and is most definitely not a study of the technology itself. (That could follow for those pupils for whom it is appropriate). Besides being the appropriate approach from an educational point of view it also means that, given suitably designed hardware, it is not necessary for the teacher responsible for delivering MFA to be a technologist or specialist in any way. Clearly, this is essential for a scheme of work which is to be implemented in every secondary school and where specialists, whether they be CDT (Craft, Design and Technology) teachers or scientists, are currently in desperately short supply. The MFA equipment also needed to be designed so that

1. It did not require specialist laboratory facilities and was readily transportable (a class set of MFA for thirty pupils fits into two moderately sized cases and that includes the power system—batteries).
2. Whilst being flexible in terms of its facilities and their use (MFA is designed to be a problem solving exercise) it needed to be constrained in layout and capability, to make it easy for pupils of all abilities to use. This criterion is also necessary so that the teacher overseeing pupil work groups can see and interpret what they have done and to spot mistakes and misconceptions in the pupils' solutions to particular problems.
3. The board layout needed to reinforce the fundamental concept of the systems structure in terms of its functional operation.
4. The board system needed to be modular so that the first experience of the pupils was with a subset of the facilities of the system. Modules are added to increase the capability of the system and introduce more concepts and techniques stage by stage.

We stated earlier that the classical system structure, and associated operations, is too complex to appreciate in one set of conceptual steps. In fact how many engineers/technicians could give a lucid, clear, coherent explanation of its form and process. However, appreciating the basic concept of the structure and its associated process is a key to being able to interpret the nature and capability of microtechnology in its many guises and applications. MFA begins the development of this appreciation with the presentation of a simplified model of the system.

The simplified representation of the classical model conveyed by the MFA experience and defining the layout of the hardware modules and the way in which they are used is as shown in Fig. 3.

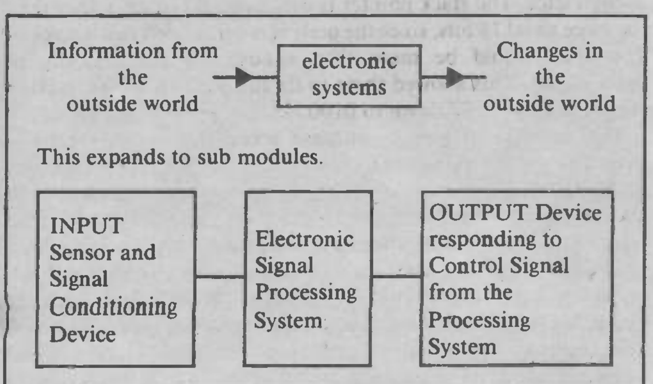


Fig. 3. Simplified representation of the classical model

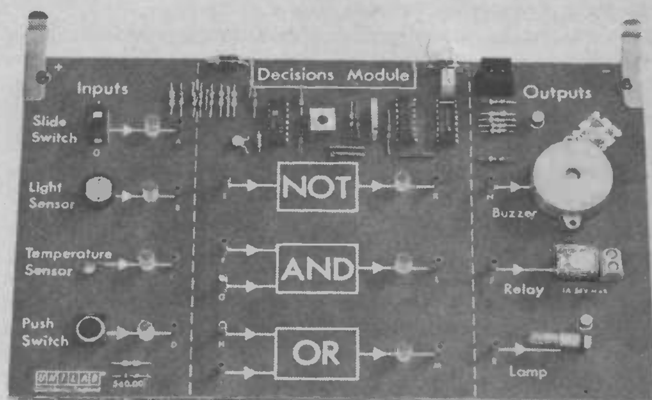
The basic MFA modules, which are on boards of physical size approx 24 × 14cm, are laid out according to this model and can be connected together in combinations.

THE FIRST MFA EXPERIENCE—DECISIONS

Pupils begin with the decisions module (photo 1) which establishes the linked concepts of sense, decide and act.

Remember the MFA scheme was devised for 11–14 year old pupils. Some will never have wired anything for themselves before and so they begin with very simple exercises designed to familiarise them with the system and to start establishing the basic concepts and techniques which they will subsequently use in solving some problems.

Photo. 1. Decisions module



On the left hand (input) side of the module are four input devices. A simple slide switch and a touch switch, both human signal devices; one to provide a permanent signal on or off input and the other to provide an intermittent signal which embodies a control function. The other two devices are also digital in operation and provide signals to indicate light and temperature levels.

A feature to bear in mind is that signal paths are indicated on the boards (by lines) and signals can be connected, inserted or intercepted via 2mm sockets.

On the right hand (output) side of the board are three devices which can be controlled by digital electronic signals. These are a buzzer, a light bulb and a relay. (The relay's significance becomes particularly apparent in later exercises with additional MFA modules when they are used in the control of devices such as motors, enabling vehicles to be moved and steered.)

A first exploration of the decisions module leads the pupil to find that light may be used to turn the buzzer on or off when it becomes dark. The answer to the question as to how the action is reversed is revealed by the use of the NOT gate.

Pupils then explore the use of the humble AND Gate as a multiple input (two in this case) information processing device and are given the following problem:

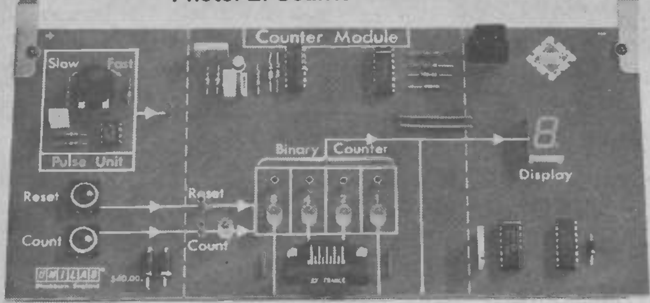
> Our Government has not realised it as yet, but if we all went to bed earlier, perhaps when it gets dark, and got up earlier when it is light, we could save a lot of energy. How could we make a clever doorbell which only sounds during the day and not at night?

The pupils then have to find out how to use the gates available on the decisions module to produce a system to solve this problem.

Please note that this is not the traditional academic introduction to logic gates with truth tables and Boolean algebra. Such an approach serves little purpose here but may be introduced at a later stage to those pupils whose interest has been stimulated by MFA to go onto further study and who have rather more advanced problems to solve.

So the pupils have explored electronics sub-systems in the role of 'sense', 'decide' and 'act' and have established these separate concepts as well as the idea of a system as a whole. Now we need to introduce the next stage of system capability, namely that of numeracy and being able to count and keep track of events.

Photo. 2. Counter module



THE SECOND MFA EXPERIENCE—COUNTING

The counter module (photo 2), which is used to illustrate binary counting and which may be simply slotted onto the decisions module, consists of a touch switch and pulse unit for input, a resettable 4-bit binary display with external connectors, and an analogue (hexadecimal) display.

Pupils are able to explore a number of concepts and techniques which they will again be able to use in problem solving work. They count how many times their 'clever' door bell was pushed while they were asleep and undisturbed. They observe binary patterns displayed and quickly perceive that these can as equally validly represent numbers as the equivalent analogue display with which they are familiar. The comparisons serve to emphasise the distinction between digital processes and representation and their analogue world.

This is an important concept when it comes to appreciate the idea of the human/technology interface and the fact that we have yet so far to go in using the capability of microtechnology to improve this interface.

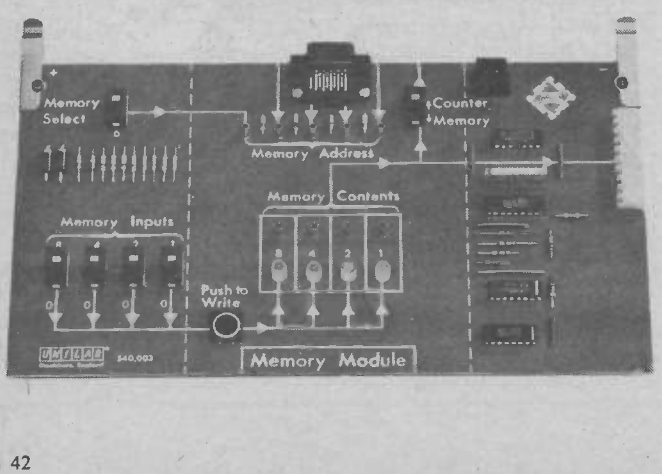
The counter system has a reset facility so pupils can begin to explore problems which help them towards an appreciation of the use of microtechnology in industry. They can count how many times a light beam (sensed by the light sensor) has been broken. This might be equivalent to the counting of objects on a conveyor belt and the pupils can arrange for a relay to be activated after a given number of counts. They readily interpret that this would be useful in a packaging process. Some support materials devised for the MFA work, such as the series of three BBC schools' television programmes, are designed to link the practical classroom experience of MFA to applications in the world outside.

The counter board also incorporates a variable frequency pulse unit, the use of which the pupils explore. They can use this as an elementary clock and they will also use it to control the output of sequences of binary patterns which can be stored in the memory module. So MFA has demonstrated 'sense', 'decide', 'act' and 'count' and now we need the ability to memorise and repeat and to implement a sequenced process.

THE THIRD MFA EXPERIENCE—MEMORY

The memory module (photo 3) is able to store two sets of 16 four-bit binary patterns. The location of each stored pattern is defined by a four-bit address which is provided from the output of the counter module by a direct link between the two modules. The two sets of memory space are separately enabled, by the memory select switch or its input socket.

Photo. 3. Memory module



The pupils explore the concepts of 'store', 'address' and of binary patterns representing information other than simple numbers by using binary patterns to control devices. Note the format of all of the modules with information coming in at the left hand side, processing in the middle and the resulting signals available for control purposes on the right hand side of the board.

One device controlled by these signals is a music module. This simply plugs onto the four-bit bus at the right hand side of the memory module and responds differently, in terms of note, to each of the 16 possible binary patterns. The best note corresponds to 0000 (i.e. silence is golden) after which the note increases in pitch by one semitone for each one unit increase in the binary pattern.

MORE COMPLEX PROBLEMS

The pupils now have lots of concepts and practical techniques available for use. One problem they are given is to arrange in the memory a sequence of notes to play the tune *Early One Morning.* They are then asked how they can couple this to their light sensor to arrange to wake them up as soon as light dawns, which is when their 'clever' doorbell is reactivated.

Exercises with the music module enable the pupils to see how a digital pattern may be used to control an analogue quantity. Another exercise in control is to see how simple on/off actions with a multi-bit pattern can be sophisticated in effect. The MFA system has a four-bit pattern storage and delivery capability. Each bit can be used to control a single device in an on/off mode. With two relays and two electric motors assembled into a 'buggy', we can make the buggy go forwards or backwards, turn right or left and spin, etc. The pupils then explore how they can cause the buggy to move through a maze pattern, according to a control sequence stored in the memory system.

They soon find that such open loop control, which has no sense or guidance, is of limited value. The ground is thus established to develop the idea of 'feedback' and the role that it plays in all our lives, and the technological systems which we develop for our use.

A FURTHER MFA EXPERIENCE—THE COMPUTER INTERFACE

So far the pupils have done their binary coding with simple switch controlled devices. The whole MFA system is now replaced by a keyboard programmable system, with its own more easily interpreted VDU display.

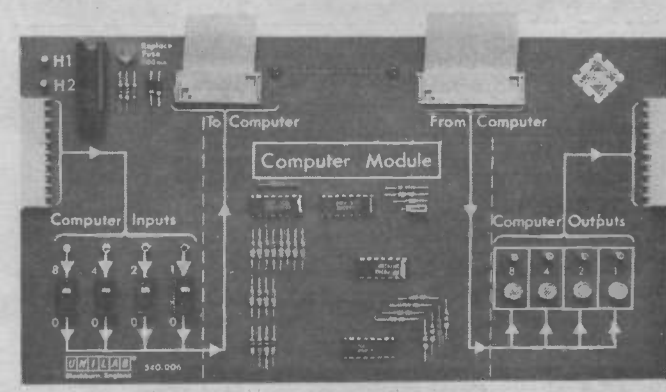


Photo. 4. Computer module

Following work with the music and movement modules on the basic MFA system, a computer interface (photo 4) is used to link the concepts and ideas that the pupils have developed to the all familiar microcomputer. They use the microcomputer with its interface to control the buggy and the music module to perform exactly similar tasks to the MFA system. They see it to be more cumbersome and expensive, but simply and conveniently programmable and vastly more capable and versatile.

Interfaces and associated software for MFA have been developed for BBC 'B', Research Machines '480z' and Sinclair 'Spectrum' microcomputers.

But what of the more sophisticated tasks of the real world. What sort of electronic systems are there in our washing machine or car? How do we achieve more effective control than that provided by the controlled sequence, open loop, system? This is where the pupils move on to Control Pathways but, before we describe this, there are one or two more issues to consider about the purpose of MFA and its materials.

THE PUPIL WORKSCHEME FOR MFA

MFA is designed for the mainstream 11–14 age range. That means the work has to start from a basic approach and be extended according to pupils' abilities, needs, aspirations and demands. An individualised practical activity like that of learning about microelectronics systems can easily meet these requirements.

All the pupils go through a series of core exercises defined on workcards (photos. 5a and 5b) which use as much illustration as possible to cut down the degree of written detail. The core exercises then lead gently into simple problems which all but the least able pupils can solve. The problems then increase gradually in demand.

In order that all the pupils may complete the full course, the workscheme is modular in an exactly parallel manner to the hard-ware. After a given time working on the decisions activities, all the pupils move onto the counter module. Clearly, some will have gone a limited way with the decisions problems while others will have completed all the problems and even made up some for themselves.

It is very pleasing to find clever pupils putting together more than one set of the modules to solve more complex problems. For example, if you want a system which can both count and incorporate a delay routine which is activated according to the system circumstances, then you need two counter modules and perhaps even two memory modules. The amount of pupil to pupil learning which goes on in this type of work is highly significant. Who says the teacher should be the only (the major?) input to the learning process?

The whole scheme of work is defined and supported through the pupil workcards and a teacher's guide. MEP has been providing 2 day MFA inset courses for teachers. With the termination of MEP at the end of March it will be up to the LEAs to provide their own inset. Unilab, the manufacturers of MFA, are currently producing and delivering about 35 class sets of MFA per week. Even that amounts to a lot of teacher training needed. Given that there are 5500 secondary schools in the UK, there is a very long way to go before every pupil gains this experience.

We in MEP most certainly believe that all pupils should be educated about the technology before they leave school. To catch the pupils already past the age of 14, MEP has developed material to enable MFA to be used in the context of a sixth form general studies course. The associated course materials are termed *IT in Society* and these emphasise the development of technology awareness among older pupils, most of whom will be intellectually very capable of translating a practical experience of MFA into an appreciation of the wider implications of microtechnology.

MFA/CONTROL PATHWAYS AND TECHNOLOGY AWARENESS

We have said that a prime objective of MFA and the subsequent work on more sophisticated aspects of control is intended to provide an awareness of technology in general, and microtechnology in particular. So what is the technology for and why do we go on developing its capability at an ever increasing pace?

Technology development has moved through certain very clear periods in our recent history. The state of the technology at each advance can be summed up as follows:

"Technology involves a process of problem solving which, by the maximisation of human skill at the design stage, aims to minimise human involvement in the operation of the solution.

"Stage One Technology substituted machines for human manual skills and provided an increased capability in terms of precision, power and speed.

"Stage Two Technology additionally substitutes silicon chip systems for human monitoring and decision making skills.

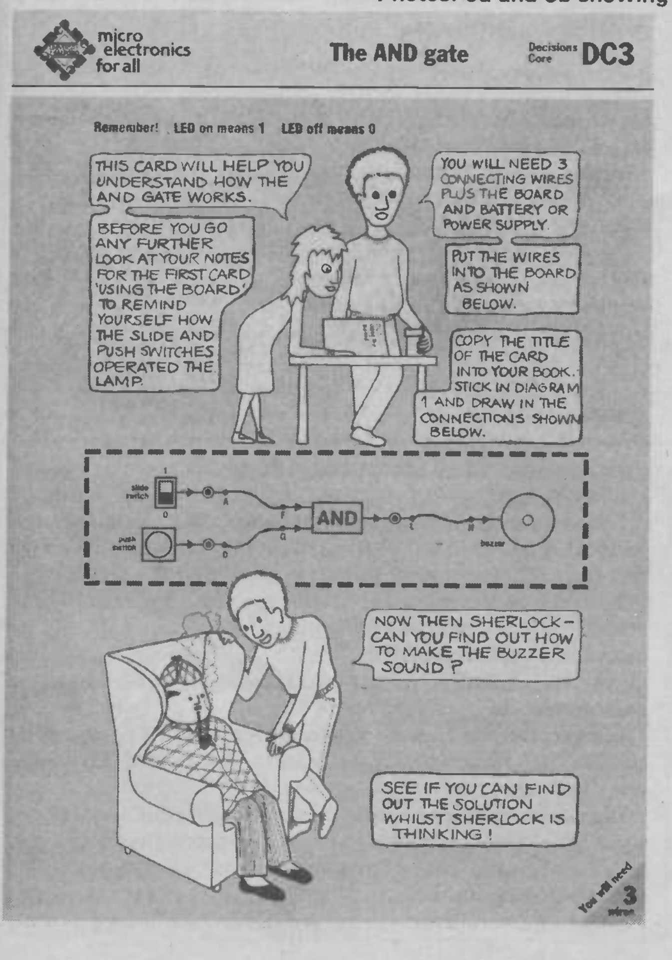
"Stage Three Technology might aim to replace the human factors in the design process. (This has not yet been achieved and many would doubt that it is possible at all)."

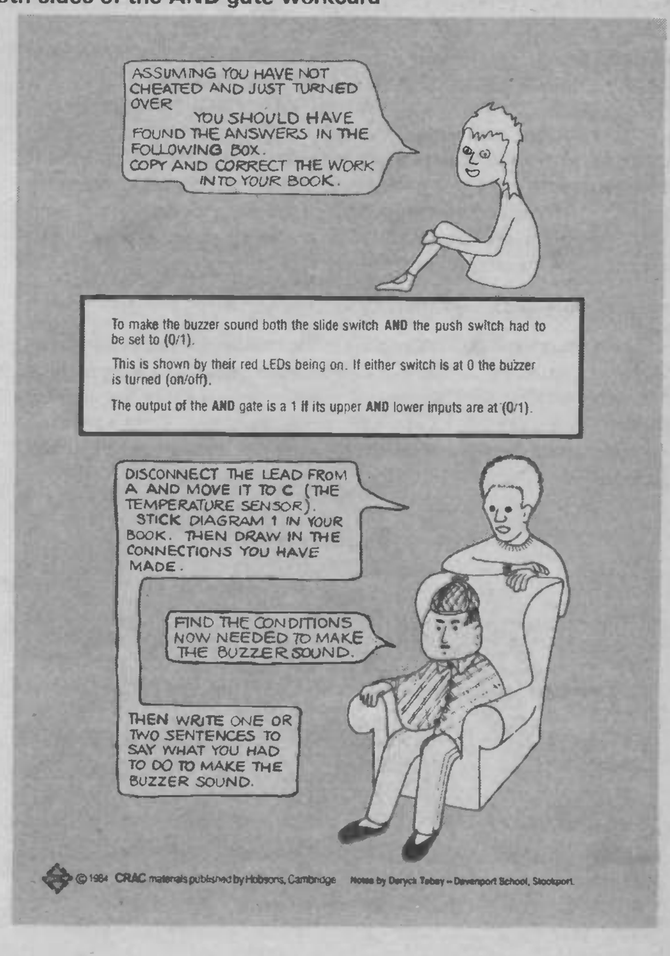
What place Luddism, then or now? Technology is about minimising human involvement in tasks which are definable and most naturally those which are repetitive. No-one in their right mind denies the advantages of utilising technology systems in place of people in 'undesirable' environments.

The significant and enormous change which is now so radically and rapidly altering the order of things is due to the fact that microtechnology can now do things like sense and decide. A whole new range of tasks are within the new capability of technology which were previously reserved for human enactment.

One further factor which has so significantly contributed to the

Photos. 5a and 5b showing both sides of the AND gate workcard





effectiveness of microtechnology is that it enables the many processes previously used in technology systems to be integrated into one common enabling technological process. We have been able to integrate gathering, storing, processing and communicating information into one single technological implementation. The full effect of this on the process of control technology, which is now assisting humans to step down from so many employment roles, has really yet to be realised. However, it is not that we are simply taking away traditional applications for human labour but that we are also creating the potential to be able to do so many things which could not have been done before.

Significantly, microtechnology has also enabled itself. We use the last generation of microchips to build systems which are used to help design, manufacture and test the next generation. So chips themselves have begotten their own evolution! But let us pause for a minute and consider. Are there limitations to the further development of this technology now or likely to appear in the future?

We could use a microtechnology system to control a machine to cut beautiful glass goblets to an exact precision over and over again. But who/what does the initial design? Are we really very near the position of jumping in our motor car and saying "Home, James" and waiting for our mini, micro-controlled, car to respond? It is an appreciation of factors like this which are so important to the education of our pupils and, indeed, equally important to the adult population.

Society is going to be faced with many decisions to make about technology and its implementation. We should all take part in that decision process from the standpoint of intelligent understanding. Never before has any section of the human race been faced with such influences for major change in the order of things. One thing is certain, no matter how much we would wish to turn the clock back to a period of slower change, which is more governable and comfortable, the reality is that the change will become ever faster and faster.

The underlying philosophy behind MFA and its extension in *Control Pathways* is to help prepare young people for the realities of that situation as understanding, contributing adults-to-be. The ambition of this aim is clearly considerable, even presumptuous. It sets huge demands on the teachers required to implement it. The teachers will require a great deal of help to convey a full meaningful experience of the form outlined above in the context of a classroom. Axiomatically this ultimate objective will be achieved only through the pupils developing their knowledge and understanding through many relevant experiences, of which MFA will be just a part.

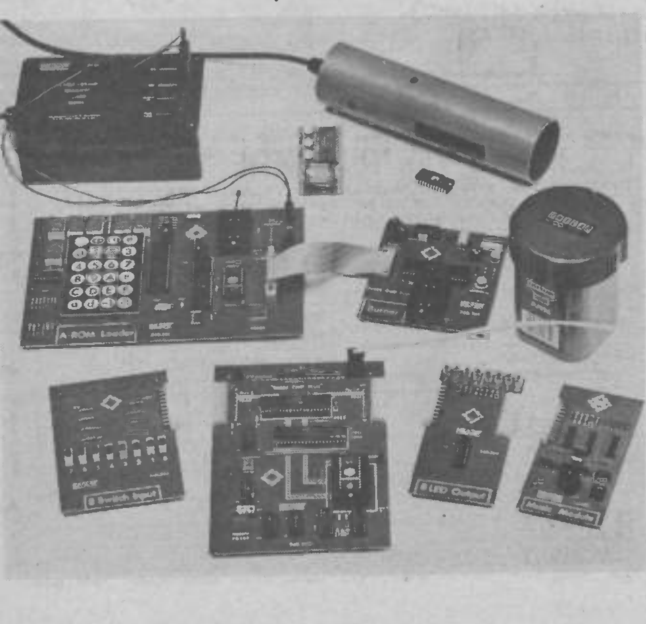
CONTROL PATHWAYS AND MEP 3 CHIP PLUS SYSTEM

Control Pathways is a range of resources designed to support a practical-based introduction to one of the most important applications of microprocessors—as the heart of programmable control systems.

It is very much a national MEP team effort, as was MFA. Even before MFA had been conceived, or developed, MEP had supported the development of a minimal microprocessor control system, called '3 Chip'. Its purpose was to enable practical work of a problem solving nature in schools, which used the powerful capability of a microprocessor system. An equally important purpose was to explode the myth, still current, that microelectronics was all about computers which have a VDU and keyboard. We wished to establish an understanding of the nature of the dedicated control systems use of programmable microelectronics which consumes the vast majority of microprocessor chips.

The '3 Chip' system was just that, the three essential 'controller' chips of processor, memory and in/out operation. For various reasons, and not all of them sensible or logical, '3 Chip' did not see the light of day as a product in its early designed form. With hindsight that has been fortunate because MEP has been able to develop what is now '3 Chip Plus' as a natural companion and extension to work with MFA. '3 Chip Plus' has been configured so that its connection system enables it to operate with the same set of devices as the MFA computer module or memory module.

The '3 Chip Plus' hardware



The '3 Chip Plus' system consists of

★ The 'controller' board—the heart of the system—based on a 6502 microprocessor with a similar memory map and ports as the input/output areas of a BBC Microcomputer

★ The 'program loader' board—with its own monitor program fitted. This board is used to develop new software at the machine code level

★ The 'program memory' board—battery-backed RAM (alterable memory) used to carry the program being developed

★ The 'burner' board—driven from the 'program loader' to transfer developed programs into EPROM or EEROM

★ A range of input and output boards—allows the 'controller' board to respond to a variety of inputs from light sensors, switches, etc, and to provide a variety of outputs for the control of motors, relays, etc. The existing MFA music and movement modules are also completely compatible with the '3 Chip Plus' system.

CONTROL PATHWAYS—ITS CONCEPT AND FORM

'3 Chip Plus' is just one microprocessor system for which the Control Pathways materials have been designed to be used. The pupils' materials are based on a range of input and output modules (original '3 Chip' modules) which can be used in a wide variety of control problem situations. The work is designed to use any one of a range of common microprocessor devices available in schools.

The Control Pathways support materials comprise a teacher's guide and a pupils' book, designed to convey the concepts of control and control systems, which is written as a general text. This is written to be used in an integrated way with a particular pupil assignments book for whichever microprocessor controller the school chooses to use.

Control Pathways provides a structured introduction to the concepts of control. The control of most systems (and not just electronic ones) embodies certain very fundamental principles; it is these that this learning material aims to address through the medium of programmable microelectronics. Each of the sections of the main pupil booklet introduces a new concept, with the most essential, and where possible the most straightforward, concepts met first. As far as possible, real-world examples are used and models of such control systems built and programmed.

Details of the conceptual route are as follows:

Section 1 deals with outputting control information— you can't do anything unless you can switch parts of the external system on and off.

Section 2 shows how to implement time delays. This makes possible the sequence, perhaps the most basic of all control programs. So far the pupil has turned fully on or fully off the control voltage on individual control lines from the controller. This enables a lamp or a motor to be switched on or off, a motor to be reversed or a control code to be output to the music module to sound a particular note.

Section 3 shows how the brightness of a lamp or the speed of the motor may be controlled. This requires a control code (which might represent a number on a scale from 0–7) to be output to an external black box that can control the voltage applied to the lamp accordingly. The concept of digital to analogue conversion has been introduced (and thus the concept of how a variable, or analogue, quantity may be controlled by a digital, or on/off, controller). Some control systems function purely as sequencers—the outputs are a function of time only—but most systems control outputs in response to changing input conditions.

Section 4 shows how to input information to the controller, and how to design the program so that the input states affect the control of the output. Almost all real-world control systems employ feedback. This means that information about (for example) the position of an arm is fed back to the input of the control system. The controller is then able to drive the arm more intelligently, basing its control decisions on where it knows the arm actually is. Without feedback, the controller must attempt to calculate or remember where the arm ought to be. The controller will not know if the arm moves more slowly than expected, hits an obstacle, or reaches the limit of its travel.

Section 5 builds on the principles of outputting and inputting and introduces this essential concept of feedback. At this stage the feedback is only two-state, or yes/no; feedback in a system controlling and monitoring analogue quantities is reserved for section 7. Section 3 allows pupils to see multi-level, or analogue, outputs.

Section 6 illustrates analogue inputs. It is often necessary for a control system to read in an analogue quantity, for example, a temperature, a light level, or the level of a liquid in a tank. The controller itself can only understand on/off, or digital information, so this time an analogue to digital converter is needed. The other important concept introduced in this section is that of processing information electronically.

Section 7 takes over the subject of feedback where section 5 left off. Pupils now develop control systems which sense analogue (multi-level) quantities and control outputs proportionally.

Section 8 presents a wide range of ideas on project possibilities.

As well as the gradation in difficulty through the sections, there is a gradation through any individual section. Each section contains a number of extension modules with a substantial design ingredient. Only the most able pupils will finish all the work in a section.

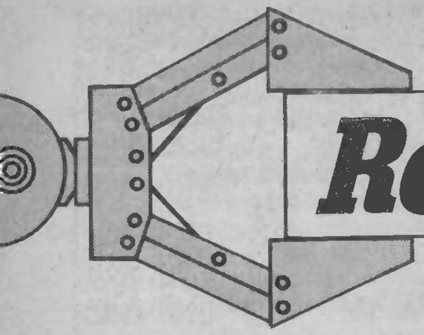
The article has mentioned the fact that all this work has been the result of team efforts. This includes both the individual project development teams and the many people who were employed by MEP as inset co-ordinators, all of whom made contributions to the design of the final system in concept, hardware design and materials support teams.

The teams responsible for MFA development comprised a number of teachers in the Greater Manchester and Lancashire area and was led by Dr John Martin who was an ECT inset co-ordinator at the beginning of the work and who became the Director of Salford Electronics Education Development Unit. The team responsible for the 3 Chip Plus development was led by Peter Nicholls, once again an ECT inset co-ordinator who became MEP regional director for the east Midlands.

We hope that, in this two part article, we have allayed some of the fears about whether electronics is on the school curriculum agenda. Of course, just because the material we have described is available doesn't mean that every school will be using it. Unfortunately, the pressure on centrally provided resources means that, unless other funding can be found, future developments are likely to be reduced.

This is particularly regrettable at a time when overseas interest in the approaches we have described is so high and the needs of industry for employees who understand the concepts is increasing. A Foundation has now been established to try to continue the work and industry and commerce are being approached for support. Let's hope that the Foundation will be able to continue the first-rate activities described above.

If you would like an information folder which contains full details of the MEP/ECT domain and its teacher-training materials, then send a large (C4) self-addressed envelope stamped with 45p-worth of stamps PLUS 50p in unattached stamps, to Mrs Beth Bevis, Ronsella, Lordswood, Highbridge, Eastleigh, Hants SO5 7HR. It would be helpful, if you are a teacher, to say in which LEA you teach.



Robotics Review

Nigel Clark

COCKROACHES provided the inspiration for a development project to build a new type of walking robot. They do not have a central nervous system or brain so cannot control their movements centrally, as do most creatures. Their legs work independently, moving one step in response to a stimulus. Obstacles are sensed by the inability to go through with a step.

"The idea came to me about ten years ago," said Arthur Collie, one of the four members of the team on the project. "When people think of robots they think of a lot of limbs working to achieve an end. I began thinking about it and like an engineer I began by breaking it down into pieces which could be worked upon. It was then that I picked on the analogy of the cockroach."

He carried the idea further by considering a six-legged device on which the legs operated independently and "sensed with its knees" like beetles do. Once a leg came into contact with an obstacle it would send a message back to a central controlling processor which could then build up a map of the area being covered.

. . . the analogy of the cockroach . . .

Ten years ago it was not feasible to have six independent legs because of the size and cost of the controllers. Microprocessors have changed that and with the help of grants from the **Royal Society**, the **Science and Engineering Research Council** and a little help from the armed forces unmanned vehicles programme he was able to take two years off from his job and set up a team at **Portsmouth Polytechnic** under the leadership of Dr John Billingsly of the Electronic and Electrical Engineering department.

Most of the development work is still in theory but it is hoped that in two years it will be possible to develop a relatively fast walking base on which other devices can be carried for a price of about £1,600.

Billingsly said that it would be unlike existing walking machines and have more in common with humans. Existing robots are stable throughout their movement. The Portsmouth plan is that while walking it should be dynamically stable but statically unstable.

Humans are permanently off balance while walking and although they are stable while moving if they come to a sudden halt they fall over. Existing robots are balanced at all times as they do not make a second movement until the first one has been completed.

What existing devices gain in steadiness they lose in speed and fluency of movement. "We do not want a walking robot so much as a cantering robot" said Billingsly.

At present, with work on the hardware only having started in July, the robot consists of only one leg. It has two joints at the hip and knee which can each move through an arc of a little more than 180 degrees. The limbs are controlled by two pneumatic cyclinders working in opposite directions so that movement is always achieved by a cylinder pulling rather than pushing.

Under the control of a BBC B the leg is pushing a small conveyor belt. Feedback is obtained from pressure sensors on the cylinders and angle sensors on the joints.

It is intended that the final project will have six legs, each with its separate single chip micro, obstacles being sensed by the pressure in the cyclinders and navigation being achieved with the help of a very simple giro.

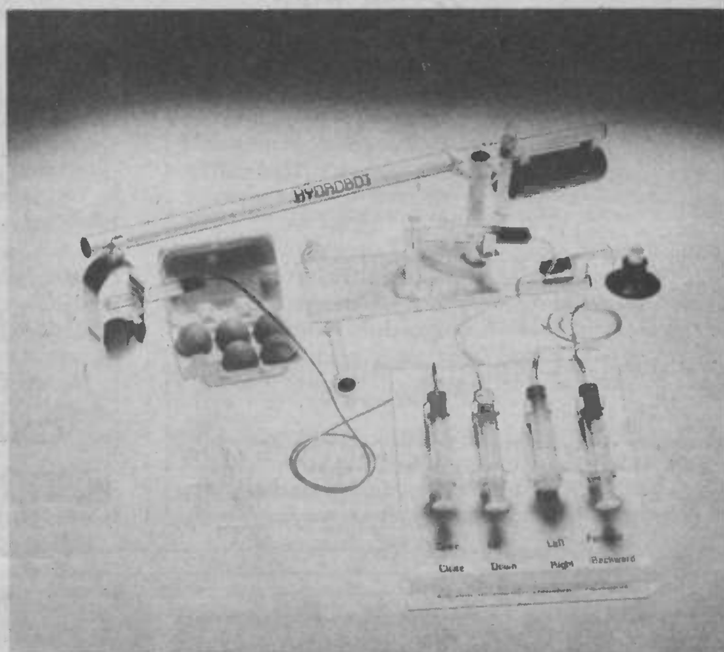
The whole machine will be controlled by an on-board micro. Collie said that software was being developed to allow it to learn how to walk rather than the knowledge being permanently built-in. That would give it the flexibility to adjust to different types of terrain, for example loose or rough ground, down a sewer or climbing a bridge.

. . . a cantering robot . . .

L.J. Electronics has developed an update to its large Atlas arm and has given it the imaginative name of Atlas II. There have not been any changes to the hardware but the software has been expanded to allow the machine to perform more complicated manoeuvres when being used with the work cell, which has recently been developed for the machine.

L.J. has provided an update kit which contains the new system on three Eproms, a test routines Eprom, editor keypad overlay and manual. As the Atlas was designed to be easy to take apart it should not be difficult to make the necessary changes for the upgrade.

As with Atlas I there are eight modes of operation but there has been a major improving of the editing function. It is now possible to carry out a number of new operations including inserting backlash compensation, ripple-through offset correction and the insertion and removal of delays.



The Hydrobot demonstration kit from Commotion. The arm is controlled by the four syringes

An on-board machine-code monitor allows Hex programs to be written and edited with a visual display of these operations. Any Atlas I program up to 2K can be converted to run on the II.

. . . controlled by four syringes . . .

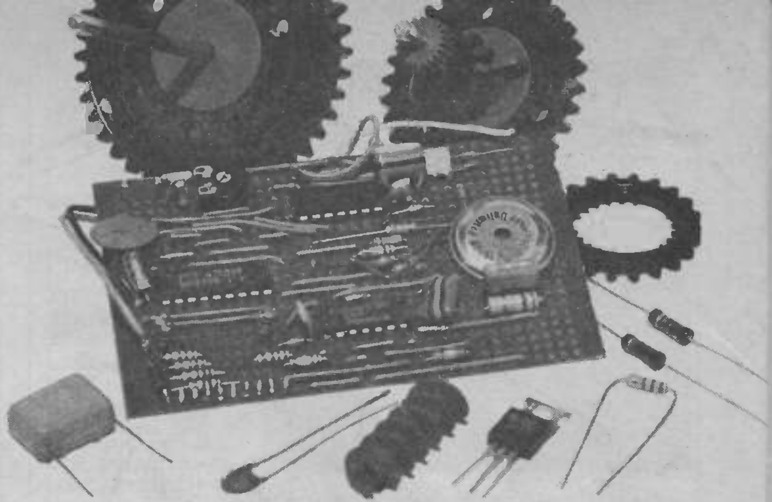
For anyone finding electronic control a little hard to grasp **Commotion** is selling an inexpensive little device called the Hydrobot. Designed by the London Innovation Centre it is powered by hydraulics and has three axes, at waist and shoulder and the complete arm can be moved backwards and forwards. There is also a gripper.

It is controlled by four syringes, one for each axis plus the gripper, which contain coloured fluid to show clearly and simply how the arm works.

Costing £20, Hydrobot comes in kit form with full instructions and projects notes and is said to take 20 minutes to build.

Another contender in the original names stakes is being developed by **Robot City Technology**. Hard on the heels of its low-cost Alfred robot arm comes the more robust version called Alfred II. It is at the prototype stage but is expected to sell for less than £1,000 and be strong enough to be used for light industrial purposes.

Details are limited at the moment but it is understood to be similar to Alfred, being a standard 5-axis arm with grippers. More details as they emerge.



Experimenting with ROBOTS

Sam Withey Part 6

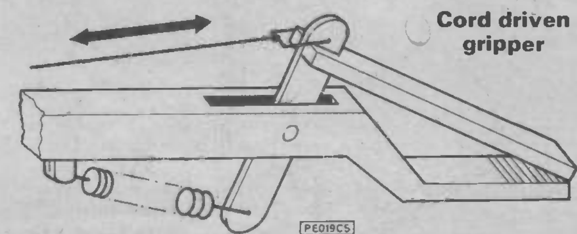
IN THIS the concluding part of Experimenting with Robots we look at testing the interface described last month and some typical methods of achieving movements in experimental robotics.

TESTING

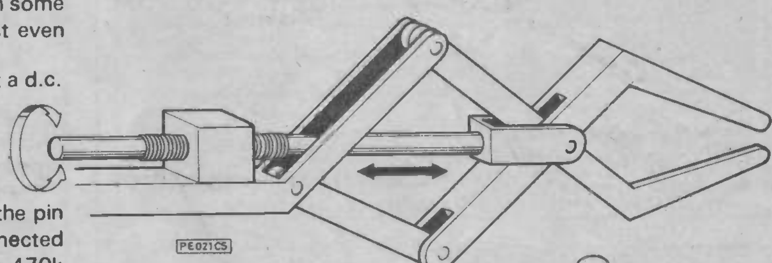
The motor driving transistors and the motors themselves require an external power supply, mainly selected to suit the motors requirements—between 5Vd.c. and 12Vd.c. Here, it may be required to use a resistor to drop the voltage down with some types of model motors, otherwise they run much too fast even with reduction gears.

After checking for dry joints and solder bridges, connect a d.c. motor and suitable supply. Next, connect a 5 volt supply between the bases of the transistor bridges at a pair of links. The motor connected to this bridge should run in one direction and reverse when changing over the leads. Next insert the opto isolators and apply a +5V supply to the pin normally connected to the computer +5V line. Whilst connected to the computer, the data lines are held high through the 470k resistors. The negative of the supply is applied, in turn, to the data bit 0 and 1 pins, just as the computer would place a logic '0' at the port. A similar result should ensue—the motor running first in one direction and then changing to the other direction. It should now be safe to connect up to the computer. Readers will probably have realised that due to the use of opto-isolators, the logic to drive the transistor bridges is reversed. This is not of importance and is taken care of, either in the programming, or by reversing the motor leads if they run in the opposite direction to that required.

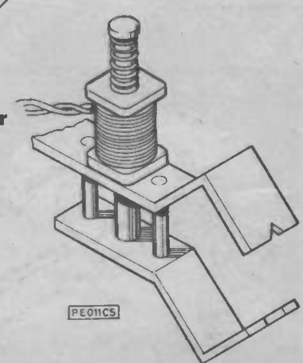
Whilst the circuit was under test using 12V *Scalextric* d.c. motors, considerable differences were found in the performance of individual motors. These motors are designed to run at much greater speeds than would be required for most computer control applications. To ensure compatibility, do not insert the resistors between the external supply and the bases of the bridge transistors (load resistors of opto-isolator transistors). Instead, tack 2 × 5k pots in their place and trim for the best balance of speed for forward and reverse directions. When a favourable value has been found choose resistors of the nearest preferred values and insert them in place of the pots. The author had a large number of *Scalextric* motors and found 3k3 to be the most suitable resistor value for the motors he chose. Also, this value proved quite suitable for driving *Sonzeboz* Type 1112 asynchronous motors as 32 step, bipolar stepper motors. Provision has been



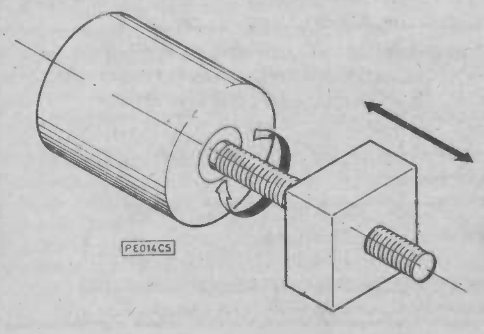
Cord driven gripper



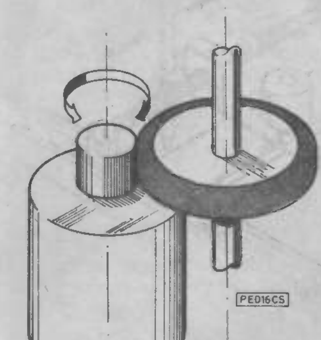
Worm driven gripper

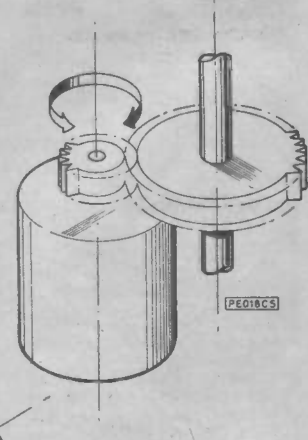


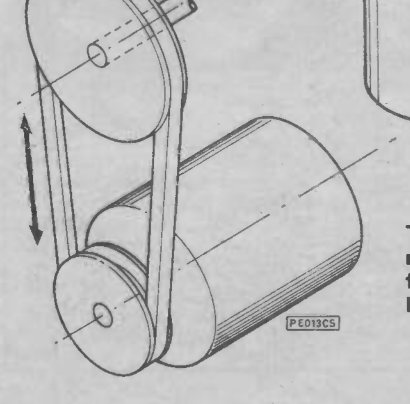
Solenoid driven gripper



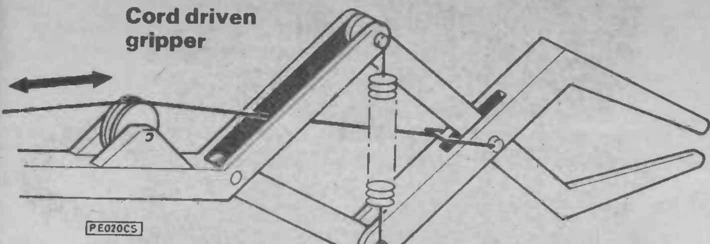
Linear motion delivered by way of the worm drive. Such is the reduction by gearing of a *worm* drive that a *snail's* pace can be achieved.



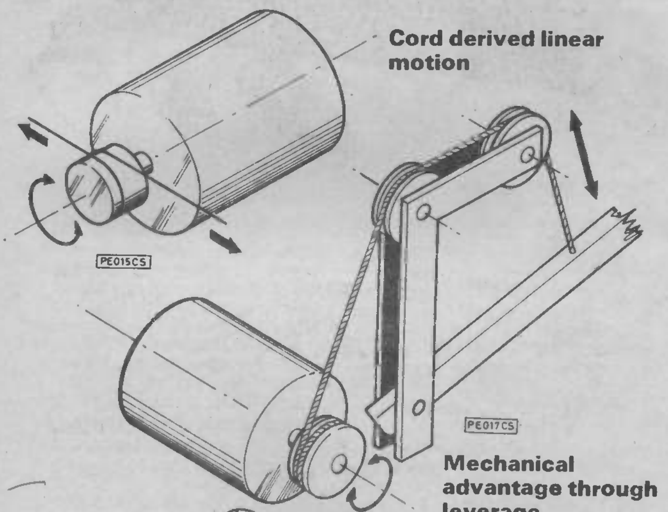




Three suggested reduction techniques: friction wheel, gears, belt

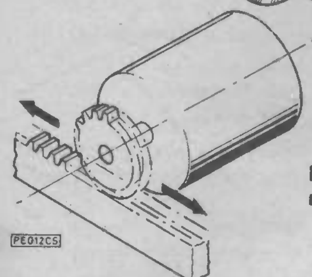


Cord driven gripper

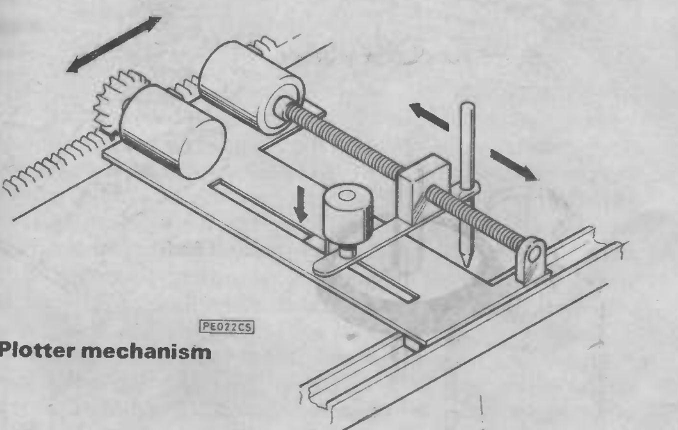


Cord derived linear motion

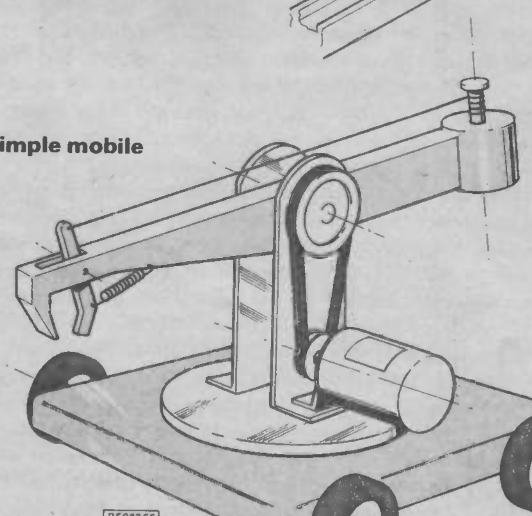
Mechanical advantage through leverage



Rack and pinion derived linear motion



Plotter mechanism



Simple mobile

made on the board for suppression capacitors, but these are often already mounted on small motors. Again, in case others might have the same experience, for some unknown reason, the *Scalextric* motors would not run with the normally mounted 1n (0·001μF) capacitors, but run at their best on 220n (0·22μF). I have discussed this with my colleagues, who are more experienced with motors than I am, but they are as puzzled as myself. Perhaps the reader might have come across this anomaly at some time. Small stepper motors normally require 470n (0·47μF) capacitors or greater.

The following shows the logic for driving d.c. motors

Motor 2 D3	D2	Motor 1 D1	D0	Hex	Dec	Motor 2 Dir	Motor 1 Dir		Suggested Single Key X–Y Control
0	0	0	0	0	0	—	—	*	0
0	0	0	1	1	1	—	CCW	*	→
0	0	1	0	2	2	—	CW	*	←
0	0	1	1	3	3	—	—	*	
0	1	0	0	4	4	CCW	—	*	↓
0	1	0	1	5	5	CCW	CCW		↘
0	1	1	0	6	6	CCW	CW		↙
0	1	1	1	7	7	CCW	—	*	←
1	0	0	0	8	8	CW	—	*	↑
1	0	0	1	9	9	CW	CCW		↗
1	0	1	0	A	10	CW	CW		↖
1	0	1	1	B	11	CW	—	*	
1	1	0	0	C	12	—	—	*	
1	1	0	1	D	13	—	CCW	*	
1	1	1	0	E	14	—	CW	*	
1	1	1	1	F	15	—	—	*	

The * indicates logic patterns that produce similar results. It can be seen that the 16 possible combinations can be reduced to 9 in practice.

To control three or four motors, a second board is required. To compile a table for simultaneous movement would be very complicated, there being 64 combinations for the motors and 256 combinations for four motors initially. However, a full set of tables would be rarely required. Single key operation could be developed from the following table, where once again movements can be reduced to nine variations. For the development of repetitive, automated sequences, single motor movements can be programmed at first to perfect the operation, then the logic values can be added together for two or more motors, to produce simultaneous movement:

Motor 4 D7	D6	Motor 3 D5	D4	Motor 2 D3	D2	Motor 1 D1	D0	Dec	Hex	Motor	Dir
0	0	0	0	0	0	0	0	0	0	—	—
0	0	0	0	0	0	0	1	1	1	1	CCW
0	0	0	0	0	0	1	0	2	2	1	CW
0	0	0	0	0	1	0	0	4	4	2	CCW
0	0	0	0	1	0	0	0	8	8	2	CW
0	0	0	1	0	0	0	0	16	10	3	CCW
0	0	1	0	0	0	0	0	32	20	3	CW
0	1	0	0	0	0	0	0	64	40	4	CCW
1	0	0	0	0	0	0	0	128	80	4	CW

For all motors to be static either 255 Dec (FF Hex) or 0 must be included.

The following program can be used to run 2 DC motors on an X–Y axis and can be modified for other functions.

```
05 PRINT"shift/clrhome":REM Clear screen symbol
08 PRINT"Do not turn external motor supply on yet":PRINT
10 POKE 37138, 15:REM Place value 15 into DDR
12 REM 15 for 2 DC motors or 1 bipolar with 4 inputs
13 REM 255 for 4 DC motors or 2 bipolar and no inputs
15 PRINT"DDR setting"
18 PRINT PEEK(37138):REM Display DDR setting
19 PRINT: PRINT:PRINT:REM Spaces
20 PRINT"Place decimal value 0 in I/O REGISTER"
30 INPUT X:REM Decimal 0 is optional but
35 IF X<>0 GOTO 20:REM initially 0 for motors static
```

```
40 POKE 37136, X:REM Places value 0 into I/O REGISTER
45 PRINT"STATE OF PORTS":REM Should be 00000000
46 PRINT"P7 P6 P5 P4 P3 P2 P1 PO"
50 Z=X; REM Put value of X into Z
55 GOSUB 200:REM Jumps to DEC/BIN conversion routine
58 PRINT:PRINT:PRINT"Turn on motor supply":PRINT
60 PRINT"Define MOTOR functions"
65 INPUT Y:REM Enter decimal value to suit motor/s direction
66 IF Y<0 OR Y>15 GOTO 60:REM See Line 13 for 4 motors
68 GOSUB 300
70 Z=Y:REM Put value of Y into Z
80 POKE 37136, Y:REM Places defined value into I/O REGISTER
85 PRINT:PRINT
100 PRINT "I/O REGISTER"
105 PRINT PEEK(37136):REM Display the contents
110 PRINT"STATE OF PORTS"
120 PRINT"P7 P6 P5 P4 P3 P2 P1 PO"
130 GOSUB 200:REM Jump to DEC/BIN conversion routine
140 GOTO 60:REM Reset I/O REGISTERS to change motors status

200 PO=Z—INT (Z/2)*2:REM Decimal/Binary conversion routine
205 Z=INT(Z/2)
210 P1=Z—INT(Z/2)*2
215 Z=INT (Z/2)
220 P2=Z—INT(Z/2)*2
225 Z=INT(Z/2)
230 P3=Z—INT (Z/2)*2
235 Z=INT (Z/2)
240 P4=Z—INT(Z/2)*2
245 Z=INT(Z/2)
250 P5=Z—INT(Z/2)*2
255 Z=INT (Z/2)
260 P6=Z—INT(Z/2)*2
265 Z=INT (Z/2)
270 P7=Z—INT(Z/2)*2
275 ZZ=INT(Z/2)
280 PRINT P7;P6;P5;P4;P3;P2;P1;PO:REM Display contensts of PORTS
285 PRINT:PRINT
290 RETURN:REM Return to line 140

300 IF Y=0 THEN PRINT"All Motors Static"
301 IF Y=1 THEN PRINT"Motor2 STOP Motor1 CCW Direction EAST"
302 IF Y=2 THEN PRINT"Motor2 STOP Motor1 CW Direction WEST"
303 IF Y=4 THEN PRINT"Motor2 CCW Motor1 STOP Direction SOUTH"
304 IF Y=8 THEN PRINT"Motor2 CW Motor1 STOP Direction NORTH"
305 IF Y=5 THEN PRINT"Motor2 CCW Motor1 CCW Direction SEAST"
306 IF Y=6 THEN PRINT"Motor2 CCW Motor1 CW Direction SWEST"
307 IF Y=9 THEN PRINT"Motor2 CW Motor1 CCW Direction NEAST"
308 IF Y=10 THEN PRINT"Motor2 CW Motor1 CW Direction NWEST"
309 RETURN:REM Return to line 60
```

Whilst the above program was tested on a Vic 20 computer, the approach to peripheral control is similar for the Commodore 64, Pet and BBC. The following shows the changes required when these computers are used:

	Vic 20	Commodore 64	Pet	BBC
Data Direction Register	37138	56579	59459	65122
Input/Output Register	37136	56577	59457	65120

The BBC replaces PEEK and POKE with ? and does not require brackets around a PEEK value.

Table 2 indicates the logic states required to step bi-polar stepper motors in each of the three modes of operation. In each instance the table refers to c.w. rotation, c.c.w. rotation being achieved by backwards stepping from any point. Full stepping is listed first, due to its primary degree of reliability. Half stepping provides additional flexibility of movement for cheaper, low-step-frequency motors and is a combination of Full stepping and Wave stepping. The Wave stepping logic sequence has beneficial effects where high speed rotation is required and the user is prepared to lose a certain degree of accuracy.

Normal, Full 4 step sequence

Step	Base Logic	Q1/Q4	Base Logic	Q3/Q2	Base Logic	Q5/Q8	Base Logic	Q7/Q6
1	0	On/Off	1	Off/On	0	On/Off	1	Off/On
2	0	On/Off	1	Off/On	1	Off/On	0	On/Off
3	1	Off/On	0	On/Off	1	Off/On	0	On/Off
4	1	Off/On	0	On/Off	0	On/Off	1	Off/On
1	0	On/Off	1	Off/On	0	On/Off	1	Off/On

1/2 step, 8 step sequence

Step	Base Logic	Q1/Q4	Base Logic	Q3/Q2	Base Logic	Q5/Q8	Base Logic	Q7/Q6
1	0	On/Off	1	Off/On	0	On/Off	1	Off/On
2	0	On/Off	1	Off/On	0/1	Stop	0/1	Stop
3	0	On/Off	1	Off/On	1	Off/On	0	On/Off
4	0/1	Stop	0/1	Stop	1	Off/On	0	On/Off
5	1	Off/On	0	On/Off	1	Off/On	0	On/Off
6	1	Off/On	0	On/Off	0/1	Stop	0/1	Stop
7	1	Off/On	0	On/Off	0	On/Off	1	Off/On
8	0/1	Stop	0/1	Stop	0	On/Off	1	Off/On
1	0	On/Off	1	Off/On	0	On/Off	1	Off/On

Note: At steps 2, 4, 6 and 8 only one winding is activated. The current logic state on the other winding must be changed so that either Logic 0,0 or 1,1 exist on all four transistor bases in order to disable the winding.

Wave step, 4 step sequence

Step	Base Logic	Q1/Q4	Base Logic	Q3/Q2	Base Logic	Q5/Q8	Base Logic	Q7/Q6
1	0	On/Off	1	Off/On	1	Off/On	1	Off/On
2	1	Off/On	1	Off/On	1	Off/On	0	On/Off
3	1	Off/On	0	On/Off	1	Off/On	1	Off/On
4	1	Off/On	1	Off/On	0	On/Off	1	Off/On
1	0	On/Off	1	Off/On	1	Off/On	1	Off/On

APPLICATIONS

For most applications of computer controlled motors, the rotary motion is converted into harnessed linear movement. Several methods of conversion are used, ranging from wheels relying on tyres to maintain accuracy of position; pulleys; geared wheels; rachet and gears; and a long, threaded shaft driving a nut along its length. (The author found a suitable source of these in the threaded extruders of the tubes containing bath sealant).

When d.c. motors are employed, some form of feedback is necessary to monitor position and provide a means of stopping the motor at a required position. These usually take the form of optical sensors or limit switches. The motor controller has provision for using both these methods. Stepper motors, on the other hand, are positional devices, enabling pre-programmed, automatic, repetitive operations. Limit switches can be used in both applications to prevent accidental over-run. Both types of motor lend themselves to keyboard control situations, but in this mode the d.c. type of motor is the more economical.

Many features on robotics just describe arm geometries such as Cartesian, spherical or polar, cylindrical and articulated or angular. The block diagram provided, whilst familiarising the reader with the language or robotics, offer little help in applying the movements practically. It is hoped that the illustrations accompanying this article can be of assistance to those who wish to attempt some simple machine control projects with limited functions.

The low torque of small d.c. motors and stepper motors can be improved dramatically with the use of reduction gears. It is a neglected fact that in the average discarded alarm clock there are at least two sets of 60/1 ratio gear movements. These can turn a cheap six steps per revolution stepper motor, as described in the *Expanding VIC-20* series into a 360 step movement, with obvious advantages. Many of the older clocks have really solid movements that can stand up to drilling and machining if necessary.★

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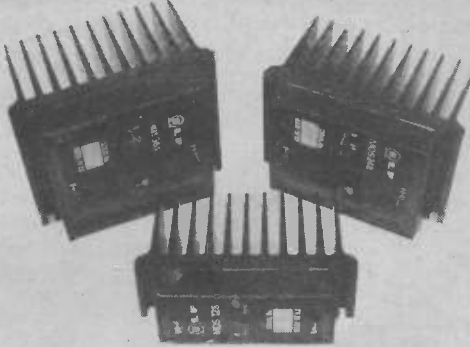

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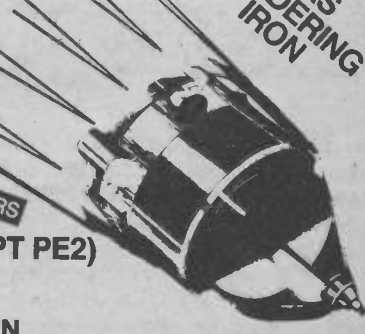

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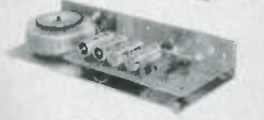

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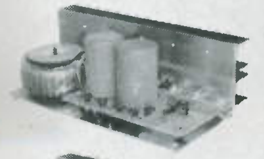

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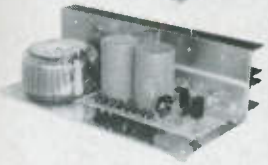

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Res. Freq. 45Hz. Freq. Resp. to 14KHz. PRICE £29.80 + £3.00 P&P ea.
15" 150 WATT R.M.S. C15 8ass Guitar/Disco.
3" ally voice coil. Oie-cast chassis. Res. Freq. 40Hz. Freq. Resp. to 4KHz. PRICE £54.99 + £4.00 P&P ea.
10" 60 WATT R.M.S. 1060GP Gen. Purpose/Lead Guitar/Keyboard/Mid. P.A.
2" voice coil. Res. Freq. 75Hz. Freq. Resp. to 7.5KHz. Sens. 99dB. PRICE £19.15 + £2.00 P&P.
10" 200 WATT R.M.S. C10200GP Guitar, Keyboard, Disco.
2" voice coil. Res. Freq. 45Hz. Freq. Resp. to 7KHz. Sens. 101dB. PRICE £51.00 + £3.00 P&P.
15" 200 WATT R.M.S. C15200 High Power Bass.
Res. Freq. 40Hz. Freq. Resp. to 5KHz. Sens 101dB. PRICE £59.45 + £4.00 P&P.
15" 400 WATT R.M.S. C15400 High Power Bass.
Res. Freq. 40Hz. Freq. Resp. to 4KHz. Sens. 102dB. PRICE £85.00 + £4.00 P&P.

WEM
5" 70 WATT R.M.S. Multiple Array Disco etc.
1" voice coil. Res. Freq. 52Hz. Freq. Resp. to 5KHz. Sens. 89dB. PRICE £19.99 + £1.50 P&P ea.
8" 150 WATT R.M.S. Multiple Array Disco etc.
1" voice coil. Res. Freq. 48Hz. Freq. Resp. to 5KHz. Sens. 92dB. PRICE £29.49 + £1.50 P&P ea.
10" 300 WATT R.M.S. Disco/Sound re-enforcement etc.
1½" voice coil. Res. Freq. 35Hz. Freq. Resp. to 4KHz. Sens. 92dB. PRICE £33.49 + £2.00 P&P ea.
12" 300 WATT R.M.S. Disco/Sound re-enforcement etc.
1½" voice coil. Res. Freq. 35Hz. Freq. Resp. to 4KHz. Sens. 94dB. PRICE £41.49 + £3.00 P&P ea.

SOUNDLAB (Full Range Twin Cone)
5" 60 WATT R.M.S. Hi-Fi/Multiple Array Disco etc.
1" voice coil. Res. Freq. 63Hz. Freq. Resp. to 20KHz. Sens. 86dB. PRICE £9.99 + £1.00 P&P ea.
6½" 60 WATT R.M.S. Hi-Fi/Multiple Array Disco etc.
1" voice coil. Res. Freq. 56Hz. Freq. Resp. to 20KHz. Sens. 89dB. PRICE £10.99 + £1.50 P&P ea.
8" 60 WATT R.M.S. Hi-Fi/Multiple Array Disco etc.
1¼" voice coil. Res. Freq. 38Hz. Freq. Resp. to 20KHz. Sens. 89dB. PRICE £12.99 + £1.50 P&P ea.
10" 60 WATT R.M.S. Hi-Fi/Disco etc.
1¼" voice coil. Res. Freq. 35Hz. Freq. Resp. to 15KHz. Sens. 89dB. PRICE £16.49 + £2.00 P&P

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