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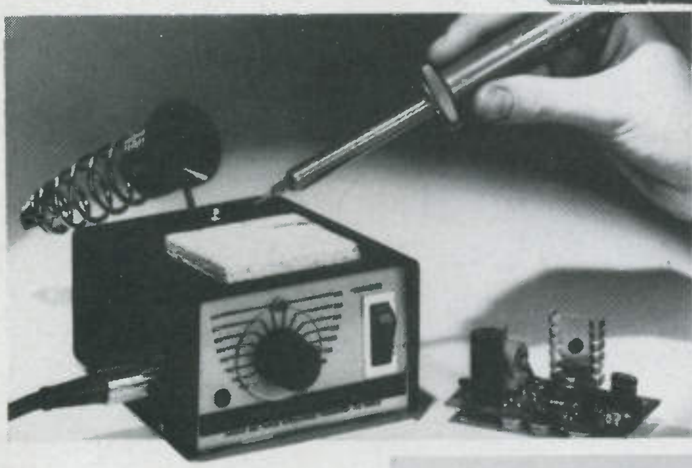

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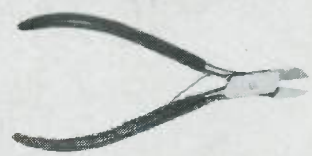

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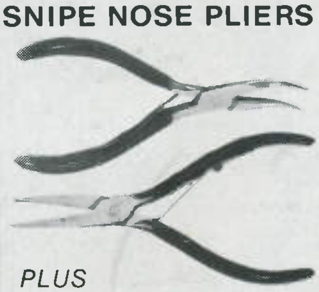

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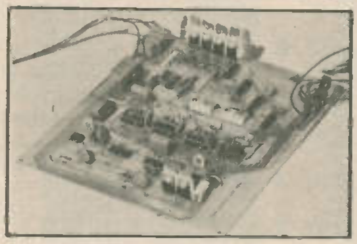
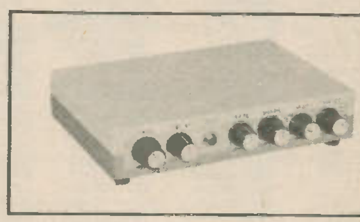
This month's front cover picture shows the National Semiconductor 32 bit microprocessor smashing a "memory barrier" formed by a floppy disc. Courtesy of National Semiconductor.





OUR NOVEMBER ISSUE WILL BE ON SALE FRIDAY, OCTOBER 4th, 1985 *(see page 27)*

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LYTIC CAPACITORS (Values in µF). **500V:** 10µF **52p**; 47 **78p**; **63V:** 0·47, 1·0, 1·5, 2·2, 3·3, **8p**; 4·7 0 **10p**; 15, 22 **12p**; 33 **15p**; 47 **12p**; 68 **16p**; 100 **19p**; 220 **26p**; 1000 **70p**; 2200 **99p**; **50V:** 68 **20p**; 100 7p; 220 **24p**; **40V:** 4·7 **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**.

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**

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250V: 1nF, 1n5, 2n2, 3n3, 4n7, 6n8, 8n2, 10n, 15n, 22n **7p**; 18n, 27n, 33n, 47n **8p**; 39n, 56n, 68n 82n, 100nF **11p**.
100V: 100n, 120n, **10p**; 150n **11p**; 220n **13p**; 330n **18p**; 470n **23p**; 680n **30p**; 1MF **34p**; 2M2 **50p**.

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

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5KΩ-2MΩ single gang D/P switch	**95p**
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	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**
1% Metal Film 51Ω-1M		E24	**8p**	**6p**

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

AC127/8	35
AC141/2	35
AC176	35
AC187/8	35
AC188	35
AD142	120
AD149	79
AD161/2	45
AF118	95
AF139	40
AF239	55
BC107/8	12
BC107B	14
BC108B	14
BC108C	12
BC109	12
BC109B	14
BC109C	14
BC114/5	30
BC117/8	25
BC140	38
BC142/3	38
BC147/8	12
BC147B	15
BC148C	10
BC149	12
BC149C	15
BC153/4	30
BC157/8	14
BC159	11
BC167A	14
BC168C	12
BC169C	12
BC171/2	12
BC173	16
BC177/8	16
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	15
BC307B	15

BC308B	16
BC327/8	15
BC337/8	15
BC441	34
BC461	34
BC477/8	40
BC516/7	40
BC547/8	12
BC549C	15
BC556/7	15
BC558/9	15
BCY41/42	30
BCY70	18
BCY71	20
BCY72	25
BCY78	30
BD131/2	65
BD133	60
BD135	45
BD136/7	40
BD138/9	40
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
BF194/5	12
BF198/9	18
BF200	30
BF224	40
BF244A	28
BF244B	29
BF245	50
BF256B	50
BF257/8	32
BF259	40
BF394	40
BF451	40
BF494/5	40
BF594/5	30
BFR39/40	25
BFR41/79	25
BFR80/81	25

BFR98	105
BFX29/84	35
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	30
BSX29	45
BSY26	35
BSY95	35
BU105	180
BU205	190
BU206	200
BU208	200
MJ2955	90
MJE340	54
MJE371	100
MJE2955	99
MJE3055	70
MPF102	40
MPF103/4	30
MPF105	30
MPSA05	30
MPSA06	25
MPSA08	30
MPSA12	32
MPSA55	30
MPSA56	30
MPSA70	40
MPSU02	58
MPSU05	60
MPSU06	60
MPSU52	65
MPSU55	60
MPSU56	60
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	130
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	70
VN46AF	95
VN66AF	110
VN88AF	120
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
2SC1678	140
2SC1679	190
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2SC1957	90
2SC1969	165
2SC2028	85
2SC2029	200
2SC2078	170
2SC2091	85
2SC2166	165
2SC2314	85
2SC2335	200
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2SC2612	200
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2SJ85	225
3N128	115
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CA3012	175
CA3014	275
CA3018	86
CA3019	90
CA3020	210
CA3023	210
CA3028A	110
CA3035	255
CA3036	270
CA3043	275
CA3045	365
CA3046	70
CA3059	325
CA3075	215
CA3080E	70
CA3081	190
CA3085	160
CA3086	60
CA3090AQ	250
CA3123	165
CA3130	90
CA3140	45
CA3160	90
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LC7130	300
LC7137	350
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LF351	60
LF353	90
LF355	90
LF356	90
LF357	100
LF398	495
LM10	325
LM301A	30
LM307	45
LM308	75
LM311	60
LM318	150
LM319	180
LM324	45
LM334Z	110
LM335Z	130
LM337	250
LM339	40
LM348	60

LM349	125
LM358	50
LM377	210
LM379	495
LM380	120
LM381N	175
LM382	190
LM384	225
LM386	90
LM387	200
LM389	160
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LM394CH	380
LM558	170
LM725CN	300
LM733	65
LM1871	300
LM1889	400
LM2907	395
LM3900	70
LM3909	95
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LM3915	345
LM3916	300
LM13600	150
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M51516L	430
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NE571	300
NE5532	150
NE5534	120
OM335	650
RC4136D	55
RC4558	55
SAB3209	425
SAB3271	485
SAB4209	295
SG3402	295
SL490	300
SL924	00
SL6270	150
SN76003	350
SN76018	150
SN76131	135
SN76227	95
SN76477	470
SN76488	525
SN76489	400
SP0256AL	425
SP8629	350
TA7120	120

TA7130	125
TA7204	150
TA7205	90
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TA7310	120
TAA900	395
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TBA120S	70
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TCA280A	220
TCA940	175
TCA950	00
TCA965	180
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TDA1034	350
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TDA2006	320
TDA2020	320
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TDB0791	420
TL061CP	40
TL062CP	60
TL064CN	95
TL071CP	40
TL072CP	70
TL074CN	110
TL081CP	35
TL082CP	55
TL083CP	75
TL084CP	100
TL091CP	60
TL170	50
TL497A	185
TL507	110
TL509	110
UA2240	120
UA78S40	225
UAA170	180
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ULN2004	75
ULN2283	150
ULN2803	190
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UPC575	275
UPC1025H	375
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UPC1181	00
UPC1182	425
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XR2206	375
XR2207	400
XR2211	575
XR2216	675
XR2266	360
ZN409C	180
ZN414	80
ZN423E	130
ZN424E	130
ZN425E-8	345
ZN426E-8	200
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ZN428E	450
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68A02	345
6820	150
68B21	220
6821	150
6840	375
6843	800
6845	650
6845SP	750
6846	625
6847	650
6850	120
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6854	625
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8154	750
8155	400
8156	400
8202	£25
8212	220
8214	495
8216	150
8224	£3

	£3
8228	310
8243	290
8250	£11
8251	350
8253	370
8255	400
8256A	£15
8257A	400
8259	400
8271	£49
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8283	450
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8288	£11
8748	£33
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8T27	150
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8T95N	90
8T97N	90
9364AP	550
9602	220
AM26LS31C	125
AM26LS32A	125
AM26LS33	150
AM7910	£30
AY-3-1015	300
AY-E-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	200
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	£16
TMS9929	£16
ULN2003	75
UPD7002	440
UPD7007	725
WD1691	£14
WD1770	£15
WD2143	850
Z80CPU 2·5	295
Z80ACPU4M	380
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
745257	225
745258	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	95
75110	90
75121	130
75150	125
75154	195
75158	150
75159	140
75160	420
75162	650
75182/3	99
75188/9	100
75322	140
75353	140
75361	150
75365	195
75376	95
75450	85
75451/2	50
75454	70
75491/2	65

TTL 74

7400	25
7401	25
7402	25
7403	25
7404	30
7405	30
7406	40
7407	40
7408	25
7409	25
7410	25
7411	25
7412	25
7413	40
7414	60
7416	25
7417	35
7420	25
7421	50
7422	35
7423	35
7425	35
7426	40
7427	35
7428	35
7430	25
7432	30
7433	30
7437	30
7438	40
7440	30
7441	90
7442	65
7443	100
7444	100
7445	110
7446	110
7447	95
7448	110
7450	30
7451	30
7453	35
7454	35
7460	30
7470	50

7472	50
7473	50
7474	45
7475	55
7476	45
7480	60
7481	175
7482	100
7483	100
7484	110
7485	100
7486	40
7489	200
7490	55
7491	70
7492	110
7493	50
7494	100
7495	60
7496	75
7497	200
74100	60
74104	70
74105	70
74107	45
74109	70
74110	55
74111	55
74112	170
74116	160
74118	100
74119	160
74120	90
74121	45
74122	65
74123	75
74125	60
74126	55
74128	55
74132	70
74136	65
74141	85
74142	235
74143	250
74144	250
74145	100
74147	160
74148	130
74150	170
74151	60
74153	70
74154	130
74155	75
74156	90
74157	75
74159	170
74160	100
74161	100
74162	100
74163	100
74164	100
74165	100
74166	130
74167	300
74170	190
74172	400
74173	130
74174	100
74175	100
74176	100
74177	110
74178	130
74179	130
74180	100
74181	300
74182	120
74184	170
74185	170
74186	70
74188	75
74190	120
74191	120
74192	120
74193	120
74194	100
74195	75
74196	120
74197	100
74198	200
74199	200

74221	150
74246	130
74247	120
74248	145
74249	175
74251	90
74259	150
74265	260
74273	180
74276	130
74278	160
74279	80
74283	100
74284	440
74285	300
74290	80
74293	80
74297	175
74298	160
74351	180
74365	70
74366	70
74367	70
74368	70
74376	120
74390	100
74393	100
74425	60
74426	60
74490	100

74C

C244	150
C245	150
C373	180
C374	425
C922	550
C923	600
C925	650

74LS

LS00	25
LS01	25
LS02	25
LS03	25
LS04	25
LS05	25
LS08	25
LS09	25
LS10	25
LS11	25
LS12	25
LS13	35
LS14	50
LS15	25
LS19	45
LS20	25
LS21	25
LS22	25
LS24	50
LS26	25
LS27	25
LS28	25
LS30	25
LS32	25
LS33	25
LS37	25
LS38	25
LS40	25
LS42	50
LS47	80
LS48	90
LS49	100
LS51	25
LS52	25
LS54	25
LS55	25
LS63	55
LS73	30
LS74	35
LS75	45
LS76	40
LS78	40
LS83	70
LS85	70
LS86	35
LS90	50

LS91	90
LS92	55
LS93	55
LS95	70
LS96	90
LS107	40
LS109	45
LS112	45
LS113	40
LS114	40
LS122	70
LS123	80
LS124	125
LS125	50
LS126	50
LS132	60
LS133	50
LS135	28
LS136	45
LS138	60
LS139	60
LS145	95
LS147	165
LS148	130
LS151	70
LS153	70
LS154	155
LS155	70
LS156	70
LS157	60
LS158	60
LS160	70
LS161	70
LS162	70
LS163	70
LS164	75
LS165	110
LS166	150
LS168	140
LS169	100
LS170	140
LS173	100
LS174	75
LS175	70
LS181	190
LS183	190
LS190	85
LS191	85
LS192	80
LS193	80
LS194	75
LS195	75
LS196	85
LS197	85
LS221	85
LS240	80
LS241	80
LS242	95
LS243	95
LS244	80
LS245	100
LS247	105
LS248	105
LS249	105
LS251	75
LS253	75
LS256	90
LS257	75
LS258	75
LS259	125
LS260	70
LS261	100
LS266	60
LS273	120
LS275	350
LS279	70
LS280	180
LS283	80
LS290	80
LS293	80
LS294	999
LS295	140
LS297	850
LS298	100
LS299	225
LS320	210
LS322	360
LS323	400
LS324	150
LS325	150

LS326	290
LS327	290
LS347	120
LS348	140
LS352	110
LS353	110
LS355	220
LS356	200
LS363	150
LS364	150
LS365	50
LS366	50
LS367	50
LS368	50
LS373	100
LS374	100
LS375	70
LS377	130
LS378	95
LS379	130
LS380	310
LS382	310
LS384	460
LS385	330
LS386	50
LS390	60
LS393	100
LS395	110
LS396	300
LS398	195
LS399	140
LS445	125
LS447	80
LS465	140
LS467	120
LS490	150
LS540	100
LS541	100
LS624	155
LS629	130
LS640	200
LS641	150
LS645	195
LS668	90
LS669	90
LS670	170
LS673	890
LS674	800
LS682	250
LS687	350

CMOS

4000	20
4001	25
4002	25
4006	70
4007	25
4008	60
4009	45
4010	40
4011	25
4012	25
4013	35
4014	60
4015	60
4016	40
4017	55
4018	60
4019	60
4020	80
4021	60
4022	70
4023	30
4024	50
4025	25
4026	90
4027	45
4028	45
4029	75
4030	35
4031	130
4032	65
4033	130
4034	140
4035	70
4036	250
4037	115
4038	75
4039	280

4040	60
4041	60
4042	50
4043	45
4044	50
4045	110
4046	60
4047	60
4048	55
4049	40
4050	35
4051	70
4052	60
4053	60
4054	85
4055	85
4056	85
4057	£10
4059	420
4060	70
4061	£5
4062	995
4063	90
4066	45
4067	245
4068	25
4069	25
4070	25
4071	25
4072	25
4073	25
4075	25
4076	70
4077	25
4078	25
4081	25
4082	25
4085	60
4086	60
4089	125
4093	40
4094	70
4095	95
4096	100
4097	275
4098	80
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	60
4503	40
4504	100
4505	350
4506	100
4507	45
4508	130
4510	55
4511	55
4512	55
4513	150
4514	115
4515	125
4516	65
4517	275
4518	50
4519	35
4520	55
4521	115
4522	125
4526	60

4527	65
4528	70
4529	145
4530	90
4531	120
4532	65
4534	365
4536	250
4538	80
4539	80
4541	95
4543	70
4544	150
4549	400
4553	245
4554	180
4555	35
4556	55
4557	250
4558	120
4559	395
4560	150
4561	104
4562	350
4566	160
4568	250
4569	175
4572	45
4580	255
4581	125
4582	99
4583	100
4584	55
4585	55
4599	155
40097	45
40098	42
40100	215
40101	130
40102	140
40103	412
40104	120
40105	220
40106	60
40107	55
40108	325
40109	100
40110	235
40114	240
40161	194
40163	75
40174	75
40175	75
40181	220
40192	75
40193	95
40194	90
40195	80
40244	195
40245	195
40257	198
40373	220
40374	220

74HC00	55
74HC02	55
74HC04	55
74HC08	55
74HC10	55
74HC20	55
74HC32	55
74HC24	135
74HC51	55
74HC74	70
74HC86	60
74HC107	70
74HC109	75
74HC139	120
74HC153	135
74HC160	35
74HC161	135
74HC164	135
74HC165	270
74HC173	120
74HC174	120

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

BB1058	40
BB106	40

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

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

DIAC

ST2	25

SOLDERCON PINS

100	45p
500	200p

OPTO

LEDS price includes Clips

TIL209 Red 3mm	10
TIL211 Green 3mm	14
TIL212 Yellow	14
TIL220 ·2" Red	12
0·2" Yel, Grn, Amber	14
Rectangular LEDs with two part clip. R, G & Y	45
Rectangl. Stackable LEDS	18
Triangular LEDs R&G	18
0·2" Flashing LED Red	56
0·2" Bi colour LEDs Red/Green	100
Green/Yellow	80
0·2" Tri colour LEDs Red/Green/Yellow	85
0·2" Red High Bright	59
High Bright Green or Yellow	100
LD271 Infra Red (emit)	46
TIL32 Infra Red (emit)	52
SFH205 (detector)	118
TIL78 (detector)	55
TIL38	50
TIL81 82; TIL100	90

7 Segment Displays

TIL321 ·5" C.An	140
TIL322 ·5" C.th	140
DL704 ·3" C.Cth	125
DL707 ·3" C.Anod	125
FND357 or 500	130
·3" Green C.A.	140
±1 ·3" Red or Green	150
Bargraph 10 seg. Red	275
Bargraph NSM3914	500

FERRIC CHLORIDE

Crystals 1lb

150p + 50p p&p

DALO ETCH RESIST

Pen plus spare tip **100p**

0·5" LCD DISPLAYS

3½ digit	495
6 digit	625

OPTO

BPX25	250
BPW21	320
BPX65	320
ILD74	145
ILQ74	275
ILCT6 Darlington Isolator	135
TIL111	70
OCP71	120
ORP12	78
2N5777	50
4N33	135
Pin diode	720
Schmitt Receiver	715

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

COPPER CLAD BOARDS

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

VEROBOARD

	Clad	Plain
2½×3¾"	95p	—
2½×5"	110p	—
3¾×3¾"	110p	—
3¾×5"	125p	95p
3¾×17"	420p	275p
4¾×18"	590p	—
Pkt. of 100 pins	55p	
Spot Face Cutter	150p	
Pin Insertion Tool	185p	

VQ Board	180p
DIP Board	395p
Vero strip	95p
PROTO-DECs	
Veroblock	480
S-Dec	395
Eurobreadboard	590
Bimboard 1	695
Superstrip SS2	£13

VERO WIRING PEN and Spool **380p**
Spare Wire (Spool) **75p**; Combs **8p** ea.
Wire Wrapping Stakes 100 **250p**

VOLTAGE REGULATORS

1A T0220 Plastic Casing

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

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		LM337T	175
+24V 5A	695	LM723	30
79HG −2.25V to		TBA625B	75
−24V 5A	785	RC4194	375
LM309K	120	RC4195	160
TL497	185	78S40	225

SWITCHES

SLIDE 250V

1A DPDT	14
1A DPDT C/OFF	15
½A DP on/on/on	40

TOGGLE 2A 250V

SPST	35
DPDT	48
4 pole on off	54

PUSH BUTTON
Spring loaded
Latching or Momentary 6A DPDT c/over **200**

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

MINIATURE
Non Locking

Push to make	15p
Push break	25p

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 plugs	465p	460p
24 way IEEE skt	485p	480p
36 way Centronics plug	395p	390p
36 way Centronics skt	480p	450p

ASTEC UHF MODULATORS

6MHz Standard	375p
8MHz Wideband	550p

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	25p
14 pin	10p	35p	30p
16 pin	10p	42p	35p
18 pin	16p	52p	40p
20 pin	20p	60p	45p
22 pin	22p	65p	70p
24 pin	25p	70p	55p
28 pin	28p	80p	65p
40 pin	30p	99p	90p

ZIF SOCKET (TEXTOOL)

24 way	575p
28 way	695p
40 way	845p

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	—

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20 way	145p	166p	125p	240p
26 way	175p	200p	150p	320p
34 way	200p	236p	169p	340p
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50 way	235p	270p	200p	470p

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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**
Sranderd 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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1·6MHz	595
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2·0MHz	225
2·4576M	200
2·5MHz	225
2·56250M	220
3·2768M	150
3·57954M	98
3·6864M	300
4·0MHz	150
4·032MHz	290
4·194304M	200
4·433619M	100
4·608MHz	200
4·80MHz	200
5·0MHz	150
5·185MHz	300
5·24288M	390
6·0MHz	140
6·144MHz	150
6·5536MHz	200
7·0MHz	150
7·168MHz	175
7·68MHz	200
8·0MHz	150
8·08333M	395
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9·00MHz	200
9·375MHz	350
10·0MHz	175
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	240
16·0MHz	220
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
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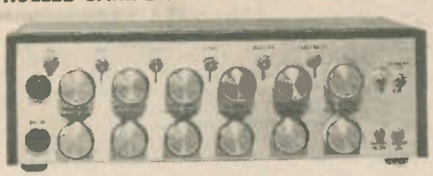

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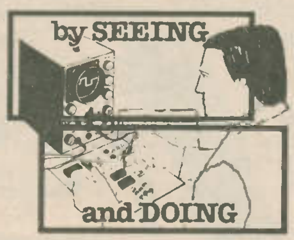

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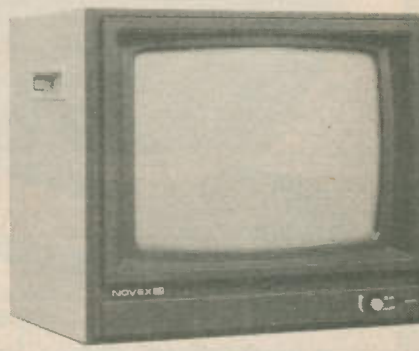

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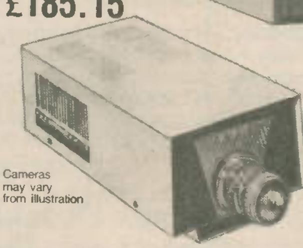

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PE VOLUME 21 №10 OCTOBER 1985

21 YEARS

NEXT month PE has been around for 21 years. I do not intend to go on too much about it now as we will be carrying a special feature (and an extra eight pages) next month. In the feature we will look at the history of PE, some of the "landmark" projects along the way, the personalities, the moves, some advertisers etc. In addition to the special anniversary issue we will increase the size of the magazine—by adding about 20mm on the height. This is the second time in the history of PE that the page size has been increased—if you do not know when it happened before, find out next month!

Twenty one years is a long time in electronics, however, it may surprise some younger readers just what hobbyists were building all those years ago. Although I was in no way connected with PE when it was launched, there are still people on the staff who were; people who have made it a success and who, with your help, ensured the magazine prospered and continued. In fact when PE was launched, I was just starting an apprenticeship with the Ministry of Aviation and never dreamed I would eventually edit the exciting new magazine we apprentices read so avidly.

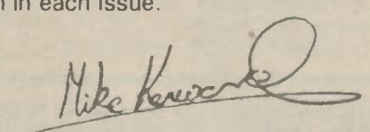
Interestingly, our history is based on three sets of seven year periods with major changes at the end of each seven years—and strangely it does seem to be happening again now!

PRICES

Perhaps it is unfortunate that we have to keep up with all aspects of progress; I am thinking of inflation and the way it affects the cost of the magazine. With this in mind I must tell you that from next month PE will cost £1.10. For some time our cover price has been lower than our competitors and we have maintained this situation for as long as possible, but economics now force us to go up 10p. For your information the first issue cost 2/6 ($12\frac{1}{2}$p for those who do not remember £.s.d.); that's about 750 per cent inflation in 21 years. However, a single transistor was then around 5/- (25p) which would be equivalent to over £2 now, instead of the 15p or so we actually have to pay.

For those who may consider the 10p price rise is to pay for extra paper the new size issue will require, let me assure you that due to the complexities of Web Offset printing the size increase has not added to our printing or paper costs.

We do try our best to contain the cover price and keep up the quality and content of each issue. You may have noticed that our type size is much smaller than some publications which means more words per page and, therefore, more information in each issue.



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

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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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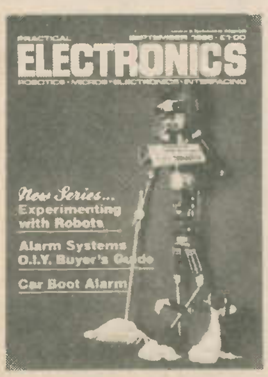

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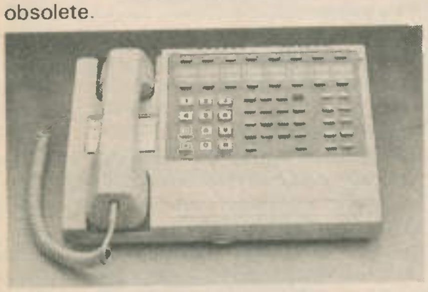
We regret that lengthy technical enquiries cannot be answered over the telephone.

ROOM FOR EXPANSION

According to British Telecom sources, if the whole of the telephone network could be 'monitored' at any one time during the average day, 25 per cent of numbers being dialled would be unanswered. If BT could persuade more people to employ answering machines then, of course, those calls could be answered. The potential increase in turnover further broadening the smiles of shareholders.

Since the majority of big businesses now have well established intercommunications set-ups, it is the smaller businesses and the man in the street that are presently being courted by BT marketeers. The machines displayed in a recent exhibition were aimed at this market.

Items of particular interest were multi-function desk phones with many switching capabilities that will undoubtedly in the long run make the standard switchboard (and it's operator) redundant. Also in the pipeline are "desk phones of the future" which might well incorporate a 'mini' data printer, it is expected, by then, that the telephone system will be essentially digital as will the desk sets—making present-day modems obsolete.



The data-transmission field has just been boosted with the launch of BT's communications service enabling the transmission of text, photo's, data and speech. This new service Integrated Digital Access (IDA) will, according to Mr Kane (BT Director of Marketing), "Transform communications in the UK and have a major impact on the business community".

The system at present is only linked from London to several key areas in the south. As the Advanced Integrated Services Digital Network (ISDN) is progressively expanded, the facility will become available to us all. It is planned that by 1987 around 190 centres in the UK will be able to use IDA.

A similar innovation is already in use, using the analogue system (via A/D converters). IMTRAN (Image Transfer) consists of a portable receiver/transmitter unit which plugs into a standard telephone socket. It can be connected directly to a body-scanner, or to a TV camera focused on X-ray pictures or medical records etc. High resolution images are received on a TV monitor screen, enabling doctors to analyse the pictures at far off locations soon after they have been taken.

SOUND INVESTMENT

A 'sound-meter' kit is now available from Cambridge Kits, with £4 off for PE readers.

This self-contained, hand-held unit, designed to BS 5969 with "A" weighted frequency response to compare both low and high frequency annoyance, measures all types of sound and checks whether legal limits in factories and residential areas etc. are being met. It is ideal for comparing appliances, lawn mowers, paper shredders etc. or measuring the effect of sound proofing or double glazing.

There is a built-in calibrator and the measurement range is from 40dB (public library) to 120dB (overhead jet take-off). It features peak sound level response, even with pulsating or irregular sounds. There is a linear dB sound scale and knob to set the measurement level, which makes an l.e.d. flash when exceeded, or the operator can watch the l.e.d. and turn the knob to measure the sound level—there is no flickering meter needle to guess at. The meter runs from an internal PP3 type battery or external 9V supply.

The kit is available at an introductory price of £23.20 including VAT and UK postage if ordered from Cambridge Kits, 45 (JF) Old School Lane, Milton, Cambridge, before the end of October 1985. Allow 28 days for delivery. From 1 November 1985 the regular price will be £27.20.

Three from Croydon

Where would you find the specifications of over 20,000 British, European and Japanese transistors? In *Towers' International Transistor Selector* (sorry, no acronym!) of course.

This compendium gives a comprehensive tabulation of basic transistor specifications and offers information on characteristics; case details; terminal identifications; applications use; manufacturers and equivalents. The devices covered are a selection of the more common current and widely used obsolete types.

Since its introduction in 1974, the book has been updated three times, the most recent (update 3) is presently retailing for a daunting £12.95.

Those of us, however, who appreciate that its predecessor (update 2, 1980) would be a very handy tool, can buy this equally extensive reference source for just £6.75, inc. VAT and p. & p., from Croydon Discount at the address below.

Also available from the same supplier is the 'Monacor' DMT-700, a handy-sized (67 × 112 × 25mm) $3\frac{1}{2}$ digit l.c.d. digital multimeter—ideal for the hobbyist/service engineer.

Ranges as follows: 0–1kV d.c. (4 ranges); 0–500V a.c. (2 ranges); 0–200mA d.c. (3 ranges); 0–2kΩ (4 ranges); Diode test; Overload protection; Auto-polarity.

This manageable, well priced multimeter is being offered to PE readers at the special price of £29.95 inc. VAT.

For readers interested in robotics (see: *Experimenting with Robots*, page 46) it should be noted that d.c. motors, microswitches, relays and other 'robotalia' can be sourced at this address. Croydon Discount Electronics, 38 Lower Addiscombe Road, Croydon, Surrey CR0 6AA (01-688 2950).

MARKET PLACE

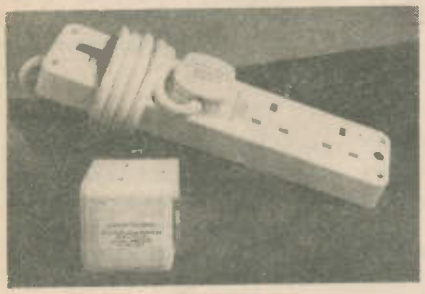
CLEAN MAINS

Most home computing enthusiasts will perhaps by now be aware of the frustrating problem of an unstable mains supply creating havoc with a micro.

Mainsborne 'spiky' transients and r.f. interference can crash a program or hopelessly corrupt computer data, necessitating many hours of further work. Several surge-filtering devices are presently available, and the peace of mind that comes with one could be well worth the purchase price.

New from Tony Firshman Services is the competitively priced 'Computer Cleaner'. Housed in a typical double-adaptor casing the basic unit incorporates capacitive filtering (1–30MHz), an inductive element for r.f., up to around 130MHz; and a mains transient suppressor.

The unit is capable of protecting more than one computer, but has only one outlet. A double-adaptor could be plugged into the unit for this purpose. A four-way trailing socket version is also available for those with a need to supply larger amounts of laundered power. The basic 'Computer Cleaner' plug costs £14 and the four-way socket £24, prices inc. VAT and p&p. (Allow 28 days for delivery). From Tony Firshman Services, 43 Rhyl Street, London, NW5 3HB. (01-267 3887).



POINTS ARISING...

MODEMS Part 3
August '85

The telephone number given for access to the Prestel 'Enterprise' computer (page 24) cannot be used from outside the London area. If in London 618 1111 *is* correct; unfortunately it cannot be prefixed with '01-' as printed. People outside the London area should ring the Prestel Information Office on 01-822 1122 for the number relevant to their area.

CYLINDER THERMOSTAT
May '85

The tendency of the cylinder thermostat relay to 'chatter' is the result of mains spikes (generated when the relay contacts open and close) being picked up by the sensitive parts of the circuit.

The easiest cure is to put a time delay in the circuit so that short interference pulses do not get through to operate the relay. In most cases a 100µF/10V electrolytic capacitor connected across R11 will provide a complete cure. This value can be increased to 1000µF or more in severe cases. The negative terminal of the capacitor is connected to the end of R11 nearest to the centre of the board.

It is also possible that interference may enter the circuit via the sensor lead in situations where the environment is particularly prone to electrical noise. To prevent this a 10K resistor should be inserted between the inverting input of IC2 and the sensor terminal block TB2.2 This can be inserted by breaking the pcb track where it passes between TR1 and VR2 and soldering the resistor across the break. It may also be advantageous to increase the value of C2 to 100nF.

The amount of electrical interference generated when switching inductive components such as pump motors and boiler solenoids is surprising. With hindsight it is clear that the modifications should have been designed in. Perhaps this experience will be of help to those designing similar circuits in the future.

Briefly...

Availability of a BBC-B interface for the 'Memocon Crawler Robot' has been announced by Red Giant, it will retail at £6.95. In the near future a further BBC-B interface will be launched for the Fischerteknic Robot Kit, this will cost around £25 with a 20 per cent reduction for schools. Details from, Red Giant Software Ltd., 3a Oakcroft Close, Pinner, Middlesex.

• • • • •

The new Greenweld catalogue has just been published. It contains a wide range of components, books, meters, connectors and all the usual requirements of the electronics hobbyist. A special listing within the catalogue (list No. 21), offers exceptional prices on a wide range of 'returned' goods. The catalogue's one pound purchase price can be redeemed with discount vouchers. From, Greenweld Electronic Components, 443 Millbrook Road, Southampton SO1 0HX (0703 772501).

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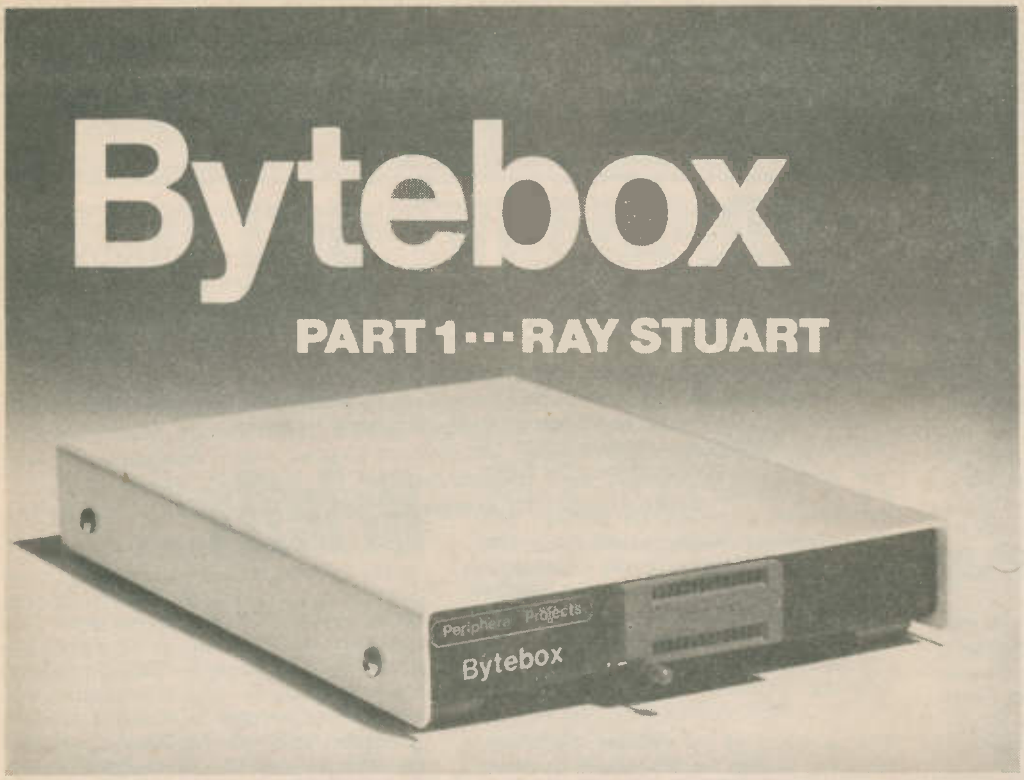
DID YOU KNOW that Prestel charge 6p per minute for computer time between 8 a.m. and 6 p.m., Monday to Friday and between 8 a.m. and 1 p.m., Saturday. However, at all other times the service is FREE.

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.

Personal Computer World Show Sept. 18–22. Olympia 2 **M**
Electron & BBC User Sept. 27–29. UMIST, Manchester **L**
Amstrad User Exhibition Oct 5/6th. Novotel **F2**
Computer Graphics Oct. 16–18. Wembley Conf. Centre. **O**
Cellular Communications Int. Nov. 5–7. Wembley Conf. Centre. **O**
Electronic Publishing Nov. 5–7. Wembley Conf. Centre. **O**
Compec Nov. 12–15. Olympia **K2**
Electron & BBC User Nov 14–17. New Horticultural Hall, London **L**
Computers In The City Nov. 19–21. Barbican Cntr. **O**
Scottish Home Computer/Electronics Show Nov. 22–24. Anderston Centre, Glasgow **W2**
Leeds Electronics Show Sept. 24–26. University **E**

A1 Inst. Electronics ☎ 0706 43661
E Evan Steadman ☎ 0799 26699
F2 Computer Marketplace (Exhibitions) Ltd. ☎ 01-930 1612
K2 Reed Exhibitions, Surrey Ho., 1 Throwley Way, Sutton, Surrey.
L Database ☎ 061-429 8157
M Montbuild ☎ 01-486 1951
O Online ☎ 01-868 4466
T1 Cahners ☎ 0483 38085
W2 Trade Exhibitions Scotland ☎ 041-248 2895



SINCE its introduction the BBC microcomputer has been widely accepted in education, industry and the home with over 400,000 units having been sold to date. This has given birth to a large quantity of software such as alternative languages to BBC BASIC, e.g. PASCAL, FORTH and LISP, and a wide range of utilities such as word processors, data bases, and machine code monitors. Much of the above mentioned software is only available in Read Only Memory (ROM) or Erasable Programmable Read Only Memory (EPROM). These are devices, programmed with the code for that particular utility, which retain their data when power is removed.

The BBC microcomputer is designed to support up to 16 of these ROMs, called "SIDEWAY (or PAGED) ROMs", numbered 0 to 15, but has only room for 4 such devices on its printed circuit board. BASIC and Disc Filing System (DFS) being the two commonly fitted ROMs. In order to allow the full complement of 16 ROMs to be available to the user, an additional printed circuit board has to be fitted to the BBC microcomputer.

This article describes BYTEBOX, a system that fulfils this and other requirements.

DESIGN PHILOSOPHY

The experiences and views of several users in education and industry as well as those of home users were considered when the design of BYTEBOX was undertaken. The system was therefore designed to allow simple installation with no soldering being necessary.

A second view expressed was that of overheating. Some people had found that the inside of their BBC microcomputer became too hot when an internal ROM board was fitted, particularly if it was also powering a disc drive and/or other peripheral devices. This they said caused "funny things" to happen after the computer had been switched on for some time. Some had cured this by running the BBC microcomputer with its cover removed. However, they found this impractical as they then tended to drop screwdrivers, coffee and the like into the exposed circuitry, sometimes with disastrous results. With this in mind the design allows the system to be housed in an external box of similar finish to the BBC microcomputer.

Most users said that they would, at some time, if not immediately, require some Random Access Memory (RAM) in their system. Some people required 16K of RAM, whilst others only wanted 2K or 4K as they found it hard to justify the £70 or so required for two 6264s. Others said that they wanted battery backed RAM with write protect facilities. In order to provide all these requirements it was decided to provide 16K of optional RAM as standard, but also to provide additional plug-in units for greater versatility. Whatever RAM was to be used it was considered essential that this would be automatically selected whenever the SIDEWAY memory area was written to. In addition the fitting of RAM onto the main board should not require links to be altered and still allow 15 ROM/EPROMs to be supported.

EPROMS

It is well known that the BBC's printed circuit board is designed for ROMs rather than EPROMs, with the result that some EPROMs from certain manufacturers will not function correctly. This is caused by incorrect, as far as EPROMs are concerned, termination of one of the ROM's pins. This was to be rectified in the design so that any make of EPROM could be used.

The inclusion of a Zero Insertion Force (ZIF) socket was thought to be a very useful addition, especially by users who evaluate or frequently change ROMs, who are developing their own or have more than 16 utility ROMs. This socket, which was to be accessible from outside the unit, was therefore included in the design specification.

The 27128 type EPROMs are expensive and sometimes difficult to find. However, 2764s are easier to find and the cost of two such devices is less than that for one 27128. An option was therefore included to allow two 2764s to replace one 27128.

In order to fulfil the first requirement, i.e. easy to install, it was necessary to find a suitable way of extracting all the required data, address and control signals as well as power via a single socket. As with all computers and microprocessor based systems it is the Central Processing Unit (CPU) that generates these signals. In the BBC microcomputer a 6502 microprocessor is used (see Fig. 1). There is only one socket in the BBC microcomputer from which all this information is available, namely, the 6502 socket.

The decision was therefore made to design a system in which the 6502 microprocessor is removed from the BBC microcomputer and located in the external system. This system is then connected to the BBC microcomputer via a 40-way ribbon cable which is plugged into the socket left vacant by the 6502.

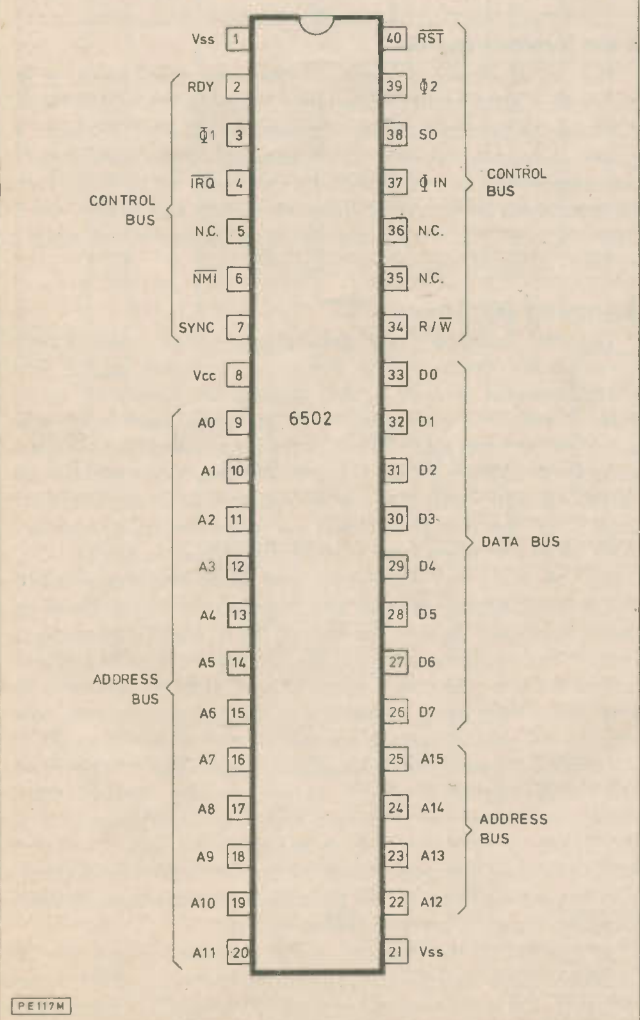
The additional circuitry necessary for the full complement of 16 ROM/EPROM/RAMs to be supported would impose unacceptable loading on the 6502 microprocessor's outputs. Therefore one of the design objectives was to buffer all address, data, and control lines used by the system. All of these objectives have been achieved in the BYTEBOX system described in this article.

SIDEWAY (or PAGED) ROM

Before BYTEBOX can be discussed in detail it is necessary to understand the concept of sideway or paged ROMs as they are sometimes called. The reason that they are called sideway ROMs is due entirely to their physical location within the BBC, in that they are located on the side of the printed circuit board, hence "SIDEWAY".

The BBC microcomputer is an 8-bit (one Byte = 8 bits) machine with 16 address lines that enable it to directly access 2^{16} (65,536) bytes of memory. This is normally called 64K bytes as 1024 is referred to as 1K. However, it can be seen that as each ROM can contain 16K bytes (if 27128 type devices are used) and, as there can be 16 such ROMs in the system the total memory contained by

Fig. 1. 6502 pin out details



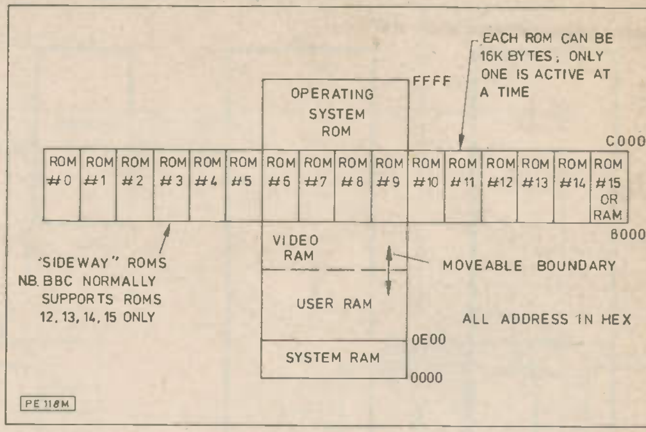


Fig. 2. The BBC Micro memory map

the ROMs alone is 256K bytes. This is far in excess of the address range of 64K. In addition, the BBC microcomputer has a further 16K of Operating System (O.S.) ROM and 32K of System RAM, thereby making a grand total of 304K of memory. How can this be so when it can only access 64K bytes?

The memory map of the BBC microcomputer is shown in Fig. 2. It can be seen that all 16 SIDEWAY ROMs in fact occupy the same memory area between &8000 and &BFFF. (Addresses are in Hex notation, a convention that will be used throughout the article and denoted by &). This is acceptable as only one ROM can be selected at any one time, thereby occupying the 16K bytes available. This can be likened to a book containing 16 pages, only one of which can be read at a time, hence the term PAGED ROMs.

In practice the BBC microcomputer may appear to use more than one ROM at a time, but what is in fact happening is that the Operating System is constantly switching between ROMs. For example, if one is running a program in BASIC (one ROM), it is possible to call a ★ command contained within another ROM; say ★CIRCLE in a graphics generator ROM. In this case the Operating System will find the graphics ROM, execute the ★CIRCLE command, and then return to the BASIC ROM. Whichever ROM is selected is called the "current ROM". The method by which the current ROM number is decided is complex and outside the scope of this article, but is well detailed in books such as *"The Advanced User's Guide"*.

ROMs and EPROMs have a pin designated "chip select" ($\overline{CS}$) which, when taken to logic 1 disables the device. This in effect removes that device from the system and it no longer plays an active role. However, if this pin is now connected to logic 0 the device is enabled and can now take an active role in the system. The trick therefore of having 16 ROMs in the system is to only enable one at a time.

In the BBC microcomputer this is achieved by arranging for a hardware 4-bit latch, located at address &FE30, to contain the number of the currently selected ROM. Only the upper two bits are decoded thereby limiting the number of useable ROMs in the BBC microcomputer to four. BYTEBOX, however, uses all four bits of its latch which are subsequently decoded to provide 16 chip select lines. The circuit is designed such that only one of these 16 lines can be at logic '0' at any one time, thereby preventing a number of ROMs trying to access the system at the same time.

BYTEBOX

BYTEBOX was designed as an external system, housed in its own case and taking its power from the host BBC microcomputer. The block diagram, Fig. 3, outlines the system design, with Fig. 4 showing the circuit in detail.

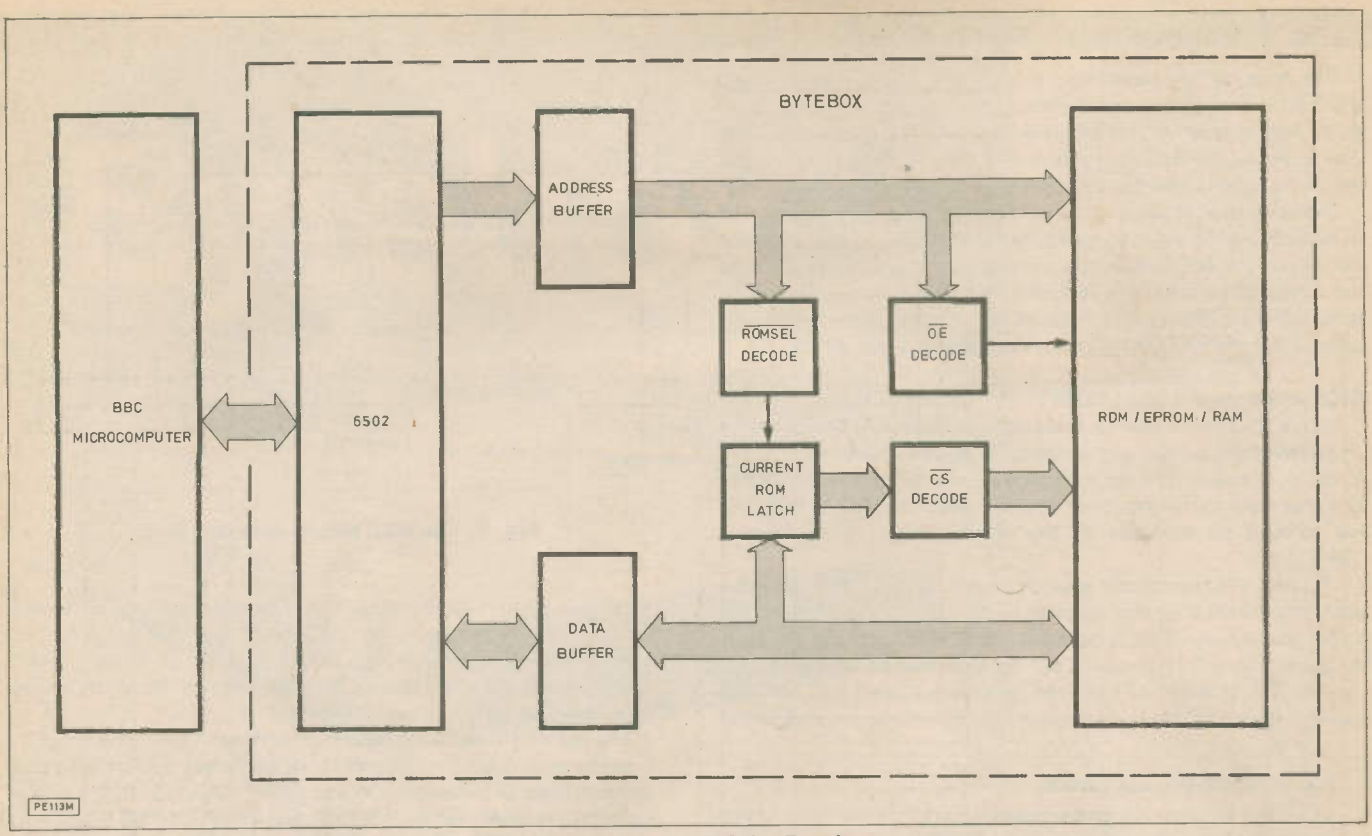


Fig. 3. Schematic diagram of the Bytebox system

BUFFERS

The main printed circuit board forms the heart of the system and contains all the buffers and decoders required to support the 16 ROM/EPROMs.

As mentioned above, the design philosophy requires that the 6502 microprocessor, normally located inside the BBC microcomputer, is moved onto this board. The BBC microcomputer is connected to the Romboard, via a 40-way ribbon cable that is plugged into SK1. The 6502 (IC1) is connected in parallel with this, thereby allowing all the signal lines to pass to the BBC microcomputer as normal. However, the signals required by the Romboard are also fed to a number of buffers to prevent the additional circuitry loading the original system.

It can be seen in Fig. 1 that the 6502 microprocessor has an output called R/W on pin 34. This signal is used to inform the remaining circuit of the data flow direction. This signal is buffered by two inverters, IC5a and IC5b, which are part of a 74LS04. The 6502 microprocessor also produces a clock signal Ø1 on pin 3, the inverted form of which is required later. IC5c is used to provide this whilst also acting as a buffer.

The sixteen address lines, A0 to A15, are fed to IC2 and IC3, two 74LS244 non-inverting tri-state buffers. In this design there is no need for these devices to be tri-stated therefore their mode select inputs, pins 1 and 19, are connected to logic '0'. Address information only travels in one direction, out from the 6502 microprocessor, so no flow direction information needs to be supplied to these buffers.

This is not the case, however, with the data bus (D0 to D7). The microprocessor not only needs to write data to the remainder of the circuit, but must also be capable of reading data from the memory devices. Therefore the type of buffer required, has to be bi-directional, with the direction of data flow being selected by the 6502 microprocessor. IC9, a 74LS245, is employed to provide this facility. The R/W line from IC5a is fed to the data bus buffer's direction control input, pin 1, to allow it to transmit data in the correct direction.

The circuit requires two sets of address decoders, one to enable the current ROM latch and the other to enable the ROM/EPROM/RAMs. First consider the decoding for the current ROM latch. As mentioned above the BBC microcomputer stores the number of the current ROM at address &FE30. However, the latch can in fact be addressed by any value between &FE30 and &FE3F, i.e. 16 memory locations. Normal convention is to denote this range by &FD3X, where X can be any hex value.

ADDRESS DECODING

The BBC microcomputer generates a signal called ROMSEL covering this range, but as this is not available on the 6502 microprocessor socket it also has to be generated on the ROMBOARD. This is achieved by using two interconnected chips, IC4 a 74LS30 and IC6 a 74LS138. The decode circuit and the bit code for &FE3X are shown in Fig. 5. The only time that the output for the 74LS30 NAND gate can be logic '0' is when all its inputs are logic 1. For this reason its inputs are connected to A5 and A9 to A15, all of which are logic 1 when the address is &FE3X. IC6, a 74LS138, is a 3 line to 8 line decoder which also has two active low and one active high chip select inputs. Only when these chip select inputs are valid will the data on the A, B and C inputs be decoded. The output from the 74LS30, is inverted by IC5f and fed to one of the low chip select inputs of the 74LS138, the other low chip select input being connected to A8, and the high chip select input to A4. All these inputs are valid when the address is &FE3X. A7 and A6 are both logic 0 for &FE3X which when combined with the R/W signal and the other decode circuit inputs mentioned above, will produce a logic 0 on the Y0 output of the 74LS138, i.e. A, B and C will all be logic 0. But why use the R/W line?. This is used to ensure that the current ROM latch is enabled only when it is written to. We have therefore reproduced the same ROMSEL signal as the BBC microcomputer.

In addition to the ROMSEL signal described above, the BBC microcomputer also generates an output enable signal OE. As with ROMSEL, OE is not available at the 6502 socket and therefore has

Fig. 4. Complete circuit diagram of the Bytebox system

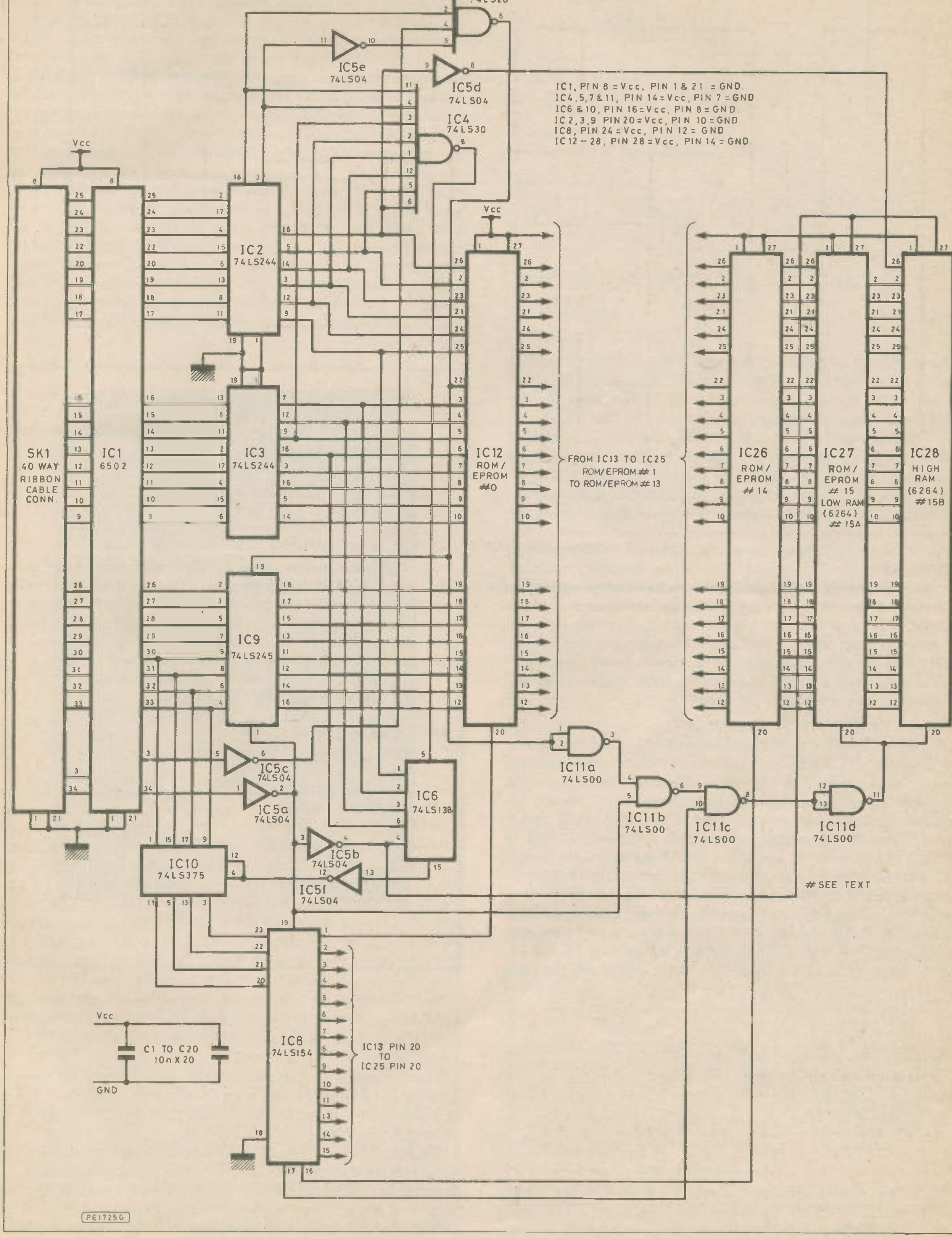
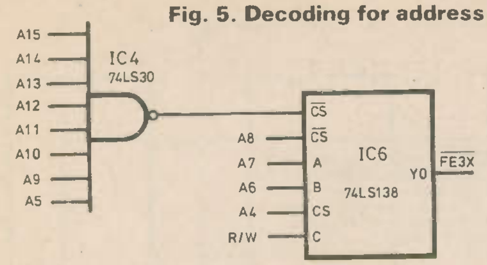


Fig. 5. Decoding for address &FE3X



A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
1	1	1	1	1	1	1	0	0	0	1	1	X	X	X	X
& F				E				3				X			

X = DONT CARE

PE115M

to be generated onboard. Fig. 6 shows the circuit and bit pattern relating to this ROM/EPROM/RAM enable $\overline{OE}$ output. This has to be valid for the address range &8000 to &BFFF as indicated by the BBC microcomputer's memory map (see Fig. 2). This is achieved by a 74LS20, a four-input NAND gate. Like the 74LS30, this chip has to have áll it inputs at logic 1 to produce a logic 0 at its output. Fig. 6 also shows the bit pattern for the address range &8000 to &BFFF. It can be seen that only A15 and A14 remain constant over the range, therefore only these two address lines need to be considered by the decoding circuitry.

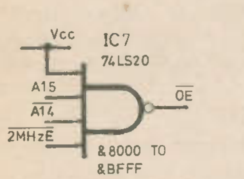
In the section on buffering it was stated that the 6502 generates a clock signal Ø1. This is also used by the decoding circuit to ensure that the ROM/EPROM/RAMs are accessed when the address and data lines are valid. In order to provide the 74LS20 with logic 1's on all its inputs it is necessary to invert the A14 line by means of IC5e, part of a 74LS04. The fourth input to IC7 is unused and is therefore tied to logic 1 to ensure correct operation.

We now have the two decoded address signals that are essential to the remainder of the circuit.

CURRENT ROM LATCH/DECODER

As stated above the BBC microcomputer writes the current ROM number into a 4-bit latch at address &FE3X, the data being present on the lower four data lines, D0 to D3. These four data lines are therefore fed to IC10, a 4-bit latch type 74LS375, and the $\overline{ROMSEL}$ signal described above is fed to its enable inputs, pins 4 and 12. Thus data is written into the latch whenever ROMSEL is active, i.e. whenever the address is &FE3X during a write cycle.

The outputs from the latch contain the current ROM number in hex form. However, 16 separate chip select lines are necessary as each of the memory devices requires its own chip select line. IC8, a 4-line to 16-line decoder type 74LS154, is therefore incorporated in the circuit. This device has two enable inputs, pins 18 and 19, which have to be at logic 0 before the device will decode the input



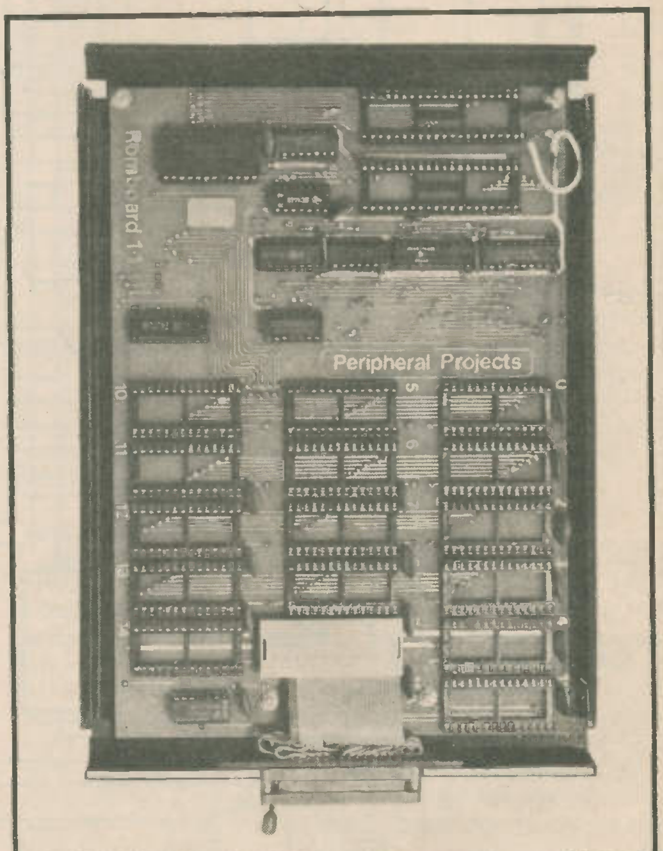
	A15	A14	A13	A12	A11 TO A0	
	1	0	1	1	1	HIGH ADDRESS
&	8				FFF	
	1	0	0	0	0	LOW ADDRESS
&	8				000	

PE116M

Fig. 6. Bit pattern for the enable output ($\overline{OE}$)

data. One of these inputs, pin 18, is connected directly to logic 0 whilst the other is connected to the $\overline{R}$/W line. When the system tries to write to the sideway memory, this signal is at logic 1. This disables IC8 thereby turning all the ROM/EPROMs off, which prevents data bus conflicts which would otherwise produce faults.

However, if RAM is fitted in the system it is necessary to generate a chip select signal for ROM/EPROM/RAM position 15 during a write cycle, for it is here that RAM will be located. In addition, this chip select line must be automatically generated irrespective of the value stored in IC10, the current ROM latch. It is therefore evident that some additional circuitry is necessary. To this end IC11, a quad two-input NAND gate type 74LS00, is incorporated. The output enable $\overline{OE}$ signal is inverted by IC11a and gated with $\overline{R}$/W line by IC11b to produce a signal, on pin 6, only when a SIDEWAY write cycle occurs. IC11c acts as an OR gate to combine the position 15 read select (from IC6 pin 17) and the write select (from IC11b pin 6) signals. Thus an active high chip select signal for memory read or write cycles is available for memory device 15. The memory devices require the chip select signal to be active low, the active high signal from IC11c pin 8 is therefore inverted by IC11d.



The three memory devices that can be used with the main printed circuit board are; the 27128 type (16K Byte ROM/EPROM), the 2764 type (8K Byte ROM/EPROM) and the 6264 (8K Bytes RAM).

It can be seen that they are extremely similiar, this is by design rather than accident, as they conform to a JEDEC standard. They only differ in 3 of their 28 pins, i.e. pins 1, 26 and 27. Pin 1 is not used by RAM or ROM but is by EPROM.

The BBC microcomputer's printed circuit board is designed to support ROM, consequently pin 1 is not connected. However, it is specified in EPROM data sheets that pin 1 must be connected to logic 1, if not spurious faults can occur. Some manufacturer's EPROMs are more prone to giving errors, when used in the BBC

COMPONENTS . . .

MAIN BOARD

Semiconductors

IC1	6502*
IC2	74LS244
IC3	74LS244
IC4	74LS30
IC5	74LS04
IC6	74LS138
IC7	74LS20
IC8	74LS154
IC9	74LS245
IC10	74LS375
IC11	74LS00
IC12–IC26	ROM/EPROM* (as required)
IC27	ROM/EPROM or 6264*
IC28	6264*

Capacitors

C1–C20 100n disc ceramic (20 off)

Miscellaneous

Printed circuit board; through link pins; i.c. sockets*; 40-way IDC d.i.l. connectors (2 off); 40-way ribbon cable; case*; insulated pillars.
* See text

6116 RAM BOARD

Semiconductors

IC101–IC108	6116 (8 off)
IC109	74LS138

Capacitors

C101–C105 100n disc ceramic (5 off)

Miscellaneous

Printed circuit board; i.c. sockets; 14-way plugs (2 off).

BATTERY BACKED RAM BOARD

Semiconductors

TR1,TR2	BC109 (2 off)
D201	OA47
IC201–IC202	6264 (2 off)
IC203	74LS00

Capacitors

C201	10µ tant.
C202	100n disc ceramic

Resistors

R201	1k5
R202,R203, R207	10k (3 off)
R204,R206	1k (2 off)
R205	4k7

Miscellaneous

P.c.b. mounted 3·6V battery; SW1 single pole p.c.b. mounted switch*; printed circuit board; 14-pin plugs (4 off); i.c. sockets.
*See text

2764 EPROM BOARD

Semiconductors

IC301–IC302	2764* (as required)
IC303	74LS00

Capacitors

C301–C302 100n disc ceramic (2 off)

Miscellaneous

Printed circuit board; i.c. sockets; 14-way plugs (2 off).
*See text

ZERO INSERTION FORCE (ZIF) SOCKET ASSEMBLY

28-pin Textool ZIF socket
28-way ribbon cable
28-way IDC d.i.l. connector*
Printed circuit board
* See text

Constructor's Note

All components, including EPROMS, printed circuit boards, case, or complete kits as well as ready built units are available from: **PERIPHERAL PROJECTS,** 25 Braycourt Ave, Walton-on-Thames, Surrey KT12 2AZ. Please send SAE for details.

microcomputer, than others due to the technology used to produce them. To prevent errors occuring in BYTEBOX pin 1 is connected to logic 1. Pin 26 on all EPROM and ROM is required to be at logic 1 for all modes other than programming EPROMs. As this system does not have provision for programming, pin 26 on all ROM/EPROM chips is tied to logic 1.

For RAM chips pin 26 is reserved for the R/$\overline{W}$ input. It can be seen that this pin is at logic 1 when a read is required, this is the same requirement as for the ROM/EPROMs. The result of this is that for position 15 (IC27) this pin is connected to the R/$\overline{W}$ line making it suitable for all three types of memory. Note: positions 0 to 14 (IC12 to IC26) will only support ROM/EPROM. IC28 is reserved for RAM only.

The 6264 device is an 8K Byte RAM chip, therefore to provide 16K bytes of RAM two are required (IC27 and IC28). As previously described, a chip select signal is available for either a read or write to these chips. A second chip select signal is therefore required to identify which of the two 6264s is to be enabled. Examination of the 6264 pinout reveals a second chip select input, pin 26, which in this case is active high. The A13 signal can be used to split the 16K memory block into two 8K halves. When A13 is logic 0 the lower half is addressed, and when it is logic 1 the upper half is addressed. All that is required therefore, is to feed A13 to pin 26 on one of the two 6264s, and $\overline{A13}$ to pin 26 of the other. $\overline{A13}$ is available from the output of the inverter IC5d. By using the above method 16K bytes of RAM can be inserted into position 15 without having to make any alterations to the board whilst still leaving space for 15 ROM/EPROMs.

NEXT MONTH: P.c.b. designs, constructional details and installation. Also battery backed-up RAM and alternative memory boards.

INDUSTRY NOTEBOOK

By Nexus

Jitters

Measured by investor confidence it was a long hot summer. The electronics industry lost its sparkle and this time round you couldn't say it was just a result of the old stock exchange maxim "sell in May and go away".

The collapse earlier in the year of Sinclair and Acorn started the rot. After all, these two enterprises had seen off a number of smaller competitors, had been profitable and looked sound enough until the PC market turned sour. Unhappily the investing public tends to equate highly publicised outfits in the consumer and entertainment sectors with the electronics industry as a whole. Rather like condemning the performance of a department store just because the toy fair had suffered a bad season.

Booms and busts are nothing new in the consumer market. The boom in video recorders in 1982 and 1983 had turned into a near slump by 1984 when deliveries to the trade fell by half. There is such a thing as saturation in any market and, when prices are falling, consumers hang back in the expectation of lower prices later on, or the novelty merely wears off.

The problems of the consumer sector of the industry were not confined to the comparative tiddlers. The giants with heavy consumer market business were also suffering. Philips in the UK had a record turnover, topping £1 billion for the first time, yet trading results showed heavy losses in 1984.

Then came warnings from chairmen of reduced profit expectations, not least from GEC and Racal. So electronic shares were marked down all round.

There were other factors which possibly contributed to a spasm of selling. Continued high interest rates, increasing wage costs, rising value of the pound, continued squabbling in the EEC, downturn in the US economy and uncertainty in oil pricing.

The mood of dejection persisted even when companies turned in good results. Cable & Wireless profits rose 29 percent from £190 million to £245 million but the share price was clipped by 20p. Ferranti profits were up 19 percent at £46 million and their shares dropped. Investment sentiment was decidedly nervous and made more so by gloomy news from Thorn EMI and STC.

It is exactly a year since I recorded on this page the purchase for £95 million by Thorn EMI of the Government holding in Inmos. My comment was that the Government was pleased to pass on a responsibility no longer welcome and to recover the taxpayers' investment. Last July Inmos announced redundancies both in the UK and USA. Also a year ago I was writing of STC's expansion plans which included the creation in STC of 3,000 new jobs. Alas, a year is a long time in the electronics industry.

Work Patterns

Scotland's Silicon Glen is a perfect example of a shifting pattern of employment in the industry. The workforce over a period of six years from 1978 to 1984 declined from 36,800 to 36,650 while output doubled and redoubled. As a proportion of the whole the unskilled operators employed fell in this period by 18 percent while scientists and technologists increased by 94 percent and technicians by 26 percent. Even the number of craftsmen declined by 9 percent.

Although electronics may be regarded as a special case this is not entirely so. According to John Cassels, director general of the National Economic Development Office, the pattern is generally the same throughout industry. In short, the unqualified will have little hope of employment.

The trend is confirmed by the scramble by progressive companies for new graduate intake with employment prospects firmer than for many years. One report claimed that 20 percent of vacancies for graduates were unfilled with the highest proportion in industry.

Another shift, this time at workbench level, is the no-strike, single-union workforce pioneered by the EETPU now under the able leadership of Eric Hammond. Universally hated by left-wing militants, he expects to double the number of no-strike deals by the end of the year.

His present membership is 365,000 but if a projected merger with the engineering workers and with the white-collar ASTMS can be agreed, then the new grouping would be 1.7 million strong. This could provide a powerful influence on the whole of the labour movement in its attitude to wealth creation and consequent security and prosperity for workers.

Even if no merger took place the electricians' example would remain that there are more sensible ways of conducting negotiations than walking out on the job which, in effect, is merely soiling one's own nest.

Pressing On

Despite difficulties in some sectors the electronics industry remains in good shape with plenty of major contracts being signed. The size of some of the orders brings the state of the industry into proper perspective.

Ten years ago the annual turnover of the Racal Electronics Group was just short of £80 million. In one three-month period up to mid-summer this year, Racal-Tacticom received orders for tactical radio equipment to the value of £81 million, and this for a single product line.

Marconi Radar in a £38 million deal is supplying an extension and update to the Sultanate of Oman's integrated air defence system. This is an enhancement of air defence capability with which Marconi was involved in 1976 and 1979.

Then there is a nice contract worth 150 million dollars to a consortium headed by British Aerospace. This is for a new generation of *Inmarsat* communications satellites. Almost without our noticing it ship-to-shore communications by satellite has had a healthy growth rate with 43 member states now participating. The first of the second generation *Inmarsats* will be ready for launch in 1988, as yet, it has not been decided whether the *Space Shuttle* or *Ariane* will be the launch vehicle.

Of course not all recent contracts are in the multi-million pound or dollar bracket but there are plenty of £1 million and upwards.

Electronics research is also healthy despite the chronic shortage of engineers. GEC has just drawn together into a single research company the three great but separate strands of the Marconi Research Centre at Great Baddow, the Hirst Research Centre at Wembley and the Engineering Research Centre at two locations in the Midlands. All the research effort will now be coordinated more efficiently in the new company, GEC Research Ltd.

The total complement of GEC Research is currently 2,500 people of whom 1,300 are scientists and engineers with first or higher degrees. Over 10 percent of the professionally qualified staff are women. Income of the company is some £60 million per annum, roughly one tenth of the total R & D spend within GEC.

There is good news for those who grouse about the Japanese who use the UK only as production units within the EEC. Matsushita, better known by the brand name Panasonic, is to set up R & D labs in the UK headed by an as yet unnamed British scientist.

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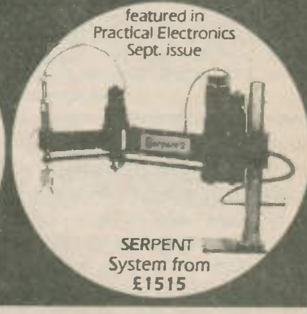

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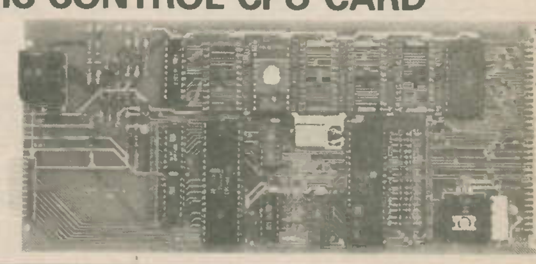

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Readout...

Confused

Sir—May I make a couple of suggestions for articles in your magazine Practical Electronics. The ideas spring from an excellent series of articles by Tom Gaskell, namely *Digital Design Techniques* which started in August 1981. Paragraph three in the introduction to the series says it all.

From a more theoretical understanding of digital electronics I am now able to design with confidence using the series as a "bible". Without this series I would neither have had the time, money and in some cases knowledge to sift through manufacturers' data sheets to extract the relevant information.

Suggestion one—I am rather confused by all the new logic families, so how about an up-date article giving relevant practical information set out in the same easily understood way of Tom's earlier article?

Suggestion two—As my designs get more sophisticated and use more i.c.s (my latest design for a burglar alarm so far contains 15 chips), the question of can I use a microprocessor instead raises its head. The answer must be yes, but where do I start? What are the practical hardware considerations to be taken into account, which is the best microprocessor to concentrate on, what about software—is it practical to use it to create large time delays, how about connecting a small key pad etc. etc?

I do not possess a microcomputer nor do I really want to, or learn a language. I understand '1's and '0's, i.e. machine code. Perhaps the first practical project for the series would be a "programmer" for entering the '1's and '0's in the ROMS.

I have a theoretical understanding of microprocessors but lack the practical knowledge (refer again to paragraph three in Tom's series).

I hope you will be able to use my suggestion.

Brian McWhinnie,
Glasgow.

Points taken—see Introduction to Microprocessor Systems *(page 20). How about that for service?*

Twenty Years of Stagnation

Sir—I welcome your editorial (July issue) on what appears to be the lack of development of "electronics" as a subject available within the curriculum of our secondary schools.

I speak as a mathematics/physics/electronics teacher with 25 years' teaching experience in Scotland and England and also on the continent and in Africa. Perhaps I am most concerned with what is happening, or rather not happening, here in Scotland, although I should say that I have an enlightened headmaster, himself a physicist, who was prepared to stick his neck out and introduce the A.E.B. 'O' level Electronics course in this school. Scotland, however, has a national policy, recently stated by the Scottish Education Department, NOT to introduce electronics as a separate subject, although Scotland is reputedly host to some 40 per cent of the European electronics industry.

It is very difficult to pin-point the reasons for this apparent apathy, or in some instances, outright opposition. I see some of them as follows:

(i) Electronics and microelectronics are somehow seen as synonymous with computing and microcomputing.

(ii) The government, in its wisdom, has seen fit to deluge schools, including primary, with computers. We now have perhaps more computers per capita in schools than any other country in the world—however, it is a known fact that the vast majority of these are underused or misused with the result that the average pupil's concept of the computer and its applications extends to being able to load a program from a tape or disc and spend countless hours playing 'Space Invaders' and similar mindless games, whilst the government and the majority of teachers think they are being exposed to 'electronics'—99 per cent will never see a transistor or a silicon chip!

(iii) These computers were largely introduced to mathematics departments where teachers rapidly became fluent in the new vocabulary without in most cases (not all, of course) having the faintest idea of how a computer works or the practical applications to which it can be put. "Interfacing" to them means 'plugging in another bit of hardware' and producing another bit of "magic". Teachers with applied science or engineering backgrounds were probably the last to be equipped with a computer—some are still waiting!!

(iv) Teacher training in this field (electronics) is grossly inadequate, probably because the trainers themselves don't have the skills. Regional education authorities no longer provide suitable in-service training or indeed refuse to allow teachers to attend such courses, even during their holidays, except at their own expense.
I myself was refused the funding to attend an excellent national course on interfacing, I was instead expected to become fully proficient, along with less experienced colleagues, in the art of interfacing by attending a 3-day "crash" course organised by my employees. When I tried to inquire into this policy, I was told that if I became better qualified I might leave and another regional authority would benefit!

(v) There is a very pronounced "no man's land" between the frontiers of pure physics and pure engineering in schools, and it takes a bold man to attempt to cross onto his neighbour's ground. Indeed, in many schools, teachers from either department are barely on speaking terms.
Again, I am fortunate in this respect. A few schools have successfully implemented courses in Technology where the fields of physics and engineering overlap.

(vi) Change in education in Britain is incredibly slow. Ten years is not uncommon—I was piloting a 16+ combined physics course in England in 1974—where are we now? We have thousands of working parties, consultative committees, pilot schemes etc. whereas with a little goodwill, common sense and adequate finance, even major changes could be introduced in a matter of months.
The teachers on the whole are willing. It is their masters, the bureaucrats, who no longer ever see a pupil or indeed who may never have seen one, who are responsible for the chaos in education today.
Opinions of practising teachers are sought, in the guise of "consultation", but it seems to me that these professional opinions are then all too often ignored. The end result is that unwanted changes are then introduced, resulting in a disgruntled, disillusioned and demoralised teaching profession.

A Clear Distinction

To conclude, I think it is high time that some or all of the following steps be taken to avoid the present chaos in education and to ensure that today's youngsters leave school prepared for the new technology without which this country will continue its headlong decline:

(1) A clear distinction must be made between "microelectronics" and "microcomputing".

(2) The government must ensure that adequate provision is made in the

school curriculum for microelectronics either as a separate subject or as part of physics or technology courses. In particular, more care must be taken to ensure that course choices are realistic so that pupils are not for example forced to make the choice between electronics and several other traditionally girls' subjects such as domestic science or secretarial studies.

(3) Resources must be made available, particularly when the expertise is to hand. It is pointless putting vast numbers of microcomputers in schools where there is no expertise and even less motivation.

(4) Teachers must be given the opportunity to re-train by attending in-service courses run by experienced, and preferably practising, teachers.

(5) Teacher-training courses in colleges must be up-dated so that at least some of the new entrants to teaching have some awareness of electronics. Far too many of the older generation of pure physics teachers are either 'afraid' of electronics or downright opposed to becoming involved.

(6) Finally, teachers' pay must be improved in order to attract suitable entrants. My 24 year old son, a graduate electronics engineer, has a far higher income than mine!

Andre H. G. Saunders, B.Sc.,
Kelso High School,
Roxburghshire.

Don't Bank on IT

Sir—As a member of a band of home computer constructors, which has a good newsletter, lots of software, including two BASICS and FORTH. I took the trouble to write to five top chip manufacturers asking for details and data sheets on various i.c.s, for instance, interfacing, real time clock, DAC's, etc.

The idea was to build up a "Data Bank" so members could get the information that they need to use that special chip. It may have even appeared as a newsletter article describing its function and use.

However, things went wrong as only one manufacturer bothered to reply; this was Ferranti, who supplied a good deal of useful information. In fact, I wrote again and they sent details of the ZN447–9 ADC's and the ZN1035E programmable timer (0·01 sec. to 3months) MPU bus compatible, to name but two!!—*Well done, Ferranti!*

To those who, like Motorola, Nat Semi, G.I., etc., who found it all too much trouble, I say shame on you; we the public are the ones who buy your products, you should keep us informed—it can only help your sales!

Lastly, to anyone out there in the manufacturing or retail business; like to send us data sheets or details? They would be most welcome!

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Introduction to MICRO SYSTEMS

MICHAEL TOOLEY BA **DAVID WHITFIELD** MA MSc CEng MIEE **PART 1**

THE MICROPROCESSOR began its life labelled by many as a solution in search of a problem. Since the early seventies, however, microprocessor systems have developed at a quite breathtaking pace. Indeed, hardly a day now passes without an announcement of some new way in which the microprocessor will revolutionise an aspect of our everyday lives. One consequence of this change is that there is now quite widespread awareness of the fact that microprocessors can do many things better, faster and/or cheaper than ever before. However, for most people a considerable mystery still surrounds the question: "What is a microprocessor and how does it work?".

Introduction to Micro Systems is a new *PE* series aimed at providing readers with a basic understanding of the concepts involved in using microprocessors. Examples of applications will be used wherever possible to make the series as relevant and meaningful as possible. The examples used will, as far as possible, be taken from the type of control applications encountered in everyday life.

At this point, we should explain that the term "micro" will be used in the series to mean microprocessor, not to be confused with a small/home computer based on a microprocessor (which we will think of as a microcomputer).

To cover the subject of micros in full detail would probably involve using all of the available pages in *PE* from now until some time in the next century. This is clearly not very realistic for an introductory series. Fortunately it is not necessary in order to give a basic appreciation of the fundamental concepts. Then, once the basics have been grasped, it should be possible to make use of the mind-boggling variety of books available on individual micros and micro techniques to answer detailed or specialist queries. This series is thus by way of an introduction to the subject of micros, and we will start by looking at a few of the basic concepts.

BASIC CONCEPTS

There are a number of basic ideas and techniques which inevitably come up sooner or later in any discussion of micros. Two which are fundamental to this series are digital logic and binary number systems. Regular readers will know that the former topic has been dealt with at some length in two previous *PE* series: *Introduction to Digital Electronics* and *Sequential Logic Techniques*.

For the benefit of new readers of *PE*, however, we will also be giving suggestions for suitable background reading as the series progresses. Before we start, however, it seems appropriate to briefly review some of these basic terms and concepts from the viewpoint of their use in this series.

Micros and micro systems are designed around electronic circuit blocks which operate on signals which can be in one of two stable states. These *binary* states are usually represented by two different voltage levels, and the circuits which manipulate them are referred to as logic gates.

In this series we shall be using positive logic notation, where the level closest to 0 volts is referred to as a logic 0, and the level furthest from 0 volts (usually close to the +5 volt supply level) is referred to as a logic 1. These logic levels are often referred to as simply 0 and 1, respectively. A typical range of voltage levels for these logic levels is shown in Fig. 1.

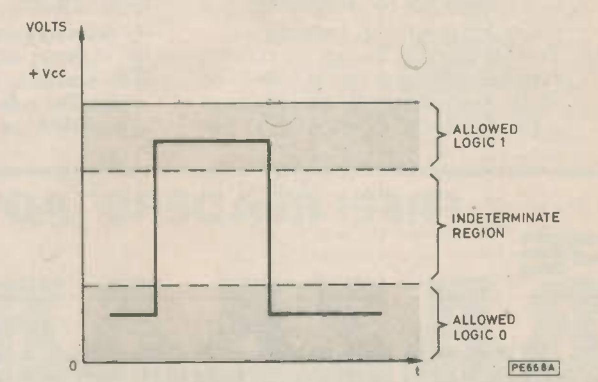

Fig. 1. Standard logic levels

Micro applications are frequently involved in counting or representing more than just two possible values or options, e.g. the temperature of a room may take a value from 0 to 30°C. It is clearly undesirable to have a different logic signal to represent each of the possible temperature values; in the example this would need 31 such signals.

Instead, the normal way of using the binary states of digital logic to represent a larger range of values involves the binary system of numbers. This provides a method of effectively coding a number of signals to represent a much larger number of combinations, and relies on the principle of binary numbers.

In the decimal number system, each digit can take one of ten different values (from 0 to 9). Each digit represents units of 1, 10, 100, 1000, etc, i.e. increasing in powers of 10. Thus, for example, the decimal number $325=(3\times100)+(2\times10)+(5\times1)$. In the binary number system, however, each digit can only take the values of 0 and 1. Each binary digit is known as a *bit* (a contraction of *bi*nary digi*t*), and the increasing bits in a binary number have values which go up in powers of 2. The decimal equivalent of the digits in a binary number are therefore, 1, 2, 4, 8, 16, 32, 64, etc. Thus, for example, the binary number 10101 has the decimal equivalent of: $(1\times16)+(1\times4)+(1\times1)=21$.

Using the binary system, therefore, a small number of logic signals can be used to represent a large number of different values, and in our temperature example, 5 bits (one signal for each) are enough to represent the temperature range. In fact, 5 bits would be enough to allow us to represent a temperature range of 0 to 31°C.

THE HEX SYSTEM

One problem with the binary system is that numbers can be cumbersome to write down, particularly for large values. Even worse, they are almost impossible to remember when they have a large number of bits; for example, 16 bits would be required for a decimal number of up to 65535. The *hexadecimal* system (i.e.

numbers in base 16), is therefore frequently used as a convenient and useful shorthand instead of binary.

A *hex digit* represents exactly four bits, and increasing hex digits count in units of 1, 16, 256, etc. To allow each digit to be expressed in only one character, the hex system uses the numeric characters 0 to 9 and A to F to represent the decimal values 0 to 15. The correspondence between decimal, binary and hex digits is shown in Table 1.

Table 1: Digit values

Decimal	Hexadecimal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

As an example of the advantage of hex, the decimal number 61680 has a binary equivalent of 1111000011110000, whereas in hex the equivalent is F0F0. Binary numbers in micros usually have a number of bits which is a multiple of four, typically 8, 16, 32 or even 64; eight bits is usually known as a *byte*.

LOGIC GATES

As has been mentioned, a logic gate is an electronic circuit whose input(s) and output(s) are all logic levels. The way in which the input and output signals are related depends on the logic function of the gate—a typical logic function (an AND gate) is shown in Fig. 2.

These gates are usually found in convenient groups in single *integrated circuits*, often referred to as "chips". The number of logic functions which can be put inside a single chip has risen steadily as technology has advanced, and the micro represents one of the most complex examples of this trend. Modern micros have the equivalent of many thousands of individual gates inside a single chip.

Digital systems are concerned with the processing of logic signals, and one of the most important elements in a digital system is the memory cell. Each cell is usually in the form of a "flip-flop", which is able to remember (or "store") the value of a single logic level (i.e. 1 or 0), even after the original signal has disappeared. There are many different types of flip-flop, depending chiefly on the way in which the storage action is to be triggered. However, the same basic storage principle applies to them all. The internal circuit for a typical MOS technology memory cell is shown in Fig. 3.

Groups of 8, 16, or 32 memory cells are often found inside micros. They are usually arranged so that all the cells in the group are loaded or cleared in the same operation. These memory cell groups are usually referred to as registers. When used in a register, all of the memory cells are usually loaded and cleared at the same time. Hence registers are used a great deal within a micro for storing binary numbers.

A CHOICE OF MICROS

Now that we have covered the basics for the series, it is time to start looking at some actual micro systems. As we have said, this is a series aimed at practical aspects of micros, and as such it is important that the examples are based as far as possible on real micros. The problem otherwise is that it can be difficult to translate the theory into practice. However, this raises the inevitable question: "Which Micro?" to use in the series.

The difficulty with this question is that there is no single answer which will satisfy the needs and preferences of everyone. Inevitably, different micros are often used in similar applications. At the other extreme, in many cases we may need to add to an existing system, where the choice of micro has already been made. Instead of settling on a single micro for the whole series, therefore, we will instead be using a number as the series progresses.

INPUTS		OUTPUT
0	0	0
0	1	0
1	0	0
1	1	1

Fig. 2. The AND gate symbol and its truth table

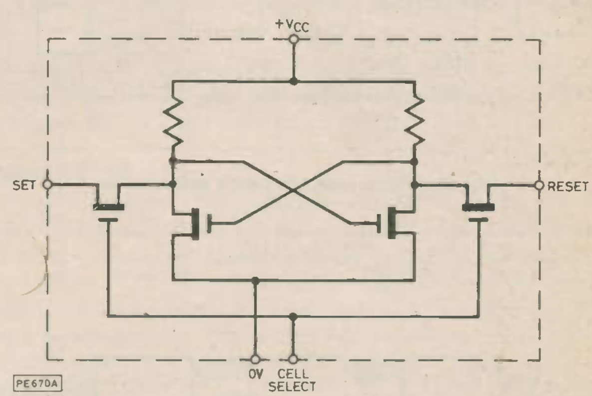

Fig. 3. A CMOS memory cell

We are starting with the Motorola 6800 micro, which although no longer quite in the "state-of-the-art" category, still has many points in its favour. Its clean and simple architecture is readily understood, and the micro is widely available with its range of support chips at low cost, e.g. the basic micro is now available for around £2 from a number of advertisers in *PE*. Once the principles have been grasped by studying the 6800, it is then a much easier step to move on to the later generations of micros. The other micros we shall be looking at will include the Z80, 6809 and 6502, all of which are used in popular home computers.

It is fashionable in certain circles to consider that 16-bit processors like the 68000 are *the* micros of today, and that nothing else is worthy of consideration. However, at around £30 for just the basic chip, these devices are still beyond the reach of the hobbyist;

even worse, they have often been the subject of early promises from imaginative manufacturers, who haven't even got samples available yet!

For around £10, on the other hand, it is possible to buy the chips off-the-shelf to build a complete 6800-based micro system. It is also true that many of the "simpler" micros are still better suited to the type of control applications found in everyday life than some of their more prestigious and sophisticated successors. It's not so much that the 16-bit machines wouldn't work in these applications, it's more a matter of their being a sledgehammer to crack a nut. After all, you would not consider using a Formula 1 racing engine to power a lawnmower. As the saying of the sage has it, a good designer is someone who can do for £10 what any fool can do for £100; a good point to bear in mind when reading of the attractions of the new wonder chips.

MICRO SYSTEMS

The internal organisation of a basic general purpose micro system is shown in Fig. 4 as a simplified circuit block schematic. An alternative way of representing this type of system, shown in Fig. 5, can be used to illustrate the typical information flow in a control application; the micro effectively forms the information switching centre of the system. We will be looking at each of the blocks in these schematics in greater detail as the series progresses, but for the moment a brief summary of each will be enough to get us started.

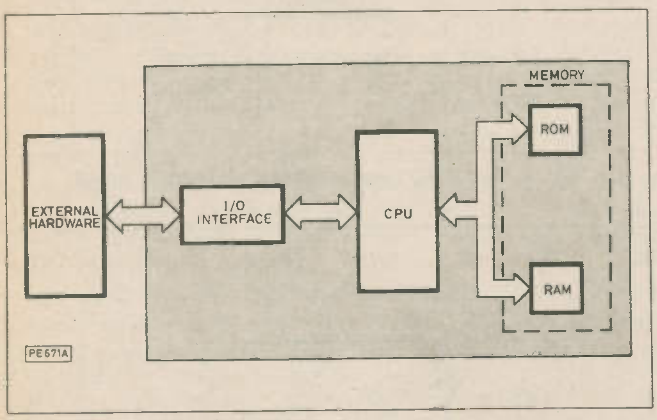

Fig. 4. Micro system block schematic

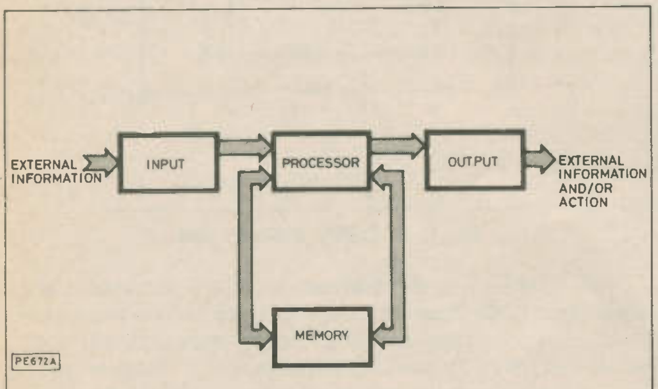

Fig. 5. Block diagram showing information flow

A micro-based system almost inevitably now consists of a number of interconnected integrated circuits. Fig. 4 shows these as including a central processing unit (CPU), memory for storing instructions and data, and some input/output (I/O) capability. These basic units are connected together by a series of buses which carry binary number values and control signals. The actual width of each bus (i.e. the number of bits used to represent a value) depends on the chip family (group of related chips) used to build the system, but typical values are 8, 16, 24 or 32 bits. The control signals are used to coordinate and control the correct operation of the system, and usually include various timing signals.

The CPU is the heart of the system. Its role is to execute arithmetic and logical functions in accordance with the program of instructions stored in the memory. In passing, it is worth noting the use of the short form spelling "program" as the accepted practice in the micro field.

The memory is an array of one-bit memory cells, which are usually arranged in groups of eight bits (bytes). In some micro systems these groups can be 16 bits (words) or even 32 bits (double-words), but internally they usually remain organised as bytes. This organisation means that each byte can store values ranging from 00000000 (decimal 0, hex 00) up to 11111111 (decimal 255, hex FF). Each byte is accessed by means of its location (its address) in the array, although only one byte can be addressed at a time. This memory organisation is illustrated diagramatically in Fig. 6.

Memory comes in two main types: read/write and read-only. The first type is known as random access memory (RAM), and is used to store, temporarily, data which is subject to change during the running of the program. In some systems, where more than one program may be loaded from an external store (e.g. programs loaded from a floppy disc into a microcomputer), the program is also stored in RAM. However, this is not common in control applications.

The second type of memory is read-only memory (ROM), which

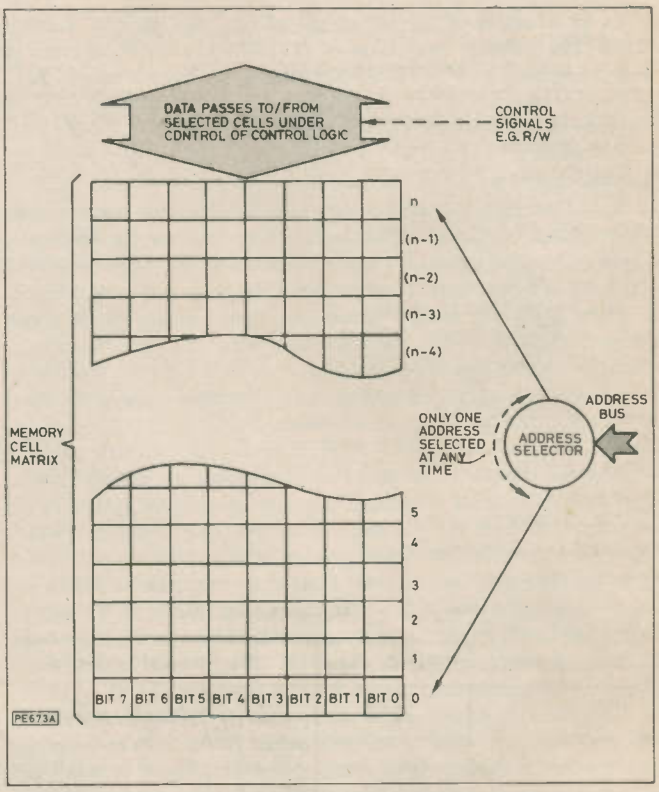

Fig. 6. Schematic diagram showing the organisation of semiconductor memory as a matrix of cells. Each address identifies a byte of data

is used to store fixed data and programs. The contents of the ROM must be "blown" during the development or manufacture of the system, and they cannot easily be changed thereafter. This permanent storage system means that the program is saved even when the power is switched off, and is immediately available at switch-on.

It must be stressed at this early stage that there is nothing physically stored in the memory which distinguishes program bytes from data bytes. It is only a matter of how the system is organised that determines how a byte is used, and it is not at all uncommon for the two to get confused during debugging; the results can be bewildering.

The system is here shown interfacing to external hardware, usually known as peripheral hardware. This hardware can take many forms, from the keyboard and display on the now-familiar home computer, to all sorts of control valves and switches, as might be found in a central heating system. The important point is that in a system of this type, the I/O forms the link between the micro and the real world. Without it, the micro would be confined to talking to itself. As you might guess, therefore, the range and ease of use of the I/O has a significant effect on the usefulness of any micro system.

Now that we have identified the major building blocks of a micro system, we can go on to look at each of them in a slightly more detailed way. Whenever we look at a new system, it is always a good idea to start by trying to identify the basic blocks just described. This then gives us a good start in the process of working out the system's basic structure. Once this structure has been established, it is then much easier to fill in the detail, already knowing how the major parts fit together.

A BASIC MICRO SYSTEM

A more detailed version of the type of system outlined in Fig. 4 is shown in Fig. 7. This system is based on the Motorola 6800 family, and represents a basic system of the type that might be found in, say, a home security system. As we go on to look inside the individual system elements in detail, it is useful to compare this schematic with the earlier one. This will provide a useful background against which to consider the workings of the individual components; the problem otherwise is that you can end up looking at the details of all of the parts of the system before you get any idea of how it works at all.

The sequence we are going to follow is typical of the order in which one might analyse a newly encountered system in order to work out how it is organised.

THE CHIP SET

The first step in analysing any micro system is a simple one, and it is to identify the micro family being used. This is usually found by looking at the larger chips' part numbers. Ignoring an alphabetic prefix (which is the manufacturer's identity code), the first two digits, and the number of digits in the part code usually give the best idea of the micro family, e.g. 68xx chips are from the 6800 family, 99xx are from the 9900 series. Once this is known, the appropriate manufacturer's data sheets can be consulted for further details. Table 2 gives examples of CPUs and typical peripheral chips from popular micro families.

Table 2: Micro Chip Sets

Manufacturer	CPU Device	Peripheral Devices
Motorola	6800	6821 (PIA), 6850 (ACIA)
Zilog	Z80	Z80-P10, Z80-SIO, Z80-CTC
MOS Tech	6502	(6522 (VIA), 6551 (ACIA)
Intel	8080	8253 (PIT), 8251 (USART)
Motorola	6809	Same as 6800
Intel	8085	Same as 8080
TI	9900	9901 (PPIO), 9902 (ACC)

As mentioned, the system in Fig. 7 is built around chips from the 6800 micro family. The CPU is the 6800 itself, and in the following discussion this should be viewed as the heart of the system. The memory shown is in two parts, one part is RAM (the 6810) and the other is ROM (the 6830). The I/O interfaces are provided by the

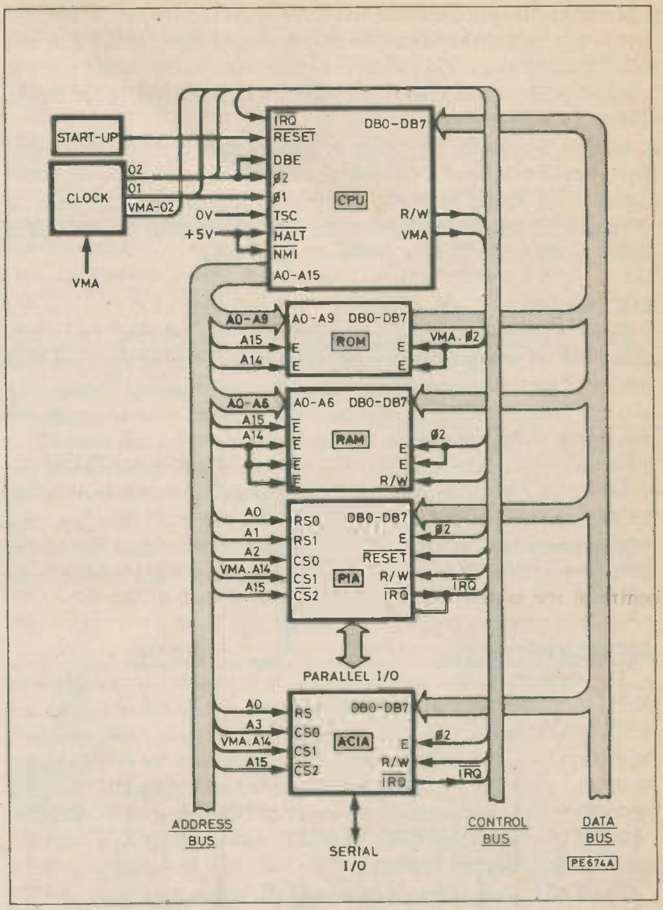

Fig. 7. System configuration for a system based on the 6800 CPU

6821 Peripheral Interface Adapter and the 6850 Asynchronous Communication Interface Adapter. The remaining elements of the system are the clock and the start-up circuits.

ADDRESSING

The CPU addresses the system devices (ROM, RAM, PIA and ACIA) via the *address bus*. The bus used by the 6800 is 16 bits wide, and is thus capable of addressing 65536 unique memory locations (hex: 0000 to FFFF). The individual lines are labelled from the least significant (A0) up to the most significant (A15) to indicate their binary significance, i.e. 2^0 to 2^{15}, respectively. Thus, for an address of F000, address lines A0–A11 are all set to logic 0, while lines A12–A15 are all at logic 1.

The address bus is a unidirectional bus which carries a 16-bit address value generated by the CPU to the remainder of the sytem. The devices on the bus are arranged so that only one responds to a particular address. To simplify the problem of a device recognising when it is being addressed by the CPU, individual devices are usually allocated blocks of consecutive addresses.

During the design or analysis of a micro system it is usual to draw out the allocation of addresses on what is usually called an address map. These maps show the whole addressing range of the micro, with address 0000 at the bottom and FFFF at the top for a micro with a 16-bit address bus. Blocks of addresses are then marked in to show how they are used, making it easy to identify any gaps or overlaps. Fig. 8, for example, is the address map for the system in Fig. 7. Although a very simple idea, an address map is an extremely useful tool in micro system design.

In smaller systems, the allocation of addresses to system units is usually arranged so that it is easy to detect which device is being addressed. For example, if addresses from 8000 (hex) upwards are allocated to the program memory, the most significant address bit (A15) can be used to select the ROM area, without looking at any other address lines. This helps to explain why not all of the parts of the system are connected to the whole width of the address bus in Fig. 7.

Indeed, by careful allocation of addresses, it is possible to avoid the need for special (address decoding) logic circuits in small systems. In larger systems, however, address decoding logic is invariably required because there are not enough address lines spare to allow this simple approach to be used.

DATA BUS

Once the CPU has addressed one of the system devices via the address bus, it needs a means of transferring data to or from that device. This is provided by means of the bidirectional *data bus*. In general, it is the width of this data bus which is used to categorise micros. In 6800 systems the data bus is 8 bits wide, and the 6800 is therefore referred to as an 8-bit micro; other examples include the 8080, 8085, Z80, 6809, and the 6502. The Z8000, 8086, and 68000, on the other hand, are examples of 16-bit micros. There is even a micro which has only a 1-bit data bus. The 8-bit data bus in the 6800 system thus allows one byte to be transferred at a time to/from the CPU.

MEMORY

The memory in this simple system is composed of one block of ROM and one block of RAM. Looking at the ROM first, this is a 6830 device, which has a capacity of 8192 memory cells, arranged as an array of 1024 bytes. In addition to the memory elements, the chip also includes a number of enable inputs to simplify address decoding. The configuration shown is arranged so that the ROM is mapped into addresses C000 to C3FF; address lines A14 and A15 are used to select the ROM.

The RAM block is provided by a 6810, which is an array of 1024 memory cells arranged as 128 bytes. The on-chip decoding is a little different from that in the ROM, but the result is the same. The RAM is mapped into addresses 0000 to 007F.

INPUT/OUTPUT DEVICES

The I/O devices in the system are connected directly to both the address bus and the data bus, and operate under program control. Each of them is controlled by a series of internal registers which appear as memory locations as far as the CPU is concerned.

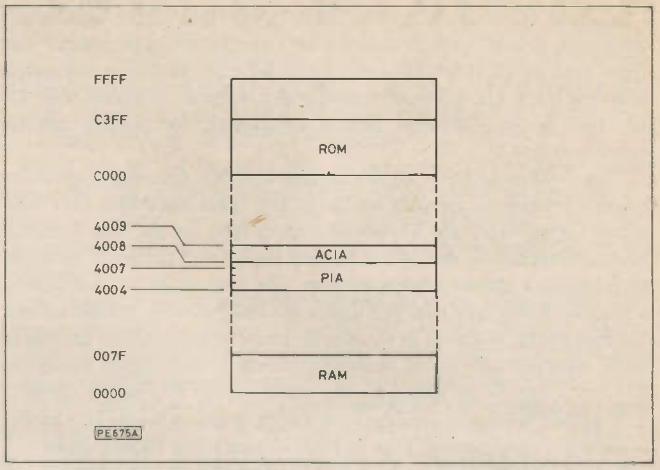

Fig. 8. Address map for 64k memory space

The various registers allow data to be transferred and control to be exercised over the interface. The six registers in the 6821 share addresses 4004-4007, while the four registers of the 6850 share addresses 4008-4009.

The 6821 Peripheral Interface Adapter (PIA) provides the system with a parallel connection to the outside world. The 6821 is a programmable device which gives the user the ability to set it up from a program to suit the particular application. This allows the 16 I/O lines to be used in whatever manner is appropriate to the application, e.g. one can be used for turning on a lamp (i.e. an output), while another may be used for detecting the tripping of a switch (i.e. an input). In addition, there are four control lines provided to allow the micro and the outside world to be synchronised.

The 6850 Asynchronous Communications Interface Adapter (ACIA) is the serial I/O equivalent of the 6821. This allows data to be converted from parallel form (as held in the memory and transferred on the data bus) into serial form as required in such applications as modems.

CONTROL SIGNALS

The final set of signals which pass around the system are for timing and control purposes. For example, because the data bus is bidirectional, an address in the RAM area could either mean that there is data on the bus to be written to that location, or that the data already in the location should be put onto the data bus. One of the signals (R/W), therefore, indicates whether the current address and data values refer to a read or a write operation.

Other signals on the control bus (which is not a bus in the true sense of the word) include signals to provide timing, reset the system, etc. It is also worth noting that in some cases, control signals may originate from outside the system shown in Fig. 7 —for example, interrupt requests and I/O "handshake" signals. However, we will be looking much more closely at these control signals when we study the 6800 CPU in detail next month.

A home computer (above) is an example of a microprocessor system. The machine shown is based on a standard 8–bit micro

NEXT MONTH: Having established some of the basic principles of micro systems, we move on to look in detail at the workings of the 6800.

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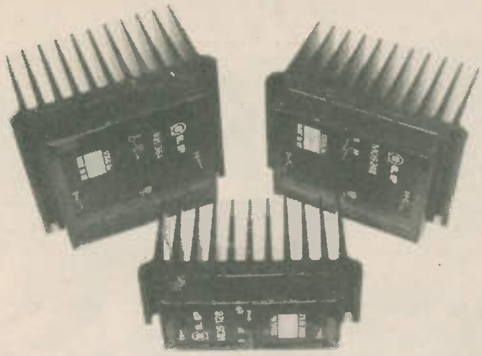

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Robotics Review

Nigel Clark

A MIDDLESBROUGH GP won the first Robat contest held as part of the European Personal Robotics Conference in London in July. Although the device of Dr John Marr failed in the aim of playing a game of robot table tennis it had potential according to the organiser, John Billingsley, and won Dr Marr a trip to San Francisco in September to take part in the U.S. finals of the competition.

. . resembled an anglepoise lamp which used a chip vision system . .

Known as Zillian, Dr Marr's device resembled an anglepoise lamp which used a chip vision system similar to the Snap system. The bat managed to make contact with the ball and made a hitting movement but was not able to control the direction the ball took after that. The bat also required some assistance in locating the ball by use of a joystick.

To help with his expenses in getting to the States, Dr Marr received £500, donated by Joe Bosworth, the founder of **RB Robot**.

In second place came John Knight and David Lowery of Fareham, Sussex, with Kung Fu, which combined a vision system of which Baird would have been proud and the combined power of a Dragon and Acorn Atom. Movement was provided by a spring, the bat being halted by a magnetic clutch.

Knight and Lowery represented Britain in the European finals in Brussels in August with the help of £100 from the Institute of Mechanical Engineers.

There were two other entries which lacked the precision of the others but contained the same amount of enthusiasm for the idea.

This was the first public showing of the devices, development of which began soon after the contest was announced by Billingsley at the beginning of last year. An earlier workshop was held to assess progress and swap ideas.

The competition has attracted a lot of interest from throughout the world but to date working devices are thin on the ground. Billingsley said that **ATT** in the States had been working on the idea but with the help of a Puma and Vax which he thought was overdoing it a little.

. . Robat was already ahead of the Micromouse . .

He added that the signs for the future were encouraging. Robat was already ahead of the Micromouse contest, which he also organises, at the same stage.

His major problem is now finding a venue for future contests. Anyone organising an exhibition in May or June next year, who would like to offer space for the Robat and Micromouse contests should contact Billingsley at Portsmouth Polytechnic.

Four new robots arms were unveiled at the Education, Training and Development Exhibition held at the NEC in the summer.

The most unusual was the HS3 Tracer Robotic System from **LJ Electronics**. It is based on the concept of an XY plotter but instead of a pen it has a small gripper which moves up and down to pick and place.

At a cost of about £600 it comes with a p.c.b. assembler kit and, in case you should want to use it as a plotter, a pen carrier and three coloured pens are also supplied. It is described as a robotic table rather than an arm.

The drives for the X and Y axes are stepper motors while d.c. motors power the up and down movement and the gripper. The company says the table was developed to be used with a vision system. It was felt that a system suitable for a normal arm was unnecessarily complicated. Restrict the area of operation and the vision system, which will be supplied in the future, can be simpler.

Max-1 marks the entry of **Flight Electronics** into the robot market. At a price of £399 plus VAT it resembles a larger version of the Ogre with a similar robust construction.

Max-1 has three axes, waist, shoulder and elbow, plus a gripper all powered by d.c. motors with optical feedback. The drive transmission to the three axes is by metal worm gears with the gripper using a lead-screw.

With the arm fully extended Max-1 is said to be able to lift 4lbs. It is to go on sale in the autumn when more details will be available.

Another machine with an autumn launch is the latest in the ever increasing range from **Cybernetic Applications**. In keeping with the names of its other products, this one is called Naiad, a water nymph, as it is hydraulically powered, using water.

. . cylinders are made of see-through acrylic . .

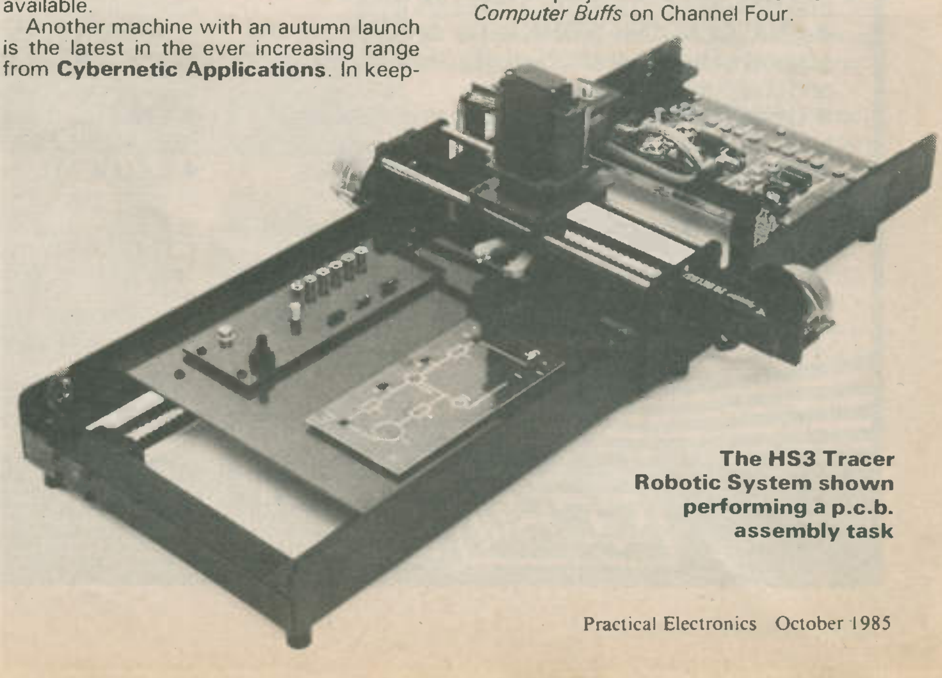
It has five axes plus a gripper with the axes powered by different kinds of hydraulic piston. The gripper is pneumatically-powered. All the cylinders are made of see-through acrylic so that students can see how they work.

Control is possible using all the normal micros, including C64, Apple, IBM PC and BBC B. It is also intended to have a model controller as do the rest of the company's arms. A price has yet to be fixed but it will be less than £1,000.

Finally, anyone with £8,250 plus VAT might be interested in the latest arm from **TecQuipment**, the MA3000. It does not have the sophistication of its smaller companion, the MA2000, but is larger and more rugged and is intended for colleges which would normally be looking at the Puma to do a similar job. It has a reach of 750mm, can lift 2kg with an accuracy of 3mm. Powered by d.c. motors, with potentiometers, it has nine speeds, five axes plus a pneumatic gripper and is controlled by a BBC B.

If you have an old ZX-81 gathering dust in a cupboard and you are wondering what to do with it there is a kit supplied by **Maplin Electronic Supplies** for £50 which will allow you to turn it into a simple line follower. The kit contains the electronics on three p.c.b.s, two d.c. motors and an infra-red sensor for line following.

Known as Trundle it was developed as a school project and was featured on *4 Computer Buffs* on Channel Four.



The HS3 Tracer Robotic System shown performing a p.c.b. assembly task

all in your **NOVEMBER** issue!

NOVEMBER ISSUE ON SALE, OCTOBER 4

TOUCH controlled PSU

R.A.PENFOLD

THE idea for this power supply came about as a result of the author occasionally connecting a new circuit to the bench power supply, switching on, and then discovering that the output voltage was too high. It had been left at the 25V or thereabouts required for the previous session, whereas the new circuit required 5V or 9V. It is surprising just how many semiconductors can be instantly destroyed by this occurrence. What is needed to combat this problem is a supply that always starts at zero volts when it is switched on, with the user then having to set the required output potential before using the unit. With this system it is obviously impossible to damage components at switch-on due to an excessive output voltage.

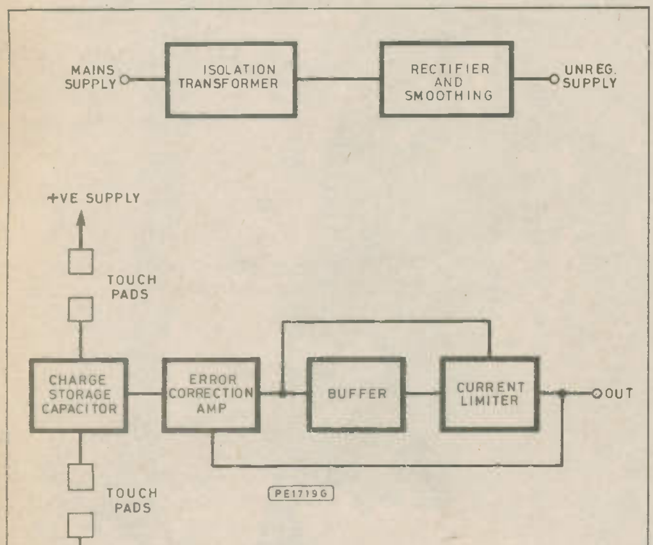


Fig. 1. Block diagram of the Touch Controlled PSU

Using a very simple system this power supply provides zero volts at switch-on. The output voltage is controlled in a novel way, with a set of touch contacts being used to increase the output voltage and a second set being used to decrease it. A built-in meter indicates the output voltage so that the desired potential can easily be set. This may seem to be a rather gimmicky way of doing things, but it does in fact provide good results with low output noise and good regulation, and is a perfectly practical approach.

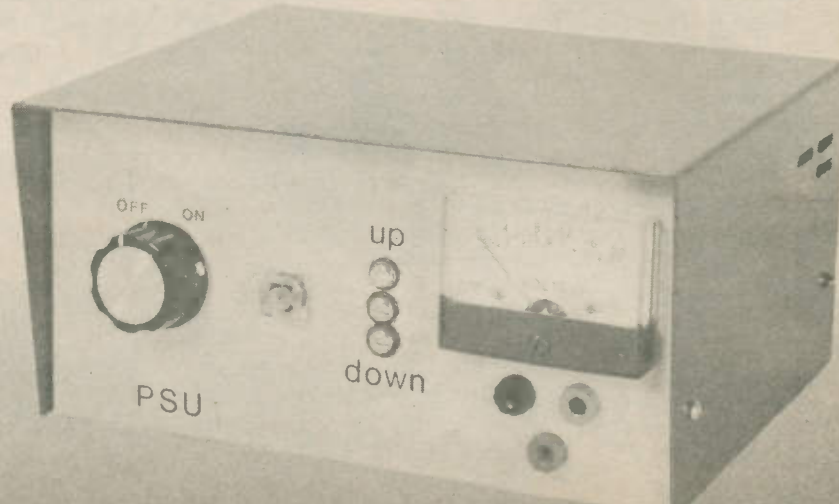
The supply has a maximum output current of 1A, and current limiting protects the unit against output short circuits and other overloads. The output voltage range is from 0V to 20V, but the full 1A output can only be supplied at output potentials of around 17V or less. This voltage range and current rating is adequate when developing and testing the majority of circuits, including such things as 5V logic circuits, 9V battery powered projects, and 12V car projects. Measured at an output potential of 10V, the regulation is better than 1% and the output noise is under one millivolt peak to peak at all output currents.

SYSTEM OPERATION

The first requirement is to derive an unregulated d.c. supply from the mains supply. A regulator circuit fed from this supply is then used to reduce the output potential to the required figure and to provide accurate stabilisation. The unregulated voltage under full load must be a few volts more than the required maximum output voltage. The extra voltage is needed to compensate for losses through the regulator even at maximum output voltage. Also, there is likely to be a substantial amount of ripple on the unregulated supply, and the voltage at the bottom of the ripple waveform must be sufficient to maintain the maximum output voltage after the voltage drop through the regulator has been taken into account.

A transformer is used to step-down the mains voltage to a more suitable level, and the transformer also provides isolation from the dangerous mains supply. A rectifier provides full wave rectification of the transformer's a.c. output to produce a pulsating d.c. supply. This is reasonably smoothed by a high value capacitor. However,

"Touch-Up" and "touch-down" control



at high load currents the ripple content will still be at least a few hundred millivolts peak to peak, and the electronic smoothing provided by the regulator circuit is essential if a low noise level on the output is to be achieved.

In order to obtain a well regulated output voltage a highly stable reference voltage is needed. The basic action of the circuit is to stabilise the output at the same potential as the reference source, and we therefore require a reference voltage that is adjustable over a range of about 5V to 20V. In a conventional power supply unit this voltage is provided by a potentiometer fed from a simple Zener stabiliser circuit. In this case we are using a charge on a capacitor as the reference source. Operating one set of touch pads feeds a current into the capacitor from the positive supply rail and increases the charge voltage (and therefore the output voltage as well). Touching another set of contacts gradually discharges the capacitor into the negative supply rail, causing the charge potential and output voltage to fall.

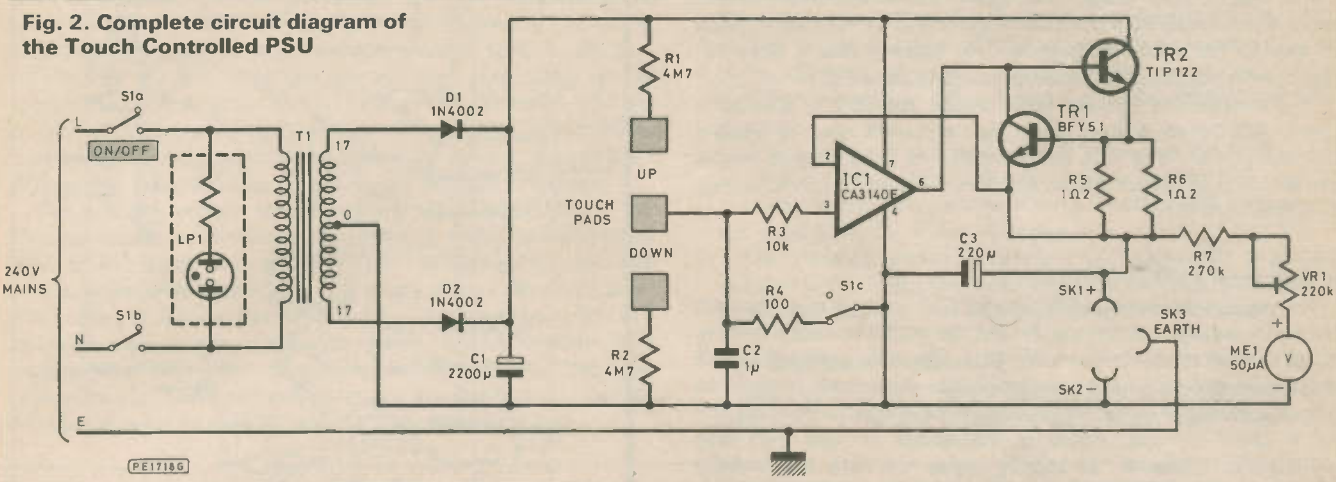
SWITCH-ON

At switch-on the charge on the capacitor is zero, and the initial output from the power supply is consequently zero volts as well. Although the circuit may seem to lack a voltage regulator, the voltage across the capacitor is in fact very stable, and is totally unaffected by noise on the unregulated supply, or any voltage variations on this supply caused by loading or fluctuations in the mains voltage. In the long term the charge on the capacitor will leak away, mainly due to slight imperfections in the capacitor itself, but provided a good quality component is used the charge voltage will not change significantly for an hour or more. This supply could not be recommended for applications that require a highly stable supply to be maintained for many hours at a time, but few amateur users will require this feature.

The reference voltage is fed to one input of an error correction amplifier. The output of this amplifier drives a buffer stage which enables high output currents to be accommodated. The other input of the error amplifier is fed from the output. The purpose of the amplifier is to compare the output voltage with the reference voltage, and make any correction necessary to balance the two signals. This is really just a simple negative feedback system.

It is important for any bench power supply to have protection against damage due to the inevitable short circuits and general overloads on the output. The most common form of overload protection, and the one incorporated in this design, is current limiting. The current limiting circuit at the output monitors the output current, and has no effect if the current is less than one amp. If the output current significantly exceeds this figure a transistor is switched on and pulls the output of the error amplifier lower in potential. This prevents any significant rise in the output current, and even with a short circuit on the output little more than one amp flows since the transistor is then switched on so hard that it pulls the output voltage down to practically zero. Note that the current limiter circuit is included within the negative feedback loop so that the feedback compensates for any small voltage variations caused by this circuit during normal operation. Of course, when the current limiter comes into action it overides the feedback action by "crowbaring" the output of the error correction amplifier.

Fig. 2. Complete circuit diagram of the Touch Controlled PSU



CIRCUIT OPERATION

The full circuit diagram of the Touch Controlled Power Supply is shown in Fig. 2.

T1 is the mains transformer and the mains supply connects to its primary winding via an on/off switch, S1. The output of T1 is rectified by D1 and D2 which make up a conventional push-pull type fullwave rectifier circuit. C1 is the smoothing capacitor.

C2 is the charge storage capacitor. In order to set the output voltage accurately it is necessary to have quite slow charge/discharge rates, but on the other hand the rates must not be so slow that it takes a long time to make large changes in the output voltage. R1 and R2 are used to limit the charge and discharge rates respectively to a suitable compromise, and it takes typically about seven seconds to take the output voltage from zero to 20V. The precise time taken depends on exact component values, and also on the skin resistance between the touch contacts (usually about 1 megohm or so). S1c is used to discharge C2 when the unit is switched off, thus ensuring that no residual charge remains when the unit is switched on again. R4 provides current limiting to protect S1c against sparking at the contacts and eventual failure.

SPECIFICATION

Input	Mains 240V a.c.
Output voltage	0 to 20V regulated
Output current	1A max.
Regulation	1% at 10V
Noise	1mV pk-to-pk
Control	Touch plates
Indication	Neon, meter

IC1 is the error correction amplifier and this is just an operational amplifier used in the non-inverting mode. Protection resistor R3 couples the voltage on C2 to the non-inverting input of IC1. The output of the power supply connects direct to the inverting input of IC1 giving 100% negative feedback and the required overall unity voltage gain. IC1 is a type which has an output stage capable of providing output voltages almost right down to the negative supply potential. This is important as it enables IC1 to function properly without having to provide it with dual supply rails. IC1 also has a PMOS input stage, and again, this is important in this application. The PMOS input stage gives IC1 an input impedance of around 1·5 million megohms. This ensures that it does not significantly discharge C2 even over a long period of time.

TR2 is an emitter follower buffer stage. The TIP122 is in fact a power Darlington device which has a current gain of several thousand times. It is thus easily capable of producing an output current of up to one amp from the drive current of a few milliamps available from IC1.

OVERLOAD PROTECTION

The parallel resistance of R5 and R6 (0·6 ohms) is in series with the positive output of the supply, and the output current therefore flows through these components. This generates a voltage across them, and this voltage is proportional to the output current. At output currents of up to 1A the voltage developed across R5 and R6 is 0·6V or less, which is inadequate to bias TR1 into conduction. However, at slightly higher currents this voltage becomes large enough to bias TR1 into conduction. TR1 then diverts some of the output current from IC1 to earth through the load, pulling its output voltage lower in the process. However hard TR1 conducts it is not possible for it to reduce the output voltage of IC1 to zero, and on the face of it a short circuit across the output could still cause a massive current to flow. In practice this cannot happen as there is a voltage drop of about 1V or so through TR2, and this enables TR1 to pull the output potential down to a level that prevents more than about 1·2A from flowing even with a short circuit on the output.

C3 provides final smoothing of the output and also aids good stability. R7, VR1, and ME1 form a simple voltmeter circuit which is used to monitor the output potential of the unit. VR1 is adjusted to give the meter a full scale value of 20V. A separate earth socket (SK3) is provided so that either output of the unit can be earthed, but neither output need be earthed. In practice it is advisable to earth one or other of the outputs unless a floating supply is essential. Apart from the improved safety this also helps to minimise breakthrough of radio frequency signals from the mains supply to the output.

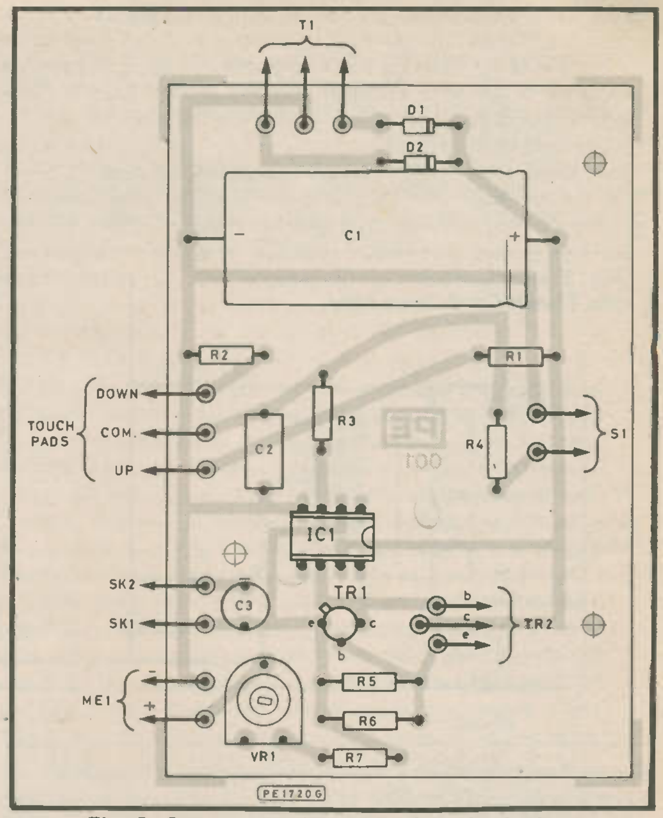


Fig. 3. Component layout and p.c.b. design

CONSTRUCTION

Start construction by fitting the components to the p.c.b. following the component layout of Fig. 3. C2 must be a carbonate capacitor or some other high quality plastic foil type, and should not be an electrolytic or even a tantalum bead capacitor. Only a good quality plastic foil type will have a sufficiently low leakage level to give good results in this circuit. It must also be a miniature printed circuit mounting type if it is to fit onto the board without difficulty.

As IC1 has a MOS input stage it requires the usual MOS antistatic handling precautions. It should be fitted in an 8-pin d.i.l. integrated circuit holder, but it should be left in the protective packaging and should not be plugged into circuit until the unit is in all other respects finished. Fit pins to the board at the points where off-board connections will eventually be made.

COMPONENTS . . .

Resistors

R1, R2	4M7 (2 off)
R3	10k
R4	100
R5, R6	1Ω2 ½W 5% (2 off)
R7	270k
VR1	220k sub-min horizontal preset

All ¼W carbon 5% unless noted

Capacitors

C1	2200μ 35V axial elect.
C2	1μ carbonate
C3	220μ 25V radial elect.

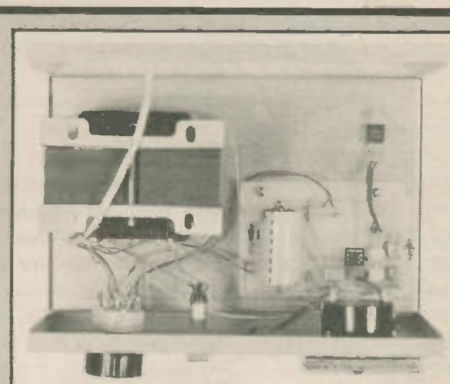
Semiconductors

D1, D2	1N4002 (2 off)
TR1	TIP122 *npn* power Darlington
TR2	BFY51 silicon *npn*
IC1	CA3140E MOS op.amp

Miscellaneous

ME1	50μA panel meter
SK1, 3	4mm sockets (3 off)
T1	Mains primary, 17-0-17V 2A secondary
LP1	Panel neon with integral series resistor
S1	4-way 3-pole with adjustable end stop

Metal instrument case about; 200 × 150 × 100mm; Printed circuit board *PE PCB Service*-100; Control knob; Touch contacts; Mains lead and plug; 8-pin d.i.l. i.c. holder; Plastic power transistor insulating kit; Soldertag, grommets, wire, pins, etc.



A metal instrument case having approximate outside dimensions of 200 by 150 by 100 millimetres is about ideal for this project. It is not essential to use the specified type, but the case must be of all metal construction, and it must have sufficient internal height to accommodate the mains transformer.

The front panel and internal layouts of the prototype can be seen from the photographs and it is advisable to keep to these general arrangements. The mains transformer is mounted on the chassis or base panel, and a solder tag is fitted on one of the mounting bolts to provide a chassis connection point for the mains earth lead. The mains transformer fitted to the prototype is a type having twin 17V, 2A windings which are connected in series to act as a 17V-0-17V winding. The unit should work well using similar transformers, such as an 18V-0-18V type rated at about 1·6A, or a twin 20V component rated at 1A or more and suitably connected. Do not use a transformer having a rating of more than 20V as this could produce an excessive unloaded voltage.

TR2 and the printed circuit board are also mounted on the chassis or base panel. The printed circuit is mounted using three 6BA or M3 bolts, and spacers must be included to hold the connections on the underside of the board clear of the metal case. The chassis or case acts as a heatsink for TR2. As its heat-tab connects internally to the collector terminal it must be insulated from the chassis or base panel using the appropriate (plastic T066) type of insulating kit. Use a continuity tester or a multimeter set to a high resistance range to ensure that TR2 is properly insulated.

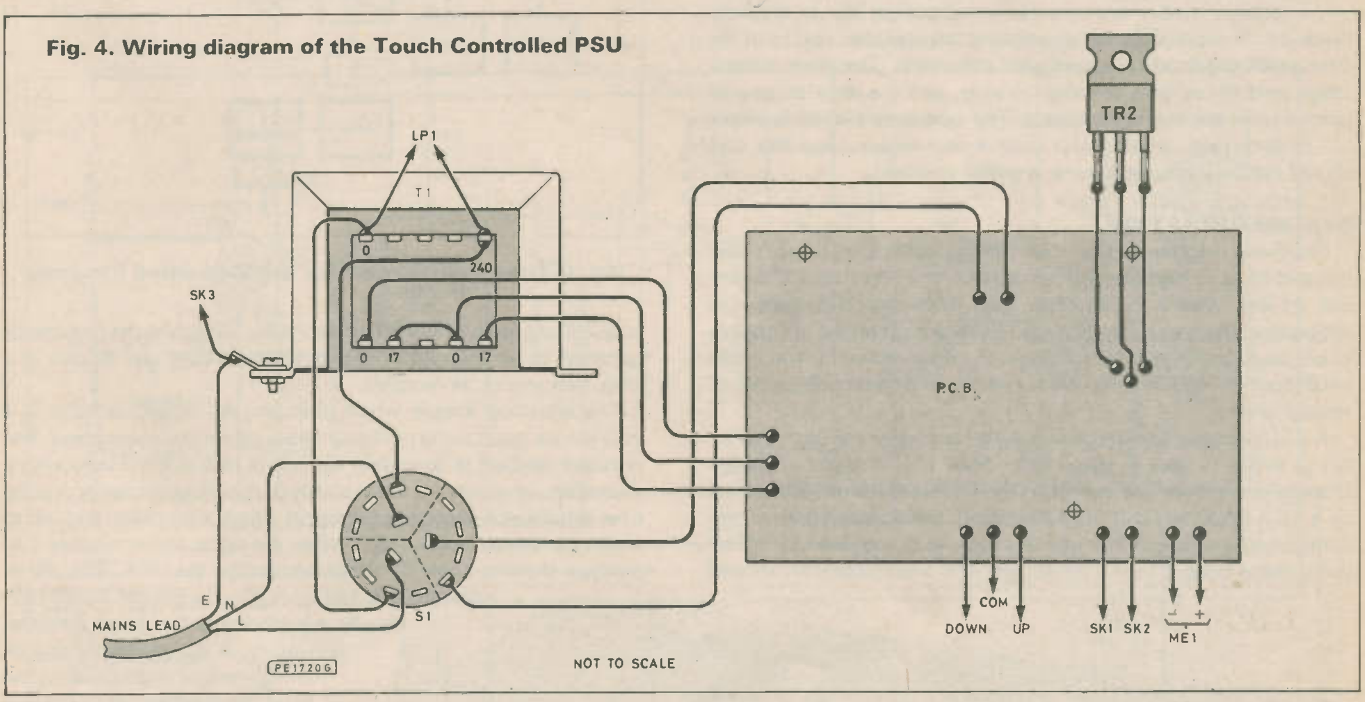


Fig. 4. Wiring diagram of the Touch Controlled PSU

Mounting ME1 might prove a little difficult as most panel meters require a main mounting hole some 38 millimetres in diameter. Probably the easiest way of making this is to use a fretsaw, but if one of these is not available a simple alternative is to drill a ring of small, closely spaced, holes just within the border of the required cutout. A needle file can then be used to join up the holes, after which a large half-round file is used to tidy up and enlarge the cutout as necessary. The meter itself can be used as a sort of template when marking the positions of the four small mounting holes.

Either proper touch pads can be obtained, or M4 panelhead screws can be pressed into service. In either case soldertags must be fitted under the mounting nuts to enable connections to be made to the contacts. It is obviously essential to insulate the contacts from the case, and this can be achieved by mounting small grommets on the front panel and then mounting the contacts in these. An alternative would be to mount the contacts on a piece of plastic sheet, and then glue this in place on the front panel. Cutouts for the contacts would, of course, have to be made in the front panel. Whatever method is adopted, mount the contacts as close together as possible, otherwise they will be inefficient and difficult to use.

A hole for the mains lead is made in the rear panel of the case and this should be fitted with a grommet to protect the cable. S1 is a 4-way 3-pole rotary switch having an adjustable end stop, and the latter is set for 2-way operation.

The unit is completed by adding all the hard-wiring, and this is all detailed in Fig. 4. As the mains supply is involved, take great care when wiring up the unit, and thoroughly check for errors.

ADJUSTMENT AND USE

Start with VR1 at about half maximum resistance and then switch on. If the unit is functioning properly there should be no significant deflection of the meter at this stage. By operating the "up" touch contacts it should be possible to build up the output voltage and obtain a strong deflection on ME1. By operating the "down" contacts it should be possible to take the output voltage back down to about zero again.

In order to calibrate the output voltmeter, a multimeter set to a suitable d.c. voltage range should be connected across the output of the unit and the output voltage is then set as accurately as possible at 20V. VR1 is then adjusted to give precisely full scale deflection on ME1. Ideally the scale plate of ME1 should be carefully removed so that the 0 to 50 scale can be replaced with a more convenient 0 to 20 one, using rub-on transfers. Meter movements are very delicate and great care must be taken if a new scale is fitted to ME1. ★

Modulated Syndrum

R.A.Penfold

THE CLASSIC and much-used syndrum sound is a falling pitch effect, usually over a high- to middle-frequency range. Most syndrums are actually capable of producing a range of sounds, but the basic effect is the same with only the frequency range and duration being variable. This syndrum design takes things a step further and in addition to the standard syndrum effect a modulated falling pitch sound can be generated. In other words, instead of a straightforward fall in pitch the tone can be made to vary up and down, with an overall fall in pitch.

This enables some interesting sounds to be generated, and the unit is certainly much more versatile in this respect than an ordinary syndrum. Three modulation waveforms are available, and both the modulation depth and frequency are adjustable. The pitch, sweep range, and decay time are also variable, giving a large degree of control over the sound produced. The output amplitude is about 3V peak-to-peak from a low source impedance, and the unit should readily drive any power amplifier or mixer.

SYSTEM OPERATION

The block diagram of Fig. 1 shows the general make-up of the unit and helps to explain the manner in which it functions. With any unit of this type it is of more than academic importance to understand the way it functions, as there are a number of controls to set up properly in order to obtain the desired sound, and it can be difficult to master this unless you have a reasonable idea of what's what.

A VCO (Voltage Controlled Oscillator) produces the basic signal, but in order to give a reasonable drum sound some envelope shaping is required. The output of the VCO is therefore processed by a VCA (Voltage Controlled Amplifier), which is fed with a high control voltage almost immediately the unit is triggered, and then this voltage decays over a period which is adjustable from around only 200ms or so to about four seconds. This gives the fast attack common to all drum sounds, plus either a short, dull sound, or a long, rich sound, as required.

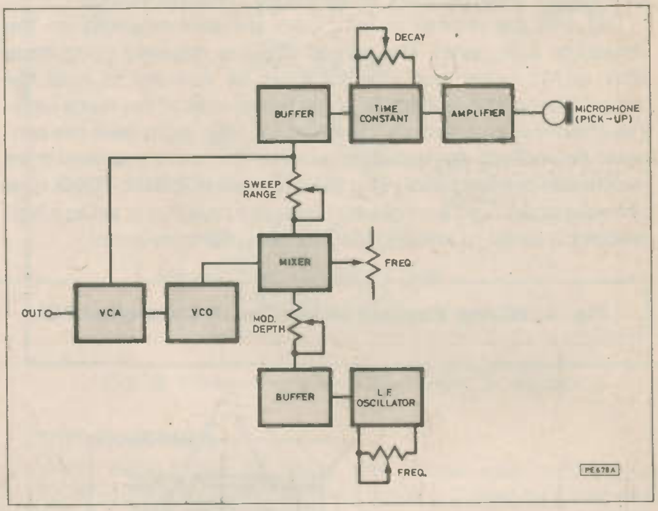
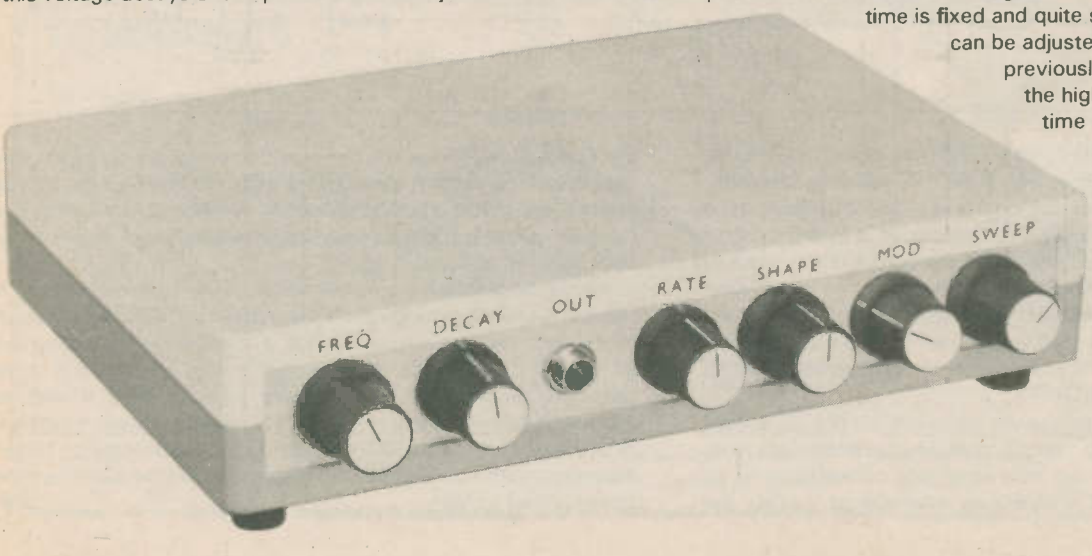


Fig. 1. The block diagram for the Modulated Syndrum

The envelope shaper which provides the control voltage is a very simple type, but is perfectly adequate for this application. The principal method of triggering the unit is to strike the case with a drumstick, or to simply tap it by hand. A pick-up mounted on the case produces a short burst of signal which is amplified and fed to a time constant circuit. This rectifies the signal and smoothes it to produce the d.c. control voltage needed by the VCA. The attack time is fixed and quite short while the decay time can be adjusted over the range specified previously. A buffer stage matches the high output impedance of the time constant circuit to the low input impedance at the control input of the VCA.



A falling control voltage is needed for the VCO in order to produce the falling pitch effect, and the obvious source for this voltage is the envelope generator. It is necessary to have control of the basic pitch of the VCO plus the sweep range so that the desired effects can be generated, and the output of the envelope shaper is therefore fed to the control input of the VCO by way of a level control and a mixer. The output level potentiometer acts as the sweep range control. Another input of the mixer is fed with an adjustable bias voltage, and it is this that sets the basic pitch of the VCO.

The modulation is applied merely by coupling the output of a low frequency oscillator into a third input of the mixer. A buffer amplifier is needed to match the high output impedance of the oscillator to the relatively low input impedance of the mixer, and a level control is included to enable the modulation depth to be adjusted.

Although the unit was designed primarily for manual triggering, a trigger input is included so that the unit can be controlled by a computer or other digital control circuit.

CIRCUIT OPERATION

The full circuit diagram of the unit is shown in Fig. 2. The VCO is built around the two transconductance operational amplifiers of IC1, and the configuration is similar to a conventional dual operational amplifier triangular/squarewave oscillator. IC1a acts as the Miller integrator and IC1b is the Schmitt Trigger.

The advantage of using a transconductance operational amplifier as the integrator is that it enables the operating frequency to be voltage-controlled by way of the amplifier bias input. In fact it is the bias current that determines the operating frequency, but the inclusion of R4 in series with this input gives a current flow that is roughly proportional to the applied voltage, and the oscillator is effectively a voltage controlled type.

Each transconductance amplifier of the LM13600N has a Darlington pair emitter-follower output stage, and discrete output buffers are consequently unnecessary: resistors R5 and R7 provide the output loads. The output from IC1a is a triangular wave and IC1b provides a squarewave output. In this application the triangular waveform with its much lower harmonic content seems to give by far the better sounds, and it is therefore this output signal that it utilized. A wide frequency range is available, and the full audio range can in fact be covered by the VCO.

The VCA is based on another transconductance amplifier, IC2. Only one section of IC2 is used, and the second amplifier and output buffer are just ignored. IC2 operates in the standard VCA configuration, but to avoid the need for dual supply rails, R1, R2 and C2 are used to provide a centre tap on the supply. This is also used to bias the VCO circuit. Although C2 may seem to have an un-

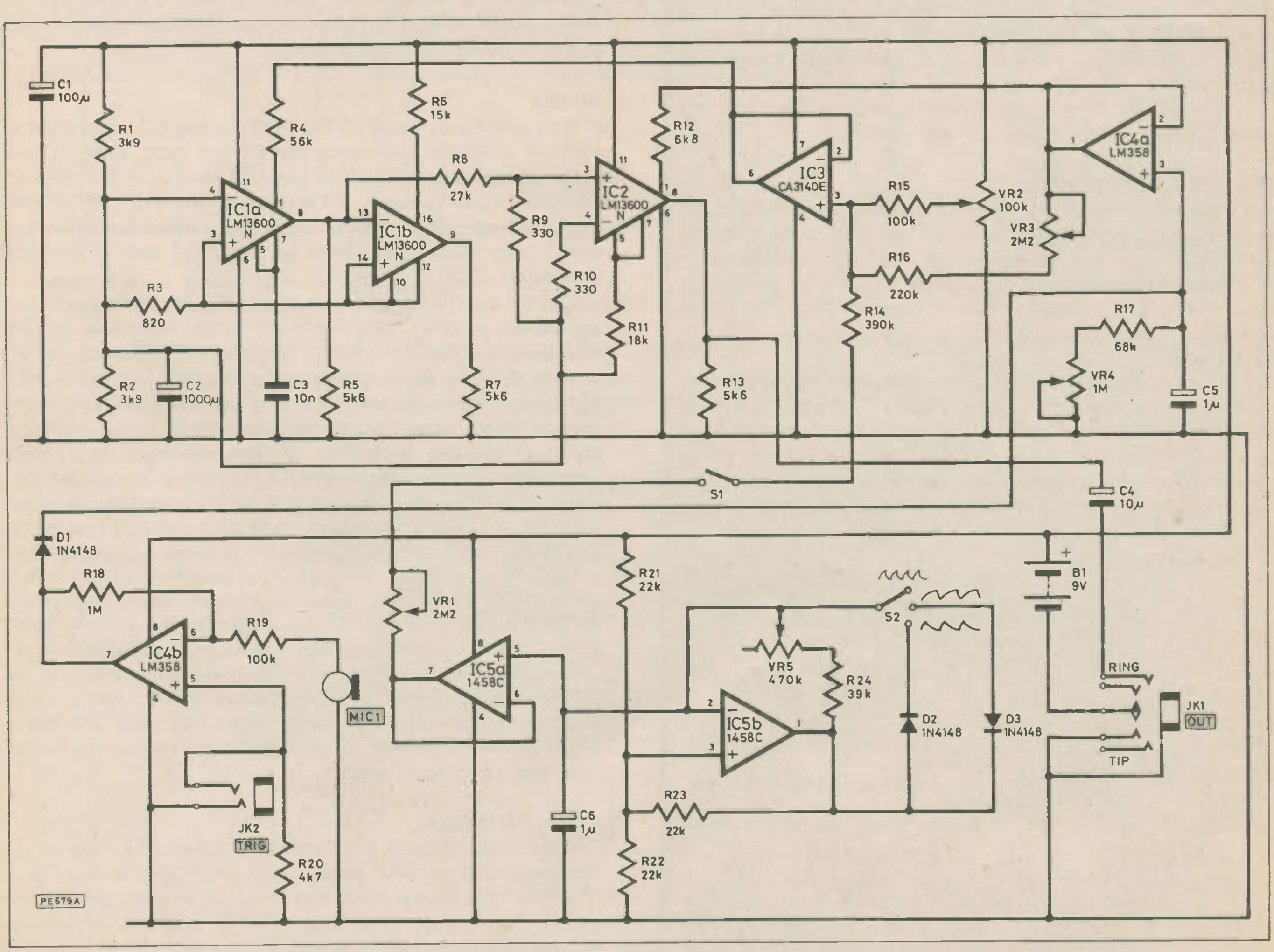
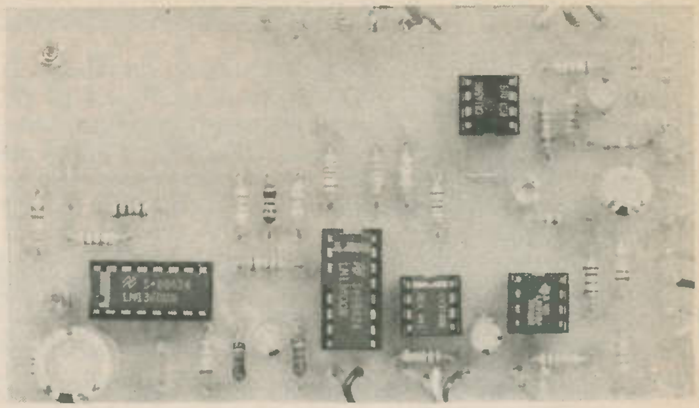


Fig. 2. The complete circuit diagram for the Modulated Syndrum

usually high value, this is in fact essential in order to prevent a significant breakthrough from the VCO to the output of the VCA when the latter is cut off. Again, the VCA is really current- rather than voltage-controlled, but series resistor R12 provides the conversion from current to voltage operation.

MIC1 is the pick-up which can be either a ceramic resonator or a crystal microphone insert. IC4b is an inverting amplifier with a voltage gain of 20dB which also ensures that MIC1 feeds into a resonably high input impedance of 100k. The non-inverting input of IC4b is biased to the negative supply rail so that the output signal is half-wave rectified. This gives a series of positive output pulses which are fed to the time constant circuit.

If a trigger pulse is fed to JK1 then IC4b acts as a non-inverting amplifier and supplies a single, but longer, pulse to the time constant circuit. Its effect is much the same though. A pulse duration of anything from about 5ms to 50ms is suitable. Note that the LM358N device used for IC4 is a type which is capable of producing output voltages right down to the negative supply potential, and that the circuit relies on this property for correct operation. Alternatives such as the 1458C are *not* suitable for the IC4 position.



The completed circuit board. Note the two link wires and the use of i.c. sockets

C5 is the smoothing capacitor, and this rapidly charges from the low source impedance of IC4b when the unit is triggered. However, D1 prevents C5 from discharging through the output stage of IC4b, and the only discharge path is through the relatively high resistance of R17 and VR4. This gives the required fast attack and slow decay times, with the decay period being variable by means of VR4. IC4a is the buffer stage which ensures that the VCO and VCA do not significantly load C5.

COMPONENTS . . .

Resistors

R1,R2	3k9 (2 off)
R3	820
R4	56k
R5,R7,R13	5k6 (3 off)
R8	27k
R9, R10	330 (2 off)
R11	18k
R12	6k8
R14	390k
R15,R19	100k (2 off)
R16	220k
R17	68k
R18	1M
R20	4k7
R21,R22,R23	22k (3 off)
R24	39k

All $\frac{1}{4}$ watt 5% carbon

Potentiometers

VR1	2M2 linear with switch (S1)
VR2	100k linear
VR3	2M2 linear
VR4	1M linear
VR5	470k linear

Capacitors

C1	100µ 10V radial elect.
C2	1000µ 10V radial elect.
C3	10n carbonate
C4	10µ 25V radial elect.
C5,C6	1µ 63V radial elect. (2 off)

Semiconductors

D1,D2,D3	1N4148 (3 off)
IC1,IC2	LM13600N or LM13700N (2 off)
IC3	CA3140E
IC4	LM358N
IC5	1458C

Miscellaneous

B1	9 volt PP3
JK1	standard jack with d.p.d.t. contacts
JK2	3·5mm jack socket
MIC1	Ceramic resonator or crystal mic. insert
S1	Part of VR1
S2	3-way 4-pole rotary (only one pole used)
S3	Part of JK1

Verocase about 205 × 140 × 40mm; printed circuit board, available from the *PE PCB Service*, order code PE-005; six small control knobs; battery connector; 16-pin d.i.l. i.c. holders (2 off); 8-pin d.i.l. i.c. holders (3 off); wire, fixings, solder. etc.

MIXER

The mixer circuit is really a passive type and IC3 is just a buffer amplifier. Although a summing mode mixer might seem to be a better choice it would not be suitable here as it provides an unwanted signal inversion. IC3 is another type which can provide output voltages right down to the negative supply potential, and again most alternatives (such as the 741C and LF351) are unsuitable.

IC5b acts as the low frequency oscillator, and this is a standard operational amplifier astable circuit. In this case it is not the squarewave signal at the output of IC5b that is required, but the roughly triangular signal across timing capacitor C6. This is not a high quality triangular waveform as C6 charges and discharges exponentially, rather than linearly, through R24 and frequency control VR5. The somewhat rounded waveform is perfectly satisfactory for the present application though. The signal across C6 is at a high impedance, but IC5a provides the necessary buffering. VR1 is the modulation depth control and S1 enables the modulation to be switched out altogether when it is not required.

The normal waveform across C6 can be changed by switching either D2 or D3 into the charge/discharge path. Switching D2 into circuit bypasses VR5 and R24 during the charge half-cycle, giving a very short charge time. This results in a sawtooth output waveform of the type having a fast attack and a ramp on the trailing edge. When D3 is switched into circuit it has a similar effect, but it is the discharge half-cycle that is affected. This gives a sawtooth waveform, but of the type having a ramp on the leading edge and a fast decay time.

CONSTRUCTION

With the exception of the controls, sockets, and battery, all the components fit onto the printed circuit board, as shown in Fig. 3. The only MOS device is IC3 and the usual antistatic precautions should therefore be taken when dealing with this component. Some component retailers now supply the LM13700N instead of the LM13600N, and either type is suitable for IC1 and IC2 in this circuit.

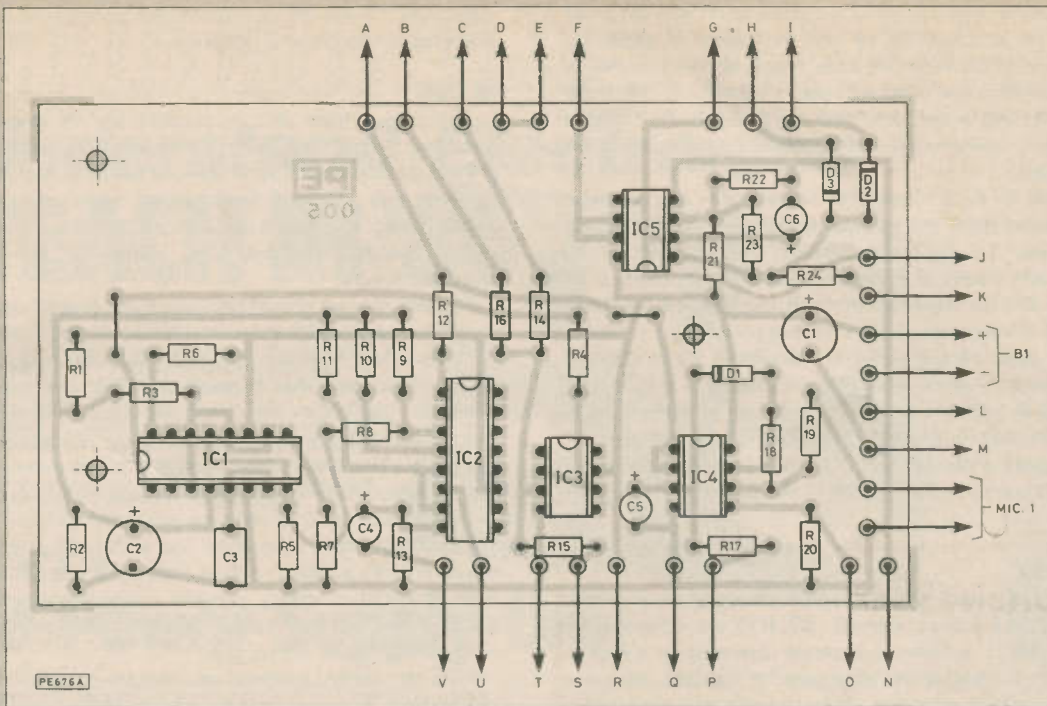


Fig. 3. Component layout on the printed circuit board. This board is available from the *PE PCB Service,* order code PE-005

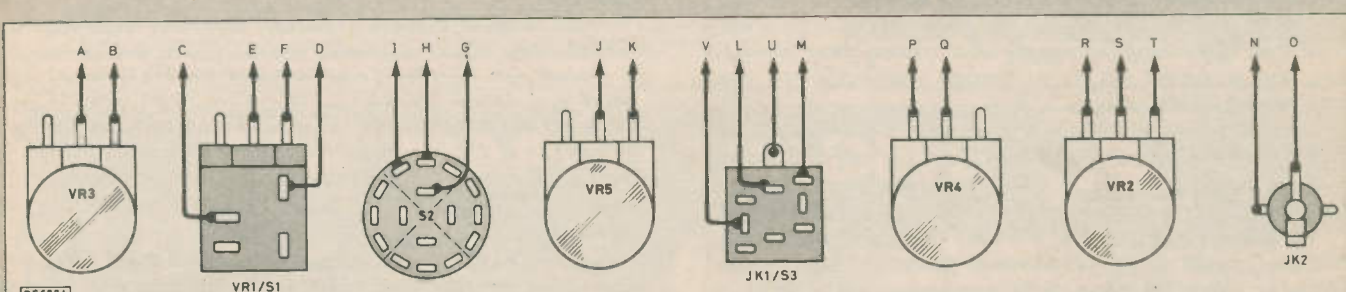
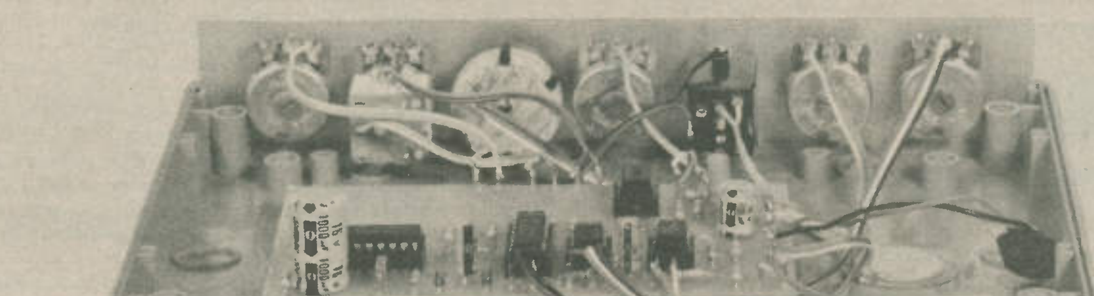


Fig. 4. Positioning of the controls. The lettered leads from the controls should be terminated at the identical locations on the p.c.b. Note that JK2 is fixed to the rear panel



The completed Modulated Syndrum with top panel removed showing interwiring and location of the p.c.b. The MIC insert is glued to the base of the case, right of the circuit board

Do not overlook the two link wires, one near to R1 and the other just below IC5. It is advisable to use the types of capacitor specified in the components list, as other types, although perfectly suitable from the electrical point of view, might not fit onto the board properly. At this stage, only pins are fitted to the board at the points where connections to off-board components will eventually be made.

The case needs to be a reasonably tough type, and a plastic Verocase with metal front and rear panels is used as the housing for the prototype. This measures about 205 × 140 × 40 millimetres, and will readily accommodate all the components. All the controls plus JK1 are mounted on the front panel—JK2 is fitted on the rear panel. S1 is ganged with VR1, but obviously a separate switch could be used here if preferred. Similarly, S3 is a set of make contacts on JK1, which has d.p.d.t. contacts (a socket with s.p.s.t. contacts is unlikely to be obtainable), and the unit is automatically switched on and off as the plug is inserted into JK1 and removed. Again, a separate switch could be used here, but it might then be difficult to find space for all the controls on the front panel.

CIRCUIT BOARD

The printed circuit board is mounted on the base panel of the case using M3 or 6BA fixings, with R5, R7, R13 etc. towards the front of the unit. MIC1, whether a ceramic resonator or a crystal microphone insert, is glued to the base panel of the case using any good quality household adhesive. Most inserts and resonators either have solder tags or flying leads, but one type of resonator does not. With this type leads must be carefully soldered direct to the inner (silver coloured) and the outer (copper coloured) contacts, and the component must obviously be mounted with this side facing upwards. Do not leave the soldering iron in place any longer than is absolutely necessary when making these connections, and be careful not to accidentally short-circuit the two contacts with excess solder.

To complete the unit the hard-wiring is added. This is illustrated in Fig. 4 in conjunction with Fig. 3 (e.g. point "A" in Fig. 3 is connected to point "A" in Fig. 4"). Provided the leads to MIC1 are kept quite short it is not necessary to use screened cable here.

If the unit is to be triggered manually using a drumstick it is advisable to use some self-adhesive plastic or foam rubber material to protect the case over the area where it will be struck. It does not matter where on the case the unit is struck since the vibrations will always be transmitted through the case to MIC1 so that proper triggering is obtained.

IN USE

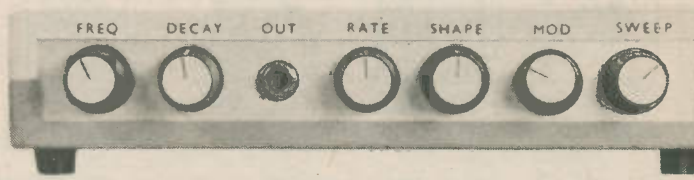
The output from JK1 is coupled to the amplifier, mixer, or whatever via an ordinary screened jack lead. As explained previously, the unit is automatically switched on when the plug is inserted into JK1, and switched off again when it is removed. When initially testing the unit it might be more convenient to plug a pair of headphones into JK1, preferably a medium or high impedance type.

Tapping the unit should produce some sort of output, and a little experimentation with the controls should soon reveal whether or not everything is working properly, and should give an idea of the range of sounds that is available. The unit should be touch-sensitive, with the sweep range and volume being to some extent dependent on how hard the unit is struck. Some picks-ups are more sensitive than others, and if the unit seems to be grossly oversensitive making R18 lower in value should cure the problem. A higher value for R18 will give increased sensitivity.

The trigger input is ideal for use with MOS and CMOS outputs which provide a logic 0 output voltage of virtually zero volts. TTL outputs could in theory provide a logic 0 potential that would prevent the VCA from fully cutting off, although this problem does not seem to occur in practice.

Note that when using the sawtooth modulation waveforms the modulation frequency will be about double that obtained when using the triangular waveform. Also, the two sawtooth waveforms will sound little different when the modulation frequency is fairly high, but the difference should be quite apparent at low frequencies.

A wide range of frequency, sweep range, and modulation is available, and it is well worthwhile spending some time familiarising yourself with the effects that can be obtained, and noting the control settings that give the best effects (there should be plenty of these). ★



BOOK REVIEWS

A PRACTICAL INTRODUCTION TO THE NEW LOGIC SYMBOLS

Author Ian Kampel
Price £11.50 hardcover
Size 223 × 142mm. 150 pages
Publisher Butterworths
ISBN 0 408 01461 X

Few engineers will welcome a title that threatens to impose yet another new standard upon them. However, the new logic symbols explained in Ian Kampel's work are already in use in some areas—notably VLSI design—and it seems likely that all the major technological countries will change to this new symbolism in the near future. The standard for symbols on which the book is based is the International Electrotechnical Commission Publication 617; the relevant British Standard is BS3939 Section 21. As the author comments in his introduction, this new language exists, and "It is also a language which has a real incentive for people to learn it: *in due course their career may depend upon it!"*

The essence of the new logic symbols is the embodiment of a "systems", or top-down approach. A single symbol can be used to represent what previously would have been given as a complex circuit diagram; but that symbol itself may be further broken down into the equivalent of block-diagram form, or even into individual gates or i.c.s.

An instructional book on such a subject is obviously welcome, and *A Practical Introduction to the New Logic Symbols* clearly defines the terms used before going on to give examples. The approach reflects the "language" itself, progressing from simple definitions to increasingly complex symbols. In this way, each chapter builds on its predecessor, so that the book has to be read sequentially, rather than as a reference work. This requirement reflects the way the new symbols themselves work: it is not a question of a simple "new-for-old" swap, but the adoption of a new method of thinking—a new grammar. Every engineer, and engineering student, needs at least to be aware of this new standard, and this book meets that need more than adequately.

D.A.B.

SPACE STATION KOUROU

The European Space Agency's probe to Halley's Comet, *Giotto*, was launched successfully from Kourou, in French Guiana, on 2 July, and is now on its way to a rendezvous with the comet on 13 March next year. Kourou, now a major rocket base, has been developed strikingly during the past few years, and has become a major commercial competitor to Cape Canaveral; since it may be said that the Ariane rocket is now just as reliable as the Space Shuttle.

A new section at Kourou is almost ready, and launchings are regular and—usually—smooth. From the coast close to the rocket base it is possible to see some of the islands in the group which includes the notorious penal colony of Devil's Island, closed as recently as 1945. Some of the ex-convicts settled in the area after their release, and it is said that one of them now runs a profitable restaurant in the town!

Elsewhere in South America, at the Cerro Tololo Observatory in Chile, a group of astronomers using the 158-inch reflector there believe that they have been able to give an accurate age-estimate for the globular cluster 47 Tucanæ, a huge, symmetrical star-system containing many tens of thousands of suns. Globular clusters lie in the galactic halo, and most of them are a long way away. Only three are clearly visible to the naked eye—Omega Centauri and 47 Tucanæ in the far south of the sky (never rising above the British horizon) and Messier 13 in the northern constellation of Hercules.

Through a telescope 47 Tucanæ is a superb sight. It is in fact more impressive than the larger and brighter Omega Centauri—because Omega Centauri fills the field of view, whereas 47 Tucanæ does not, and its form can be clearly seen. The Cerro Tololo astronomers have studied the most massive stars in the cluster, and have estimated their ages as being about 16,000 million years.

This is said to be more accurate than any previous values. It also raises some important problems, because the age of the universe itself—that is to say, the time which has elapsed since the so-called "big bang", when the universe in its present form came into existence—has been given variously as between 15,000 and 20,000 million years, with a decided preference for the lower value. If 47 Tucanæ really is 16,000 million years old, then our preferred estimates must be revised upward.

GARNET STAR

A few bright naked-eye stars are strongly red. Betelgeux in Orion is one, Antares in the Scorpion another; Aldebaran and Arcturus are orange, and so on. Optical aid shows that many fainter stars are extremely red. But of all the naked-eye stars perhaps the most strongly coloured is Mu Cephei, in the far north. Sir William Herschel, discoverer of the planet Uranus, nicknamed it "the Garnet Star", and likened it to a glowing ember.

Cepheus is not a distinctive constellation; it adjoins Cassiopeia, with its celebrated W-formation, and is so near the celestial pole

The Sky This Month

Bright planets are fairly well represented this month. Venus is brilliant in the eastern sky before dawn, and on 21 September it passes close to Regulus in Leo—a good opportunity for amateur photographers!

Jupiter is an evening object and, with a magnitude of −2·3, is far brighter than any other star or planet apart from Venus; but it is well south of the celestial equator, and by the end of the month it sets around midnight. Saturn is also an evening object in the south-west after sunset. The rings are wide open, so that the planet is a beautiful sight in even a modest telescope.

Mercury and Mars are close together in the early part of September; again in the morning sky, but they will not be particularly easy to make out. Mars incidentally, is three magnitudes fainter than Mercury.

The minimum separation between the two is 46 seconds of arc. It is surprisingly seldom that one plant occults another; the last occasion was on 3 January 1818, when Venus passed in front of Jupiter, and the next will not be until 22 November 2065, when the same thing will happen.

Halley's Comet is still faint, and perhaps the main interest this month will centre upon Comet Giacobini-Zinner, which will be by-passed by the American probe ICE (International Cometary Explorer). Giacobini-Zinner, with its period of 6·6 years, can sometimes reach the fringe of naked-eye visibility.

It will not do so this year, but as the magnitude will reach 8 or so it will be a reasonably conspicuous telescopic object. Positions for September will be as follows:

Sept. 2	*R.A. 5h 12min*	*dec. +36°27′*
12	*5 55*	*22 32*
22	*6 27*	*8 58*

At the end of the month the comet will cross the celestial equator, and by December the declination will be −38°, so that British observers will lose sight of it; the magnitude will have faded to about 11. Photographers would be well advised to practise upon Giacobini-Zinner in preparation for Halley.

During September evenings the "Summer Triangle" of Vega, Deneb and Altair is still very much in evidence, with Ursa Major at its lowest in the north and the W of Cassiopeia not far from the zenith.

Pegasus, the Flying Horse, dominates the southern aspect, with its four main stars making up the famous "Square". It is difficult to understand why Alpheratz, one of the four, has been transferred to the neighbouring constellation of Andromeda.

Andromeda is, of course, celebrated because of the presence of Messier 31, the nearest of the large spiral systems at a distance of 2·2 million light-years. It too can be used as a convenient "photographic rehearsal" for Halley's Comet.

Low in the south, look for Fomalhaut in Piscis Australis (the Southern Fish) which is of the first magnitude and is one of our nearer stellar neighbours; it was also found by IRAS to be associated with an infra-red excess indicating cool, possibly planet-forming material. In the east the Pleiades have come into view, soon to be followed by the orange-red Aldebaran, the so-called "Eye of the Bull". By the early hours of the morning Orion has come back into view, led by the red supergiant Betelgeux and the glittering white Rigel, at least 60,000 times more luminous than our Sun.

that it never sets over the British Isles. Mu Cephei lies not far from a triangle of fairly dim stars of which one is Delta Cephei, the prototype short-period variable.

Mu is itself variable; the magnitude range is from about 3·6 to 5·5, so that the star is always visible with the naked eye, but it is far from conspicuous, and when it is near minimum the colour is hard to discern without binoculars or a telescope. Yet when any optical aid is used, Mu Cephei lives up to Herschel's nickname.

How far away is it, and how luminous is it? Clearly it is a red supergiant—a star which has used up its main store of hydrogen "fuel" and is approaching senility; but its distance has never been well determined. One estimate gave around 1500 light-years, in which case the star would have something like 50,000 times the luminosity of the Sun—as against a mere 15,000 Sun-power for Betelgeux.

STELLAR HEAVYWEIGHT

New studies of it have now been carried out at the high-altitude Pic du Midi Observatory, in the French Pyrenees. Using the 2-metre reflector there, N. Mauron has examined Mu Cephei in the light of sodium, and has announced that the star is surrounded by a vast envelope with an apparent diameter of as much as one minute of arc.

He also finds that Mu Cephei is much further away, and much more luminous, than has been previously believed. The power is now given as about 100,000 times that of the Sun, outclassing even such cosmic searchlights as Deneb and Canopus.

According to Mauron, the circumstellar "cloud" is shining because sodium atoms are scattering light in the outer part of a violent stellar "wind". We have become used to talking about the solar wind—a stream of atomic particles being sent out by the Sun constantly in all directions and which, incidentally, has a marked effect upon some types of comet-tails, driving them outward; but we have heard less of the much stronger "winds" produced by very massive stars. And if the new data are correct, Mu Cephei is very massive indeed, and is the equal of 20 Suns. This is not a record, but it puts Mu Cephei very much into the class of stellar heavyweights.

Moreover, the star itself is huge. The diameter has been estimated as over 800,000,000 miles, which is comparable with the size of Jupiter's orbit round the Sun. Again this may not be a record but it dwarfs Betelgeux, whose diameter is no more than 250,000,000 miles at most!

DECEPTIVE APPEARANCES

In astronomy, as in so many other subjects, appearances can be very deceptive. Looking at Betelgeux and at Mu Cephei, it seems that Betelgeux is much the more impressive of the two; it is in fact one of the brightest stars in the sky. But in reality things are very different. If Mu Cephei were as close to us as Betelgeux, it would cast perceptible shadows, and if it were as near as Alpha Centauri at a mere 4·3 light years, it would appear almost as a second sun.

If you have a pair of binoculars, I suggest that you go out on the next clear night and locate Mu Cephei. You cannot fail to recognize it; its hue is so striking that there is no fear of mistake. It may seem like a tiny, glowing point, but we have to realize that it is one of the most remarkable stars we know.

What will happen to it eventually? It is squandering its reserves of energy; it will not last for nearly as long as the Sun before disaster overtakes it. It may collapse into a neutron star, or even produce a black hole. But this will not happen for tens of thousands of years at least, so that there is plenty of time for us to look at and admire the "Garnet Star".

Ingenuity Unlimited

Why not submit *your* idea? Any idea published will be awarded payment at £40 per magazine page.

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.

FACED with the problem of providing a realistic sounding ringing telephone for an amateur dramatics group, the usual answer is to use a sound effect recorded on tape. However, this has disadvantages, namely: it must be exactly set up on the tape deck so that it can be started precisely on cue; it does not 'resonate' after the phone has been answered, something you do not notice until you try it; and what if you run out of sound effect before the actor answers the phone?

REAL PHONE

These problems can be overcome by using a real phone which can be answered by the actors on stage.

A surplus phone can be picked up at an 'electrical junk' shop for a few pounds these days. The circuit provides all the timing to produce the familiar 'ring ring .. pause ... ring ring' effect of a real telephone. All the operator has to do is hold a button down! The circuit is based around three CMOS i.c.s and its operation is reasonably straightforward.

Looking first of all at the phone end, the bell mechanics consist of two coils and a pivoted hammer which alternately strikes one of two bells. To make the phone ring it is necessary to pulse each coil in turn, to pull the hammer back and forth. The coils come wired in series and are designed to run from about 48 volts. However, the bell will work satisfactorily on a 24V supply, and if we alternately switch 12V across each coil independently, this has the same effect. This is achieved by TR1 and TR2; being a complementary pair, a pulse input to both their bases switches them alternately. Note that to achieve the correct magnetic polarities the coils must be wired up as shown – if the circuit does not work first go, try reversing one pair of the coil connections. D1 and D2 protect the circuit from induced voltage spikes.

IC2c and IC2d are wired as a 25Hz oscillator which drives the coils via TR1 and TR2. This would make the bells ring continuously, so it is gated on and off at the correct times via IC1b, by the rest of the circuit.

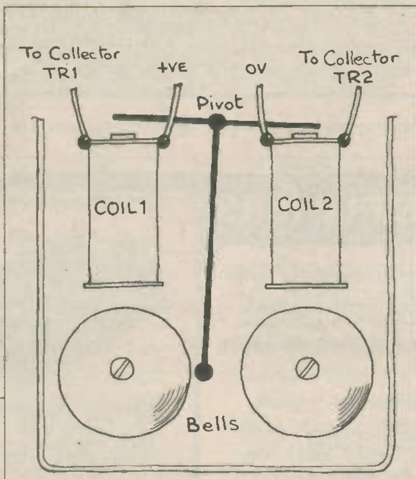


Fig. 1. The bell

LATCHES

IC3a and IC3b are D-type latches wired in series to form a divide by two counter. Ordinarily they would count 0,1,2,3 then repeat, but IC1d detects the '3' state and resets the counters to zero via IC1c. The counters are clocked by a 1Hz oscillator built around IC1a, IC2a and IC2b. This determines the overall circuit timing.

The output of the 1Hz oscillator also goes to one input of IC1b; the other input is from the inverted counter output, Q of IC3b. When and only when both inputs of IC1b go high, the bell ringing oscillator is activated. This will occur during the '0' and '1' counts of IC3a and IC3b. In between these counts when the oscillator output goes low, and during the '2' count when the Q output of the counter is low, the bells will pause. Thus we achieve the required 'ring ring ... pause' sequence.

The 1Hz control oscillator is gated on and off by a pushbutton marked 'Ring', via IC2b. This button also resets the counters to zero via negative edge detector C2 and R3, and IC1c, when initially pressed. If required, the button could be routed through the receiver cradle switch in the phone, so that it stopped ringing as soon as the receiver was picked up.

G. Durant,
North Yorks.

TELEPHONE BELL RINGER

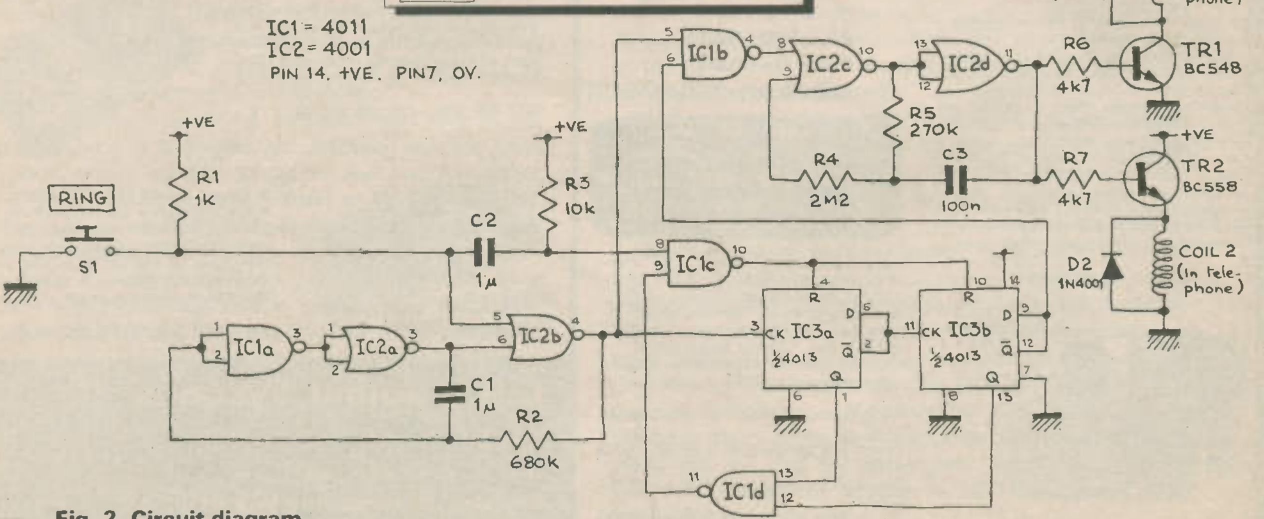


Fig. 2. Circuit diagram

IVAX Review

Phil Dane (Powertran Cybernetics)

In the past the design of robots has followed the basic form of the human arm but recently there has been a distinct trend for assembly machines to be of a more rational concept. It has become obvious, through experience, that it is both difficult and impractical for machines to successfully emulate the discrete and complex movements of humans.

SCARA

An increasingly common rationalisation of robot design is that of the SCARA (Selective Compliance Assembly Robot Arm). This type of robot arm (Fig. 1) consists of a horizontal jointed arm with a gripper which has both vertical and rotational movement. The arm is set to a predetermined height which means that the only change in potential energy occurs when the gripper is being raised or lowered. This is not so with a conventional anthropomorphic arm.

Noting this trend towards the use of SCARAs in industry, Powertran have developed a bench top machine which may be used in education or training and incorporates all the features of its industrial counterpart.

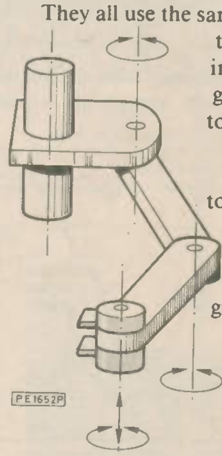
IVAX

The new SCARA from Powertran has been named IVAX and is said to be more sophisticated than some other designs as it employs four servo controlled axes rather than three. The extra axis provides controlled vertical movement using a rack and pinion drive. This allows the arm to be tolerant to small variations in the height of the workstation otherwise each station would require discrete height adjustments.

IVAX has been designed with a total concept in mind, to enable complete emulation of many industrial applications, with work stations which may be expanded or re-configured as and when required. Also its open frame design means that many of the moving parts including the optical encoders may be viewed whilst the machine is in operation, a facility very useful to students and trainees.

MECHANICS

The three rotational axes of the IVAX are illustrated in Fig. 2. They all use the same type of d.c. motor with integral gearbox, optical disc read by two slotted opto switches (giving phase/quad) and precision 30 to 1 secondary gearbox. Axes 0 and 1 also make use of constant torque springs which eliminate the effect of back lash in the secondary gearbox.



Axis 3 in addition drives through a 1 to 1 toothed belt which is shown in Fig. 2d. The gripper (see photo) has parallel jaws and is self centring. It has 'vee' grooves in both the horizontal and vertical planes to ensure positive gripping action. The gripper is actuated through a pneumatic circuit controlled by a three-way valve, and for those establishments without a separate compressed air facility the IVAX has its own tiny compressor which is 'whisper' quiet.

SPECIFICATION

Description
D.c. servo powered SCARA robot arm with independent input/output. Microprocessor controlled. Command entry from hand-held teach pendant or external computer via parallel interface.

Configuration
Arm with two rotational axes of motion in horizontal plane. Gripper with vertical and rotational position and on/off control.

Drive
D.c. servo motors driven from Pulse Width Modulated amplifiers. Pneumatic gripper.

Feedback
Open frame optical encoders providing continuous positional feedback on all four numerically controlled axes.

Control
Resident Z80A microprocessor or additionally external computer via parallel interface.

Resolution
1:3240 on all rotational axes (5 minutes of arc). Better than 0·2 millimetres on vertical axis.

Operating Envelope
Partial toroid; external radius 280mm, internal radius 108mm, depth 40mm.

Speeds
Rotational speeds to 60 deg/sec in steps of 0·25 deg/sec.

Movement

Rotational axes	270 deg
Vertical linear axis	40mm
Gripper opening	15mm

Work Cell Interface
16 Inputs: Switch to ground or 5 volt digital.
16 Outputs: Open-collector sinking 30 milliamps.

Other Features
Optional EEPROM non-volatile storage provided for 3 programmable sequences of 32 steps.
Optional large capacity RAM for storage of 15 programmable sequences.

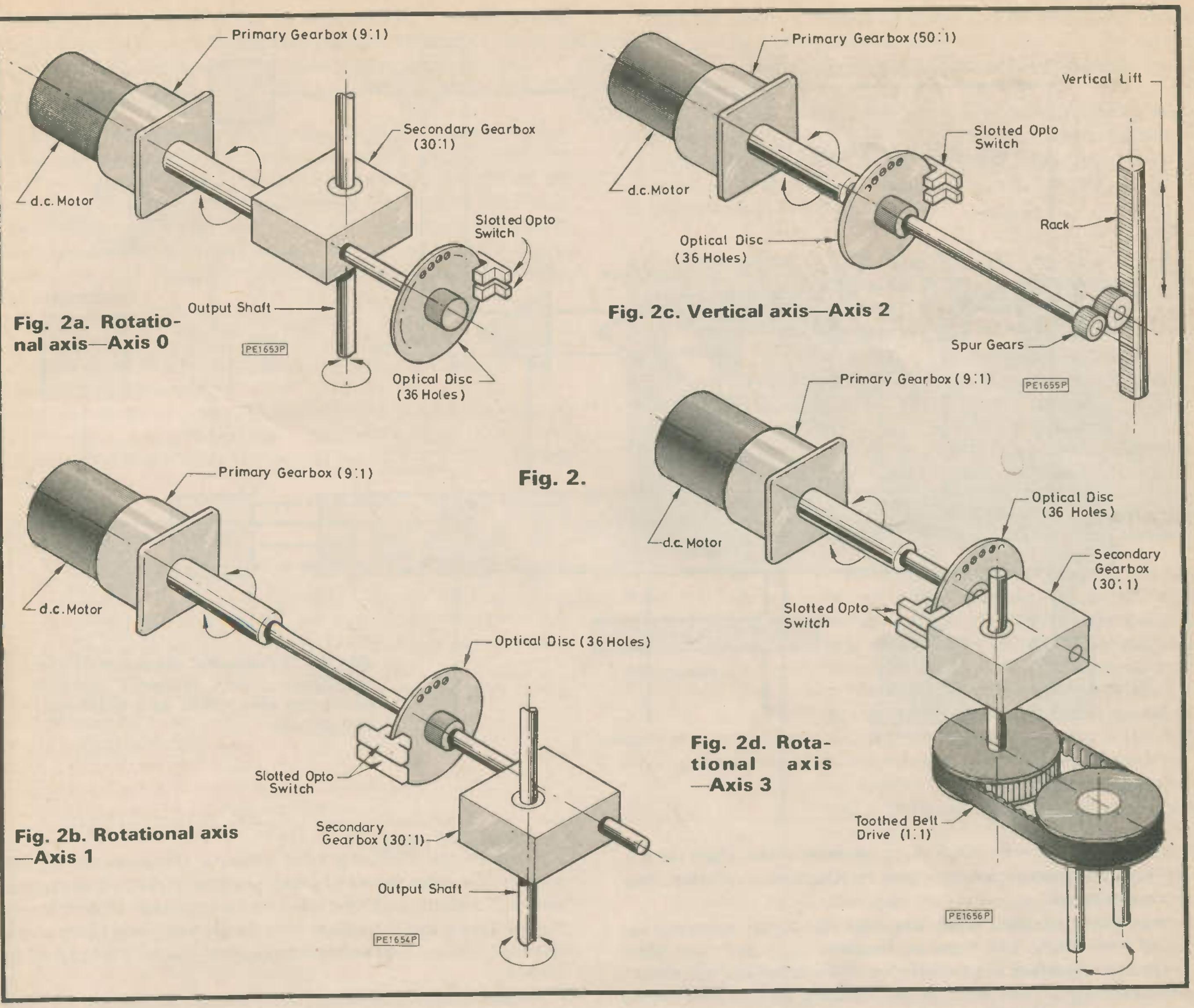


Fig. 2.

Fig. 2a. Rotational axis—Axis 0

Fig. 2b. Rotational axis—Axis 1

Fig. 2c. Vertical axis—Axis 2

Fig. 2d. Rotational axis—Axis 3

ELECTRONICS

The electronic control system makes use of complex circuitry which is illustrated in the schematic diagram of Fig. 3.

The heart of the IVAX controller is the Z80A microprocessor running at 4MHz. The controller monitors the inputs, controls the axes of IVAX (speed and acceleration), has sequence control, monitors for errors in the closed loop system, updates the EEPROM (if fitted), communicates with the host computer and receives information from the teach pendant. The controller also executes commands from the host computer and teach pendant. On board RAM can either be 2K or 8K bytes, enabling a storage of 3 to 15 sequences respectively (a sequence is 32 steps). An optional non-volatile storage (2K) can be fitted in the form of EEPROM. This option enables up to 3 sequences to be stored so that the system can be switched off, or during mains failure the program stored in EEPROM will not be corrupted.

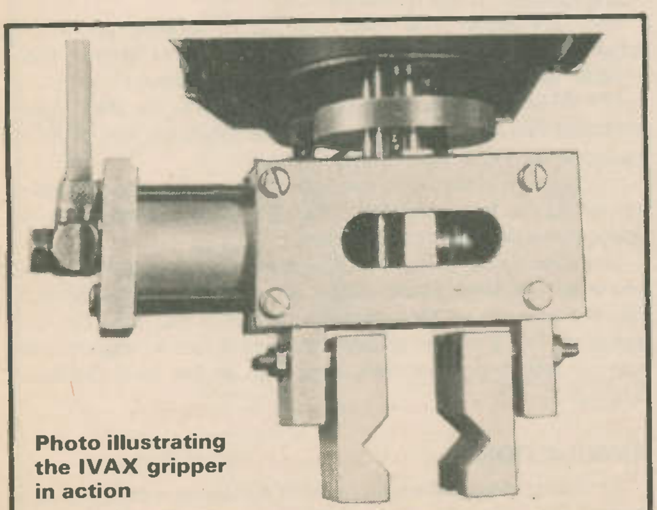


Photo illustrating the IVAX gripper in action

For educational courses in maintenance, testing and fault finding on microelectronics systems, test points have been provided so that all areas of interest can be monitored. An added facility of the system is that the IVAX firmware includes setting up tests which demonstrate the correct functioning of all circuit elements.

An EEPROM is an electrically erasable and programmable read only memory for use where permanent storage is required but also offering the ease of changing the data stored if required.

An expansion port is fitted which allows the electronics to control a further four axes and numerous other input/output devices. Half of the Z80A input/output address map, together with all necessary signals, is available for further control. Numerical control of each of the robot's four axes is achieved through independent closed loop systems to give reliability, accuracy and repeatability. Optical

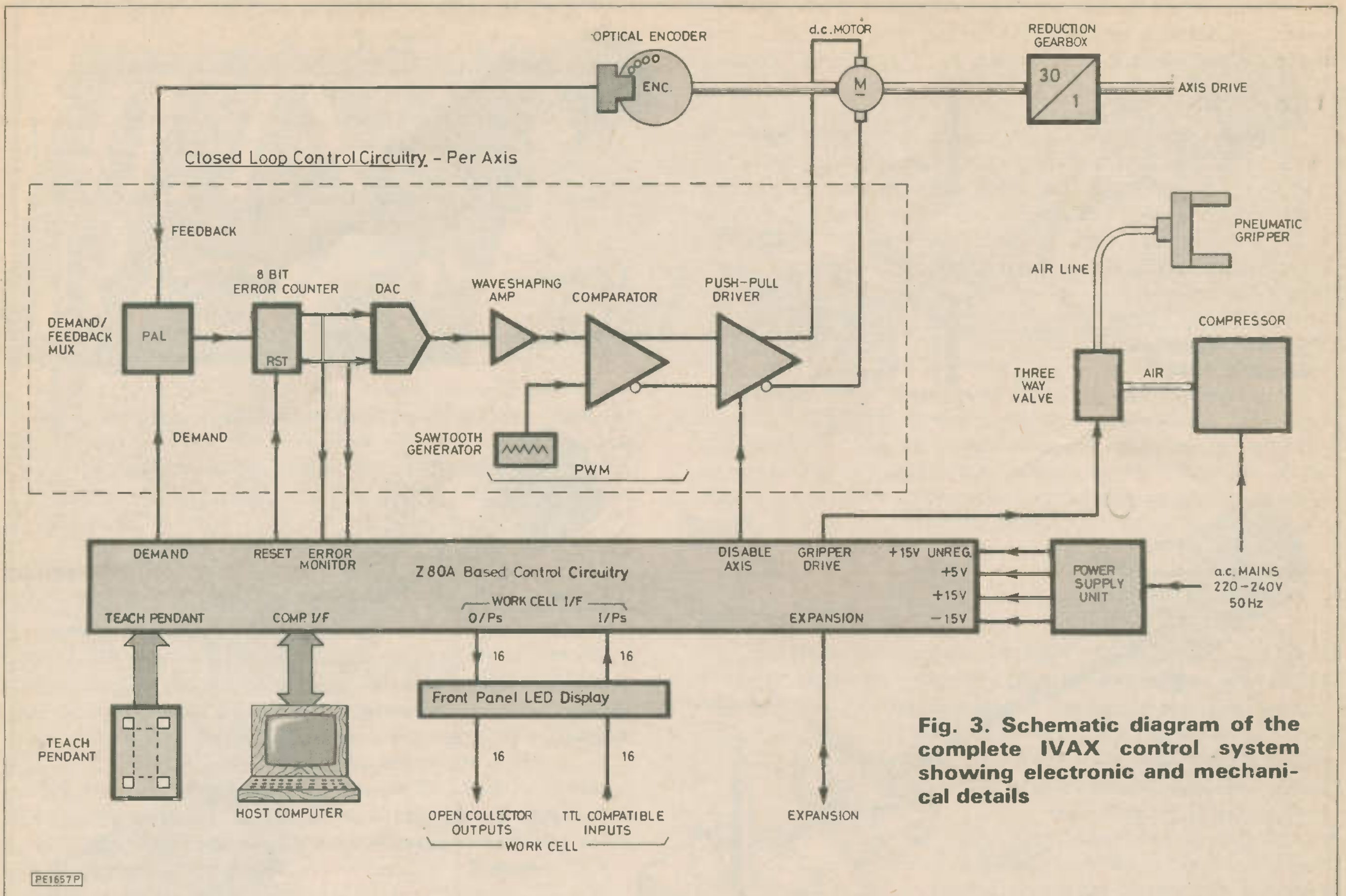


Fig. 3. Schematic diagram of the complete IVAX control system showing electronic and mechanical details

encoders are used with pulse width modulated amplifiers for d.c. servo drives to give a resolution on the major axes of better than 5 minutes of arc.

A watchdog circuit is incorporated into the system to protect the robot from abuse. The firmware monitors the robot's operation every 5ms. If stalled, for example, by a person holding the robot's arm, the firmware will halt the robot, reducing the axis error to zero and thus protecting the robot from damage; however, the robot's position is still maintained. The inputs and outputs are continuously displayed on the control unit by light emitting diodes (l.e.d.s). The outputs can be individually or simultaneously programmed through single host computer commands.

HOST COMPUTER (BBC 'B' OR APPLE IIE)

Although the IVAX can be controlled by using the teach pendant, its full potential can only be realised using a host computer, which will allow the digital inputs to be monitored and the outputs to be controlled. The host computer also enables programs to be written for the IVAX in which decisions can be made on the basis of the digital input status. As IVAX is capable of off-line programming and conditional sequence control, it is possible to write programs on the host computer which can be down-loaded to IVAX to allow the host to be used elsewhere.

PROGRAMMING

The supplied software consists of procedures and functions so that the IVAX can be controlled entirely using BASIC commands from a host computer such as the BBC. The co-ordinates for the commands are simple cartesian x,y,z co-ordinates with an angle (in degrees) for the gripper orientation. With the x,y and z dimensions being in millimetres the writing of off-line programs becomes a simple matter.

Consider the following brief example (Program 1): In this program the robot moves to a start position, picks up a workpiece, moves to a position where a tolerance testing gauge is fitted, inserts the workpiece into this gauge, tests for the workpiece being within tolerance (input 2 low) and switches output 3 on for 'GO' and off for 'NOGO'.

As can be seen the procedure name implies the function the robot is performing thus making programs very simple to follow. Many other simple to use procedures exist. Impressive examples of which include being able to program speed and acceleration of an axis with just a single command for each. Speed can be set to any number in the range 1 to 255 with 255 being the maximum speed of 60 degrees/second for the rotational axes.

User procedures also exist and are invaluable for writing programs, for example being able to record the present robot position and gripper state with just a single command.

The BASIC software gives complete access to the Z80A based controller and allows user programs to be simulated, run, or downloaded to the IVAX quickly and easily.

Any location of the IVAX controller memory can be read from or written to the host computer, thus providing a window on the operation of the Z80A based system.

Complete listing of the IVAX firmware is made available and provision has been made within the firmware for students to enhance and extend the operation of the IVAX. This not only makes the IVAX robotic system a learning device for engineers but also for system programmers using high or low level (machine) languages.

SIMULATION

As with its industrial counterparts IVAX comes complete with its own graphic simulation for the BBC so the principles of simulation and off-line programming can be demonstrated. When condition sequencing has been written into the program the simulator stops at that point and enquires as to the state of the appropriate input.

THE WORKCELL

A typical workcell (see photo) consists of two input conveyors (with component feed rate control), measuring gauges, reject bins and an output conveyor. The robot picks components from the conveyors and presents them to the measuring devices, one checks for oversize, one for undersize, which give either a go/nogo signal to the inputs of IVAX. Reject components are placed in the appropriate bin and passed components are placed on the output conveyor.

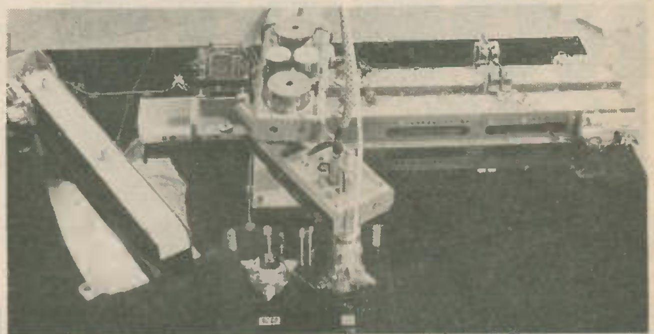
The robot may also be programmed to:

1. Alternate between servicing each input conveyor if there is a component present on each (components are detected by a reflective opto switch).
2. Concentrate on one conveyor if there is a queue of components and may also stop the conveyor. (See flowchart Fig. 4.)

Alternatively the robot is available with a CNC Mill and feed conveyor.

With the ability to analyse 16 inputs and set 16 outputs, IVAX can cope with an immense number of events and can take a tremendous variation of actions, provided all have been anticipated by the programmer.

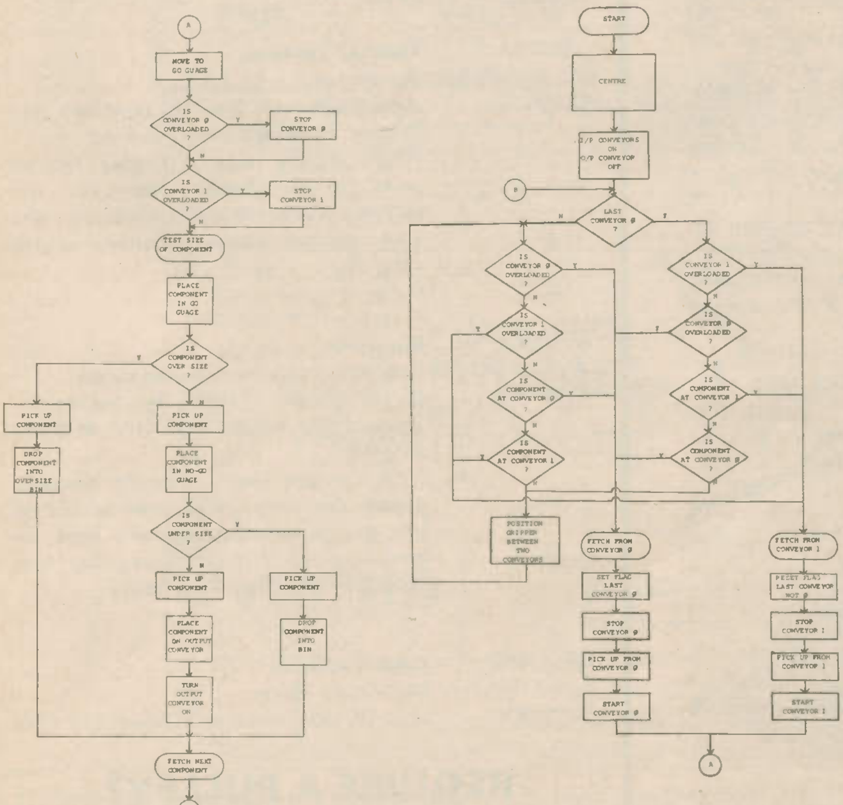
With the system being so flexible in both hardware and software it makes an ideal tool for project work. The increasing use of robots in industry implies a need for the training of a substantial number of personnel of all levels, but especially technicians and engineers in the technology of robots.



Program 1

```
10 PROCINIT                        REM: INITIALISE FIRMWARE VARIABLES
20 RMODE=ROBOT                     REM: ROBOT MOVEMENT ONLY
30 SMODE=STPINS                    REM: ROBOT MOVEMENT/INSERT INTO MEMORY
40 PROCDROP (-90,-230,0,-180)      REM: START WITH GRIPPER OPEN
50 PROCPICK (-90,-230,25,-180)     REM: WORKPIECE POSITION THEN CLOSE GRIPPER
60 PROCPICK(-90,-230,0,-180)       REM: RAISE GRIPPER
70 PROCPICK (0,280,0,0)            REM: TEST POSITION
80 PROCDROP (0,280,30,0)           REM: LOWER WORKPIECE INTO GAUGE
90 PROCWAIT (1)                    REM: PAUSE
100 PROCIFLO (2,20)                REM: IF 'GO' JUMP TO LABEL 20
110 PROCOUT (3,FALSE)              REM: TEST 'NOGO' OUTPUT 3 OFF
120 PROCGOTO (5)                   REM: JUMP TO LABEL 5
130 PROCLABEL (20)                 REM: LABEL 20
140 PROCOUT (3,TRUE)               REM: TEST 'GO' OUTPUT 3 ON
150 PROCLABEL (5)                  REM: LABEL 5
```

Fig. 4. Program flowchart



Robot technology encompasses not just the mechanical engineer but also the electronic engineer. They must come together to work as a team to develop the automation of production. This calls on universities, colleges and training establishments to provide courses with hands-on experience to enable technicians to retrain in the new robot technology and Flexible Manufacturing Systems. This is the reason why Powertran Cybernetics Education Division has developed the SCARA IVAX robotic workcell.

Up until now the robots available for education and training have only been able to pick and place, with many of them no more than toys. The IVAX SCARA is different. It has been designed to simulate an industrial robot having conditional sequence control. The Powertran IVAX SCARA robot has taken the state of the art technology used on industrial FMS and scaled it down to perform actual production line techniques involving: measurement, palletising, decision making, assembly work and milling.

BUYERS NOTE:

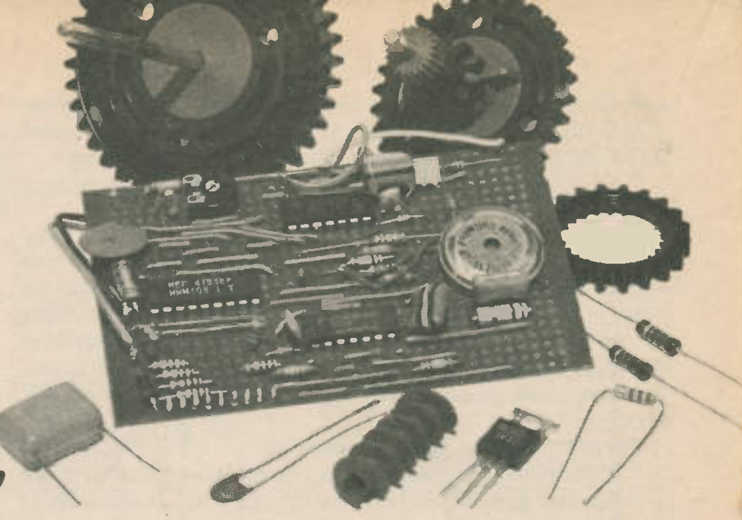
The basic system comprises: a power supply unit, control unit, IVAX SCARA robot, teach pendant, software, manual and coursework.

If purchased in kit form a comprehensive construction booklet is provided.

This product can be obtained from:
Powertran Cybernetics Limited
(Education Division),
Portway Industrial Estate,
Andover,
Hampshire,
SP10 3PE.
☎ (0264) 64455.

Experimenting with ROBOTS

Mike Abbott Part 2



LAST month we looked at a robot interface with four conventional servo channels, plus an unconventional channel dubbed the *TACACOOGA*. This month we look at the construction of that interface. It is designed, where possible, to use the kind of cheaper components most likely to be found in the constructor's "junk" box. We also illustrate the ultra-simple gripper (Fig. 5).

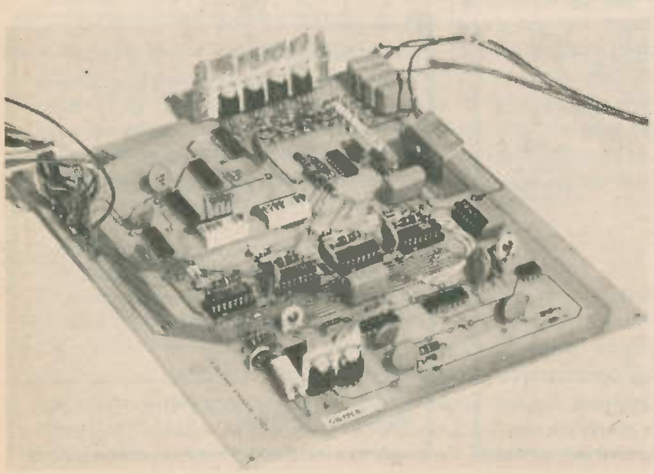
MECHANICAL ADVANTAGE

Should you wish to use a more sophisticated gripper mechanism, in which the motor is geared down to drive the jaw, then the *TACACOOGA* may be used *in reverse*, but a single-pole changeover type limit switch is required.

Only two changes are necessary. One is to swap the gripper motor wires so that the automatic cut-off (stall current detect) operates when the gripper is *closing* instead of opening. The other change is to remove the link between A and B in LK2 and wire a microswitch so that it detects when the jaw is fully open, switching point B to point C (0V).

With this arrangement the Torque control preset might as well be set to maximum motor speed. The stall current cut-out feature will activate when the gripper bites onto the object it is to grasp. Note that even with VR10 set to maximum sensitivity your gripper might only pick up an egg safely if it is hard boiled. Part of the entertainment of experimental robotics is in the matching of electronics and mechanics to application.

In this slightly more conventional arrangement, I suppose the circuit name should be truncated to ACOOC (Automatic Cut-Off On Closure). This configuration does assume a high reduction gearing between motor and jaw, so that when the motor is de-energised the jaw cannot roll back from the object in its grip. A worm drive is a typical arrangement for this purpose.



NEED A GEARWHEEL?

Listed below are some useful addresses for those who wish to procure modular mechanical and electrical components suitable for *Experimenting With Robots.* The common denominator with all these type building media is cost. Components are not particularly cheap, but they do offer the advantage of being re-usable, so that when the initial outlay is divided by the number of variants constructed each individual machine works out to be quite inexpensive. In addition to this, these modular systems are highly educational in a subject area of great importance to future industry.

MEDIUM: **Fischer Technik**
AVAILABILITY: Toy stores
SUPPLIER: Artur Fischer UK Ltd., 25 Newtown Rd., Marlow, Buckinghamshire SL7 1JY
(The complete range of Fischer Technik parts is surprisingly extensive, and includes many electronic modules). The little engineer appears courtesy of this company

MEDIUM: **Meccano**
AVAILABILITY: Specialist model engineering shops
SUPPLIER: M. W. Models, 4 Greys Rd., Henley-on-Thames, Oxfordshire RG9 1RY. ☎ 0491 572436.
(This company seems to be the Meccano *Mecca*, providing a mail order service to UK and overseas customers from an amazing stock. Write to "Everything Meccano", or telephone for details.)

MEDIUM: **Lego Technic**
AVAILABILITY: High Street shops
SUPPLIER: Lego UK Ltd., Wrexham, Clwyd LL13 7TQ

REQUIRE A PULLEY?

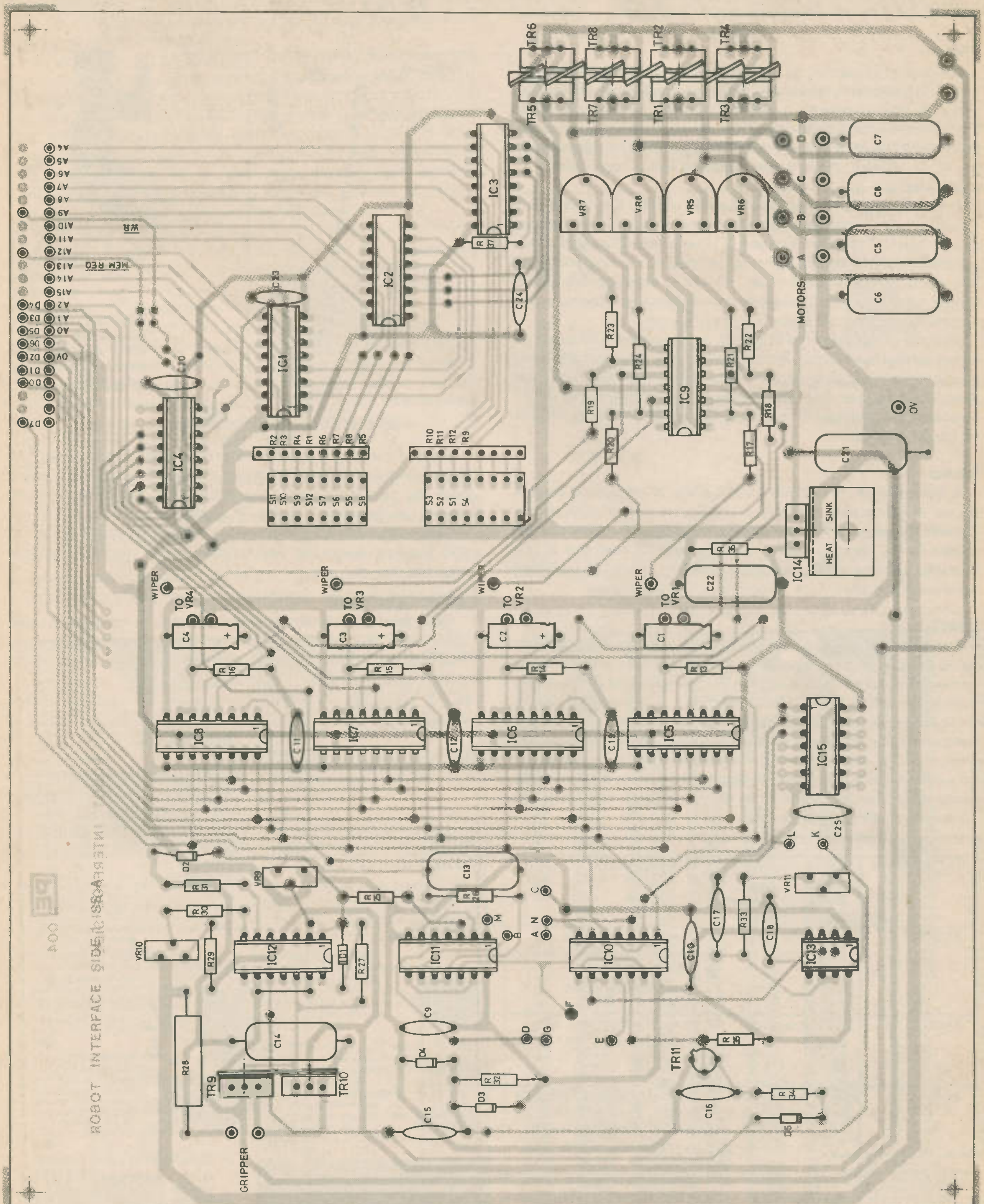


Fig. 4. Component layout on the double-sided p.c.b. Note that the black "dots" represent through-board links. Use eyelets, or tinned copper wire to make these connections first. Last month's Components List requires correcting. The 100n capacitors are as follows: C9–12, C15–20, C23–25 (13 off). This board is available through the *PE PCB Service,* order code 004

PAG

The gripper circuit may be used in yet another configuration, and this is called *Pulse Activated Gripper*. In this mode of operation the gripper motor is driven for a preset time period generated by IC13 triggered from the $\overline{\text{Enable E}}$ line. The time period is the same for each motor direction. The options link table should be referred to if the p.c.b. is used. Table 2 also indicates which components to omit or link out.

The PAG may work to your satisfaction with C17 at 100nF, but should a longer motor duration be required for a particular gripper design then C17 may be increased in value to suit. The pulse width generated by IC13 should be set to just long enough in duration to fully open, or fully close the jaw. No undue strain on the motor should result from the energisation period lasting a fraction of a second longer than the motor's limits of travel.

With the circuit operating in this mode, the preset VR9 ought to be set to maximum torque, although altering its setting might allow you to null a slight difference in motor travel time between each direction of the jaw. Alternatively, the torque limiting facility might be utilised to advantage in the "close" direction, to control the grip on fragile objects.

SPAG

A Symmetrical PAG (SPAG) can be built if the torque control aspect of the circuit is of no use, and still more components saved. Table 2 shows how VR9 can be lost, and if the link references are related to the circuit diagram in Fig. 3, it will be seen that IC12a operates as a straightforward linear amplifier, and IC12b becomes redundant.

EPUD

Although the experimenter may discover other ways to configure the gripper circuit, the *Electromagnetic Pick-Up Driver* is the last variation to be discussed here. By removing the components indicated in Table 1, the circuit becomes a simple solenoid driver for a robot capable of picking up ferrous objects. The Torque control facility remains intact, and allows greater freedom of choice of the solenoid rating. Since the solenoid might be an unspecified "junk box" item, stripped from a relay, or even home spun, VR9 can be adjusted until the pick-up has adequate "attraction" without overheating.

MODE	FUNCTION	P.C.B.	LINKS
TACACOOGA	Torque Adjustable Closure, Automatic Cut-Off On Opening Gripper Actuator	Fully populated	A – B D – E J – H M – N
ACOOC	Automatic Cut-Off On Closure	Wire limit switch with *n.o.* contacts between link positions B and C. Board fully populated Change R27 to 68k	D – E J – H M – N
PAG	Pulse Actuated Gripper	Omit R29, R30, R31, R32, R34, D3, D4, D5, TR11, VR10, C15, C16	B – G D – E L – K M – N
SPAG	Symmetrical Pulse Actuated Gripper	Omit as PAG, plus VR9, C13 and D2. Short out R28. Short out D1. Change R27 to 56k. Link VR9 (top) to VR9 wiper position	B – G D – E L – K M – N
EPUD	Electromagnetic Pick-Up Driver	Omit R29–34, VR10, VR11, C13–18, D3, D4, TR10, TR11, IC13. Replace C14 with 1N4001 diode. Link out R27	A – B B – G M – P

Table 2. TACACOOGA options. All unmentioned links should be left open

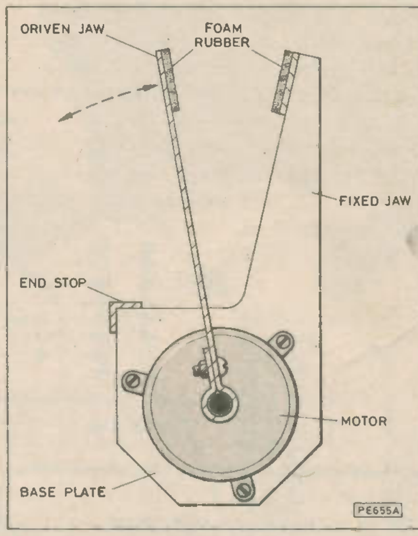


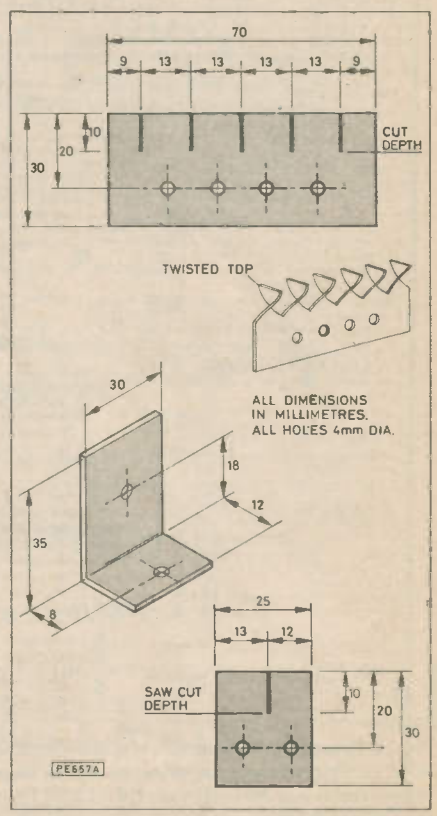
Fig. 5. The simplest gripper possible? A pair of 'electric pliers' for use with the TACACOOGA. An old cassette recorder motor will probably prove adequate

It is worth noting at this point that driving an op. amp. from TTL outputs in the way that IC11 drives IC12a will work reliably only if both the op. amp's inputs are driven from the same piece of silicon, i.e. the same TTL chip. It appears at a glance that in the EPUD configuration R25 might just as well be connected directly to 0V, but if it were, the driver circuit would probably become unstable.

CONSTRUCTION

Only one or two notes are necessary in connection with assembling the p.c.b. (Fig. 4). The first step is to decide how many channels are required initially, and therefore how much of the

Fig. 6. Heatsink dimensions



p.c.b. is to be populated. The next step is to decide which mode the gripper circuit should be used in; whether it is to be used as the full *TACACOOGA*, as a derivative thereof, or as a straightforward motor (or electromagnet) switch.

When ready to proceed with construction, first insert the through-board links. Although the p.c.b. is double-sided, through-plating has been omitted to control its cost to the constructor. Eyelets or pieces of 22 s.w.g. tinned copper wire should be used for these links where they occur underneath i.c.s and other components, but elsewhere the use of solder pins will create an abundance of "easy clip-on" test points. The through-board links should be made *before* any components are inserted, of course, particularly those located beneath IC5–8 and IC13.

If the p.c.b. is drilled to 0·8mm for the i.c.s, you may find it necessary to open out the holes to 1mm for the passive components, or greater in the case of power components.

Sockets should at least be used for IC5–8, if not all d.i.l. components, including the addressing switches.

The three heatsinks are cut out of sheet alloy, and their dimensions are shown in Fig. 6. The two shared heatsinks require the use of mica washers and 4BA nylon nuts and screws to secure the transistors. Heatsink compound should be applied, and the transistors mounted loosely on the heatsink before inserting them in the p.c.b. If they are tightened to the heatsink whilst in situ, and *then* soldered, the transistors' leads will not be left under permanent stress.

The remaining components may be soldered in any order, and the i.c.s inserted in their sockets afterwards. During any subsequent experimentation with the board it must be borne in mind that there are three distinct 0V systems on the p.c.b. which meet at a common "star" point. These are: *Analogue Ground, Digital Ground,* and a high current line for the motors, called *Motor Ground*. Cross wiring these during any excercise will most likely lead to unwanted voltage drops along p.c.b. tracks which in turn upset the digital logic, or the accuracy of the analogue circuits. This point is particularly important to remember if you intend building all, or part, of this interface on stripboard.

SOFTWARE

A program to demonstrate the complete interface, and written in BASIC for the standard ZX81, is shown in Listing 1. The program assumes that all the address decode switches are off (logic 1's), so that the interface is located at base address 65520. ★

Listing 1 Demonstration Program

```
10  LET L=65520
20  PRINT "WHICH CHANNEL: 0,1,2,3,4 ?"
30  INPUT C
40  CLS
50  LET M=L+C
60  PRINT "CHANNEL ";C
70  IF C = 4 THEN GOTO 200
100 PRINT"POSITION: 1 – 255 ?"
110 GOTO 230
200 PRINT "SELECT . . ."
210 PRINT "1) OPEN GRIPPER"
220 PRINT"2) CLOSE GRIPPER"
230 INPUT P
240 POKE M,P
250 PRINT"                              "
260 GOTO 20

210 PRINT "1) CLOSE GRIPPER"   } Alternative lines for
220 PRINT "2) OPEN GRIPPER"    } ACOOC
```

NEXT MONTH: Give your robot shifty eyes!

BBC Micro Forum...

David Whitfield MA MSc CEng MIEE

THIS month *BBC Micro Forum* moves on to look at some of the less obvious elements of the analogue port. First under the microscope are the two pushbutton inputs nominally provided for joysticks.

JOYSTICK FIRE BUTTONS

One of the most popular uses for the analogue port (in the early days of owning a computer, at least) is for connecting the games joysticks. Most of us just plug them in without a second thought, and then get on with alien blasting, or whatever, until the early hours of the morning. It may be of interest, however, to look at just how the joysticks are usually connected up to the analogue port. As shown in Fig. 1, each joystick is, in fact, a pair of potentiometers wired between V_{ref} and ground. The fire buttons act by shorting the pushbutton inputs to ground. The figure shows the connection from the wiring side of the plug. With the four-channel ADC (described last month), there is clearly no problem catering for two independent joysticks.

The 'fire' or pushbutton inputs are internally connected to PB4 and PB5 on the system VIA. The levels on these inputs are normally at logic 1, but change to logic 0 when the corresponding button is pressed. The easiest way to read the state of the bushbuttons, however, is to use the Basic ADVAL function. Using the following statement:

X = ADVAL(0) AND 3

will give the following values for X, depending on the button states as follows:

X=0 no buttons pressed
X=1 left button pressed
X=2 right button pressed
X=3 both buttons pressed

The left button is labelled button 0, and the right one button 1 on the connector drawing.

Clearly the fire buttons can be replaced by almost any other switch, or by any circuit which switches between two states. This can be a useful adddition to the user port in applications which require more lines than those available.

LOW COST JOYSTICKS

Adding joysticks to the BBC Micro can be relatively expensive since analogue potentiometer types are required. *Mr. A. Moran* of Reading has suggested a simple way of interfacing the lower cost switch type of joystick via the user port. Usually, it is necessary to build some form of interface between the analogue port and this type of joystick, but his approach does away with that problem, and allows a lower cost solution to be produced. Indeed, if you don't already own one, you could even try building your own switch joystick using two 2-way centre-off switches, some rubber bands, and a pushbutton switch; any offers for a design?

The interface to the user port is shown in Fig. 2, where the connections are those for a Philips G700 joystick. The connections for other popular models such as the Atari, Competition Pro, Quickshot, etc., are all similar. If in doubt, a simple battery and bulb arrangement will allow the exact connection details to be determined. The pull-up resistors are to ensure good noise immunity. With the joystick connected in this way, the switches will return a logic 0 when closed. Listing 1 provides an interesting demonstration of the joystick at work. The relationship between the user port bit values, and the joystick movements, are given in Table 1. The program allows an asterisk to be moved around the screen, and produces a satisfying 'zap' when the fire button is pressed. The program also allows diagonal movement by testing each direction independently.

In passing, readers may already have noticed in last month's column that long lines in program listings have been broken for printing. This has been done manually (hence all of the mistakes are mine!), in an attempt to break each line at an identifiable point. This is to try to avoid the problems which can occur when an automatic line breaker is used, and I do try to break lines at obvious points like commas or where extra spaces will do little or no damage.

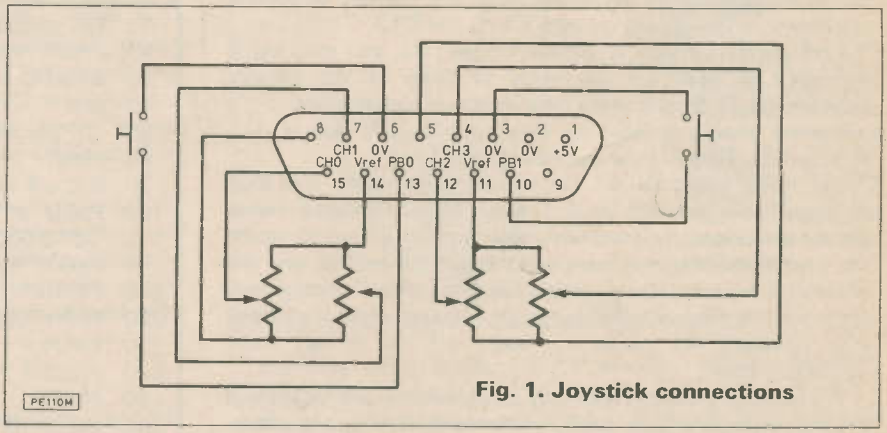


Fig. 1. Joystick connections

User Port	Joystick Movement	Value Read
Bit 0	LEFT	1
Bit 1	RIGHT	2
Bit 2	UP	4
Bit 3	DOWN	8
Bit 4	FIRE	16

Table 1. Switch values

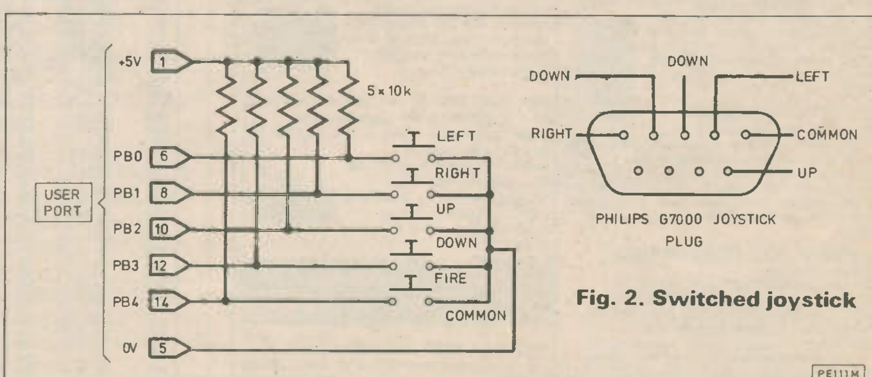


Fig. 2. Switched joystick

FIRE BUTTONS FROM ASSEMBLER

It will not always be the case that reading the fire buttons is something which you will want to do from a Basic program. If speed is of the essence, or if the buttons are to be read from a sideways ROM, machine code is really the only answer. In previous months we have looked at how to read the VIA registers directly. The operating system, however, includes powerful and flexible facilities which can be called from either Basic or machine code programs. One group of facilities available to the machine code programmer is provided by the **OSBYTE** calls. In order to use these it is simply a matter of making a subroutine call to &FFF4. When the call is made, the CPU registers should be set up with the following states:

A selects the OSBYTE facility is required
X may contain an OSBYTE parameter
Y may contain an OSBYTE parameter

Only some OSBYTE calls take parameters, but when they are required, they are passed in the X and Y registers. So far, so good, but how do we read the fire buttons? An OSBYTE call with A=&80 and X=0 is the equivalent of the ADVAL(0) call in Basic. When the call is completed, the value in bits 0 and 1 of the X register (i.e. the two least significant bits) indicate the logic state of the fire buttons. A bit is set to 0 if the button is pressed, since the circuit is such that when a button is pressed, it connects the otherwise floating input to ground. As with all theory, however, we really need a practical example to see all of this at work.

LIGHT SENSOR

The simple interface shown in Fig. 3 detects light falling on the photo-Darlington transistor. In darkness or low light levels the transistor is virtually non-conducting, and hence the output is very close to +5 volts. When sufficient light falls on the lens of the transistor (which has a transparent case), it turns on and the output level falls to less than 1 volt.

The logic gates following the sensor output provide some simple signal processing. Gates (a) and (b) buffer the transistor output to indicate 'light' and 'dark', respectively, when the output is at logic 1. The remaining gates are arranged as a latch which allows any change to be remembered.

```
10 REM Joystick Demo: Andrew Moran
20 REM --------------------------
30 :
40 ENVELOPE 1,1,4,-4,12,10,20,20,
   100,0,0,-5,100,100
50 MODE 7: X=0: Y=0: ?&FE62=0
60 :
70 REPEAT
80  OldX=X: OldY=Y: J=(255-?&FE60)
90  IF J>=16 SOUND 1,1,50,1: J=J-16
100  IF J>=8 J=J-8:IF Y<23 Y=Y+1
110  IF J>=4 J=J-4:IF Y>0 Y=Y-1
120  IF J>=2 J=J-2:IF X<38 X=X+1
130  IF J=1 AND X>0 X=X-1
140  PRINTTAB(OldX,OldY)" "
150  PRINTTAB(X,Y)"*"
160  UNTIL FALSE
```

Listing 1. Joystick demo

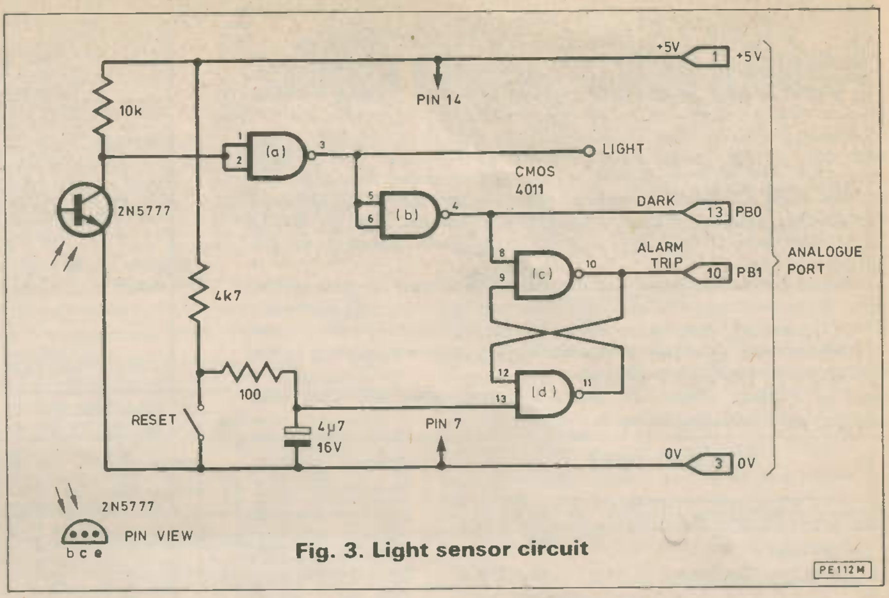


Fig. 3. Light sensor circuit

The latch is reset by a low level from the manual reset switch; this could easily be replaced by an input to pin 13 on gate (d) from a computer output line, e.g. the user port. The latch allows the circuit to remember any event which causes the transistor to switch until the computer has time to take note. Holding the reset switch in the reset position all the time disables the latching action. Depending on whether the 'light' or 'dark' input is fed to the latch (pin 8), the latch will remember either a dark or light event, e.g. a beam of light being broken, or a light being turned on, respectively.

INTRUDER ALARM

One of the natural applications for this type of interface (which will work just as well with the user port) is in intruder alarms. This is how the circuit of Fig. 3 is shown configured. The flip-flop is arranged so that when the beam of light falling on the transistor is broken, the latch output changes from 0 to 1, and stays there until the reset line is taken to a 0. The 'dark' output is at 1 when the beam is broken, but reverts to 0 when the beam is restored. An advantage of this arrangement is that if either lead is cut, the line will float to an alarm level, hence defeating the attempt to silence the alarm!

In use, it is best to limit the field of view of the transistor by enclosing it in a case with a small aperture cut in one side. The curved surface of the transistor package acts as a lens to direct the light onto the base junction. The light source can be almost anything; daylight from a window or room lighting at night. If the alarm is set off continuously, reduce the amount of stray light by using a small tube (painted matt black on the inside) over the aperture pointing at the light source.

Listing 2 is an example of an intruder alarm based on the circuit given. The software assumes that the latched output is connected to the right fire button (**PB1**), and that the 'dark' output is connected to the left (**PB0**). The program includes the

```
10 REM Intruder Alarm
20 REM --------------
30 ON ERROR GOTO 280
40 DIM Code% 100
50 Beam = &70: Latch = &71
70 OSBYTE = &FFF4: D$ = CHR$141
80 PROCAssemble
90 *FX210,0
100 *FX212,136
110 *FX213,200
120 *FX214,3
130 MODE 7: VDU 23,1,0;0;0;0;
140 Redflash$=CHR$129+CHR$136
150 A$=D$+Redflash$+"INTRUDER"
160 C$=D$+CHR$130+"   CLEAR  "
170 PRINTTAB(12,3)CHR$131;D$;
180 PRINT"Intruder Alarm"'TAB(12);
190 PRINT CHR$131;D$;"Intruder Alarm"
200 PRINTTAB(2,21)"Alarm will sound
    if beam is broken"'TAB(8)"Press
    RESET to silence"
210 REPEAT:CALL Read
220  PRINTTAB(3,14)"Beam ";
230  IF ?&70=0 PRINT "broken  ":
     ELSE PRINT "unbroken"
240  PRINTTAB(27,14)"Alarm ";
250  IF ?&71=0 PRINT "tripped":
     ELSE PRINT "clear  "
260  IF ?&70=0 OR ?&71=0 PRINT
     TAB(13,10)A$'TAB(13)A$:VDU7:
     ELSE PRINTTAB(13,10)C$'TAB(13)C$
270  X$=INKEY$(40): UNTIL FALSE
280 PRINTTAB(0,24);: *FX212,144
290 *FX213,101
300 *FX214,7
310 VDU 23,1,1;0;0;0;:END
320 :
330 DEF PROCAssemble
340 FOR opt% = 0 TO 3 STEP 3
350   P% = Code%
360   [OPT opt%
370   .Read
380   LDA #&80:LDX #0:JSR OSBYTE
390   TXA:AND #1:STA Beam:TXA
400   AND #2:LSR A:STA Latch:RTS
410   ]NEXT opt%
420 ENDPROC
```

Listing 2. Light sensor demo

machine code technique described above for reading the fire button inputs. The alarm goes off when the light beam falling on the transistor is broken; simply press the reset button to silence it!

NEXT MONTH

BBC Micro Forum will be looking at a simple light pen for your micro.

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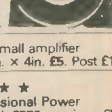

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Top Ten Kits

THIS/LAST MONTH			DESCRIPTION	CODE	PRICE	BOOK
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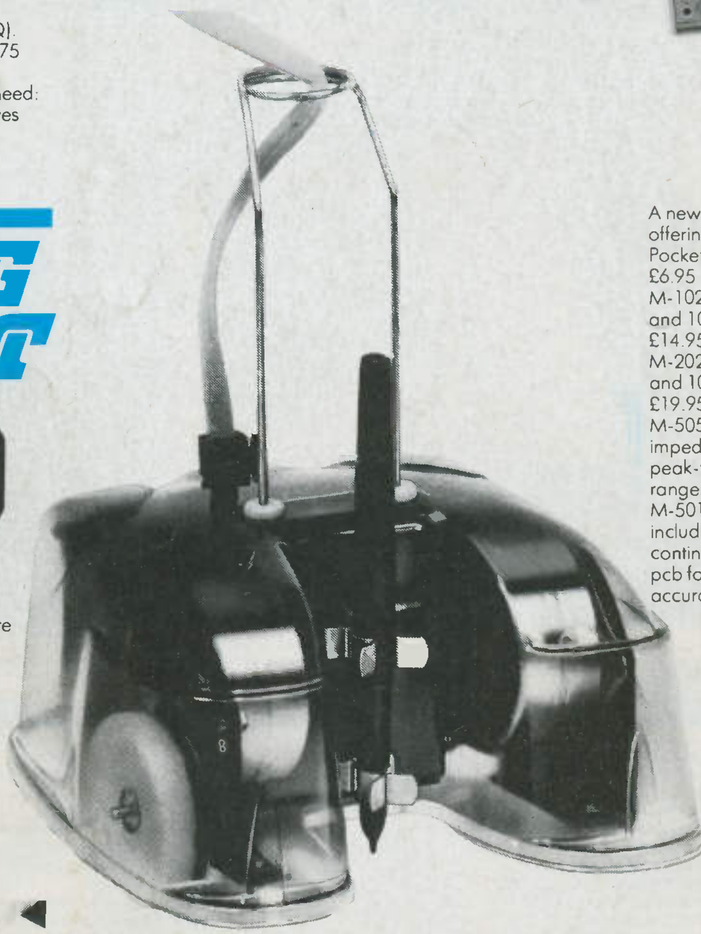
2.	(2)	◆◆	75W Mosfet Amp.	LW51F	£15.95	Best E&MM
3.	(3)	◆◆	Car Burglar Alarm	LW78K	£7.49	4 XA04E
4.	(7)	◆	Logic Probe	LK13P	£10.95	8 XA08J
5.	(5)	◆◆	U/sonic Intrudr Dtctr	LW83E	£10.95	4 XA04E
6.	(4)	◆	Portylite	LW93B	£10.95	Best of E & MM
7.	(6)	◆	8W Amplifier	LW36P	£4.95	Catalogue
8.	(–)	◆	Noise Gate	LK43W	£9.95	Best E&MM
9.	(9)	◆◆	Computadrum	LK52G	£9.95	12 XA12N
10.	(–)	◆	DXer's Audio Processor	LK05F	£9.85	7 XA07H

Over 100 other kits also available. All kits supplied with instructions. The descriptions above are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate Project Book mentioned in the list above.

Is it a turtle? Is it a robot? Is it a buggy? Yes! it's Zero 2.



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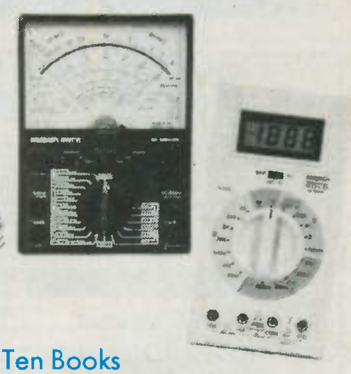

Top Ten Books

1.	(1)	◆◆	Loudspeaker Enclosure Design and Construction	WM82D	£3.25
2.	(4)	◆	Mastering Electronics	WM60Q	£4.70
3.	(3)	◆◆	Remote Control Projects	XW39N	£2.75
4.	(9)	◆	How to Build Your Own Solid State Oscilloscope	XW07H	£2.10
5.	(5)	◆◆	International Transistor Equivalents guide	WG30H	£3.25
6.	(8)	◆	How to Design and Make Your Own PCBs	WK63T	£2.05
7.	(2)	◆	Power Supply Projects	XW52G	£2.10
8.	(–)	◆	Radio Control for Beginners	XW66W	£1.95
9.	(–)	◆	How to Use Op-amps	WA29G	£2.45
10.	(7)	◆	Electronic Synthesiser Projects	XW68Y	£1.95

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