PRACTICAL
ELECTRONICS
APRIL 1977

40p

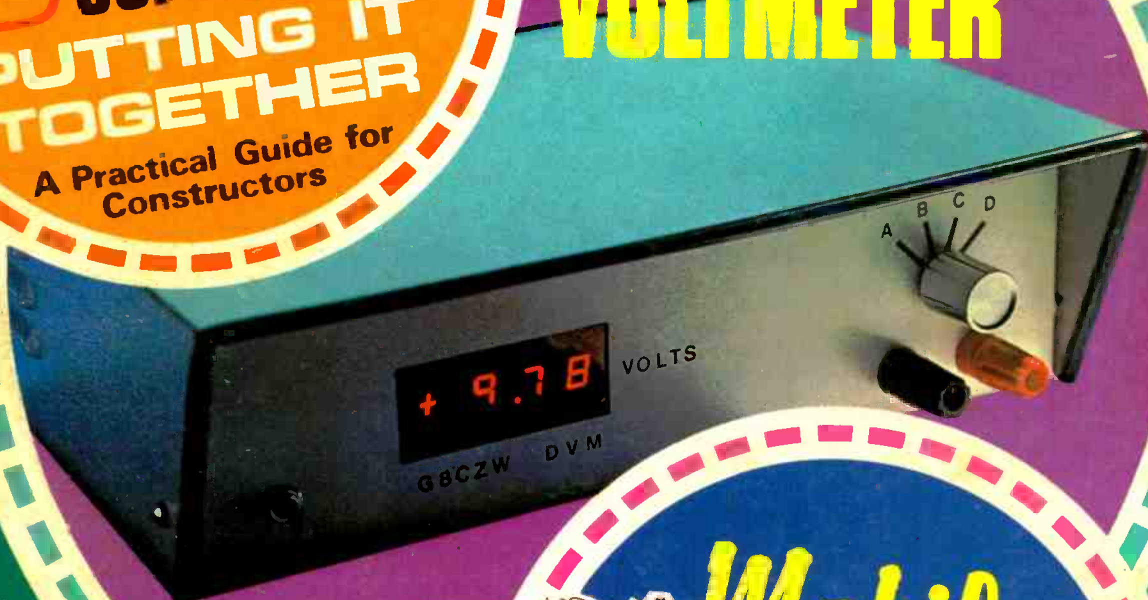
Extra

8 PAGE SUPPLEMENT

PUTTING IT TOGETHER

A Practical Guide for Constructors

DIGITAL VOLTMETER



Mobile DISCO Techniques

Special 2 Part Feature

Also:

Transient Generator

Day Indicator

Microprocessors - Explained... Part 2

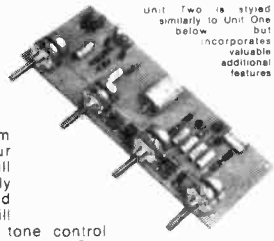
Stirling Sound

Q.V. MODULES FOR COST CONSCIOUS CONSTRUCTORS

MADE IN OUR OWN U.K. FACTORY

NEW THIS MONTH

UNIT TWO MAGNETIC PRE-AMP WITH ACTIVE TONE CONTROLS



Unit Two is styled similarly to Unit One below but incorporates valuable additional features

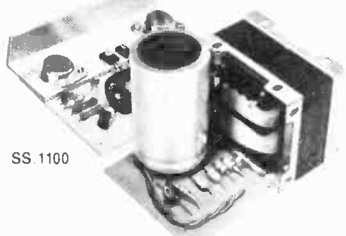
Here's another real money saver from Stirling Sound! Wire this unit into your system and style it how you wish. Full instructions make this completely straight-forward. Use Stirling Sound power amps for choice, but Unit Two will work superbly in any system. Active tone control circuits give bass and treble rise and cut of ±15dB each, accepts inputs from 1 to 5mV. RIAA corrected adaptable also input for ceramics, etc. S/N ratio 60dB, channel separation typically 56dB, frequency range 30–20,000kHz ±1dB. Tested before despatch (ready built) and guaranteed. For 10–20V operation

£10·85

100 Watt R.M.S. POWER AMP and matching 70V POWER SUPPLY

Your chance to save £1·95

Today's best 100 watt value now made even greater for disco, P.A., guitar use, etc. Normal selling price for items bought separately is £22·95*



SS.1100

SS.370

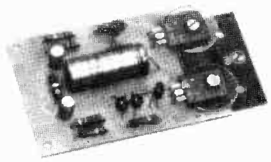
SS.370 70V/2A power supply with low volt take-off — **£12·50***

SS.1100H (with large heat-sink) and SS.370 — **£21***

SS.1100 100 Watt R.M.S. power amp with heatsink type mounting flange — **£9·45***

Full size heat-sink — **£1***

MORE STIRLING SOUND Q.V. MODULES TO SAVE YOU MONEY



POWER AMPLIFIERS 3 TO 40 WATTS R.M.S.

SS.103 3 watt r.m.s. mono I.C. with short circuit protection — £1·75

SS.103-3 Stereo version of above, using two I.C.s — £3·25

SS.105 5 watts r.m.s. into 3 ohms, using 12V — £2·25

SS.110 10 watts r.m.s. using 24V and 4 ohm load — £2·75

SS.120 20 watts r.m.s. into 4 ohms, using 34V — £3·25

SS.140 40 watts r.m.s. into 4 ohms using 45V supply. Ideal small disco or P.A. unit — £3·95*

VAT on power units ordered with amplifiers SS 103–SS 120 becomes 12½%

TONE CONTROLS/ PRE-AMPS

SS.100 Active tone control. Stereo ±15dB on bass and on treble — £1·60

SS.101 Pre-amp for ceramic cartridges, etc. Stereo. Passive tone control details supplied — £1·60

SS.102 Stereo pre-amp for low output magnetic P.U.s. R.I.A.A. corrected — £2·65

UNIT ONE TONE CONTROL PRE-AMP

A real money saver this. Compatible with all relevant Stirling sound modules as well as other makes. Combined pre-amp with active tone-control circuits. ±15dB at 10kHz treble and 30Hz bass. Stereo. Vol./balance/treble/bass 200mV out for 50mV in. Takes 10–16V — £7·80

FM TUNING MODULES

SS.201 Front end tuner, slow geared drive, two gang, A.F.C. facility. Tunes 88–108MHz — £5·00

SS.202 I.F. amplifier. Metering and A.F.C. facilities — £2·65

SS.203 Phase lock loop Stereo Decoder for use with the above or other FM mono tuners. A LED may be fitted — £3·85

SS.203-1 Coil-type stereo decoder for use with SS.201 and SS.202, recommended where economy is called for

SS.203-1N with I.C. for neg. earth — £2·50

SS.203-1P transistor type for pos. earth — £2

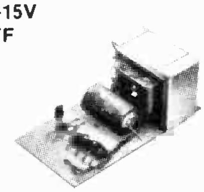
WHAT Q.V. MEANS TO YOU

It means Stirling Sound QUALITY and VALUE from modules made in our own Essex factory. They are all tested, guaranteed and offer unbeatable value. Designed by highly specialised electronic engineers with wide experience of the constructor and experimenter market. WATCH HOW THE STIRLING SOUND RANGE GROWS!

POWER SUPPLY UNITS

WITH 13–15V TAKE-OFF POINTS

Except SS.312



NOW 8 MODELS TO CHOOSE FROM

Complete with mains transformers and low-volt take-off points (except SS.312). All at 8% VAT rate. Add 50p for P. & P. any model (except SS.300 at 35p and SS.370 at £1).

SS.312	12V/1A	£3·75*
SS.318	18V/1A	£4·15*
SS.324	24V/1A	£4·60*
SS.334	34V/2A	£5·20*
SS.345	45V/2A	£6·25*
SS.350	50V/2A	£6·75*
SS.370	70V/2A	£12·50

SS.310/50 STABILISED POWER SUPPLY with variable output from 10 to 50V/2A. Protected against shorting (P. & P. 50p) — £11·95*

SS.300 POWER STABILISING UNIT 10–50V/2–8A adjustable. For adding to unstabilised supplies. Built-in protection against shorting (P. & P. 35p) — £3·25*

Large 12p S.A.E. brings latest Stirling Sound 16 large page equipment and components price list

WHEN ORDERING add 35p for P. & P. unless stated otherwise. VAT add 12½% to total value of order unless price is shown* when the rate is 8%. Make cheques, etc., payable to Bi-Pre-Pak Ltd. Every effort is made to ensure correctness of information at time of going to press. Prices subject to alteration without notice.

Stirling Sound

A member company of the Bi-Pre-Pak group, Est. 1959

Dept. PS4, 220–224 West Road, Westcliff-on-Sea, Essex SS0 9DF
Phone Southend (0702) 46344

Personal callers welcome

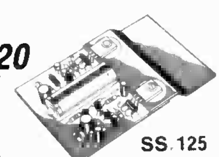
De-luxe 25 watt hi-fi amp bargain

Made to sell at £7·25

LIMITED NUMBER AVAILABLE AT

£5·20

*This is the Bi-Pre-Pak **SS.125**, designed and made for the connoisseur market of hi-fi and technical specialists. 25W r.m.s. into 8 ohms using 50V; 22W r.m.s. into 4 ohms from 33V. Input sensitivity—150mV for full output; distortion less than 0·05% at all powers. With full instructions. Tested and guaranteed. Limited number only available.*



SS.125 De-luxe Power Amp

PRACTICAL ELECTRONICS

VOLUME 13 No. 4 APRIL 1977

CONSTRUCTIONAL PROJECTS

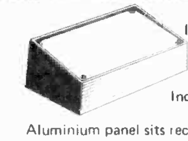
GENERAL FEATURES

NEWS AND COMMENT

SPECIAL 8-PAGE SUPPLEMENT

Our May issue will be on sale on Thursday, April 7, 1977
(for details of special free booklet and other contents, see page 287)

MINI CONSOLES



Ideal for small desk control panels and consoles. Moulded in orange, blue, black and grey ABS. Incorporates slots for holding 1.5mm thick pcb's. Aluminium panel sits recessed into front of console and held by screws running into integral brass bushes.

MC 161 x 96 x 58mm £1.53 (1-9) £1.50 (10+)
MC 215 x 130 x 75mm £2.20 (1-9) £2.17 (10+)
Add 25p per £1 order value for Post & Packing

ECONOMY QUALITY LED's

50 for only £5 — 100 for only £9
Mixed bags, all sizes, various colours

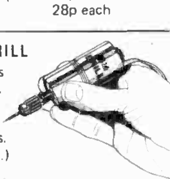
Full specification LED's also available
Red (specify size) 75p per pack
Green, Yellow, Orange (specify size) £1.20 per pack
Packs contain 5 LED's, mounting clips and data

TYPE A NEON INDICATORS

Supplied with resistor for 240 Volts operation
Held in 8mm hole by plastic bezel
150mm wire leads

Red, Amber, Clear, Opal 19p each
Green 28p each

12 VOLTS MINI HAND DRILL

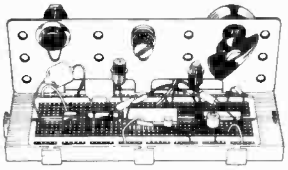


Ideal for drilling pcb, chassis etc as well as model making. Supplied with 2 collets that accept tools and drills with 3/32" and 0.50" dia shanks.
£7.56 (Includes VAT & P.P.)

Stop wasting time soldering

The NEW MW BREADBOARD accepts

Transistors, LED's, Diodes, Resistors, Capacitors and all DIL packages with 6 to 40 pins



Includes slot-in Component Support Bracket and has over 400 individual sockets, plus Vcc and Ground Bus Strips
Price £9.72 (includes VAT & P.P.)

TYPE MP NEON INDICATOR

Supplied with resistor for 240 Volts operation
150mm leads, held in 6.4mm hole by nut

Red, Amber, Clear, Opal 20p each

SEVEN SEGMENT DISPLAYS

Economy quality
Red, yellow and green
Only 45p each
Common Anode – 0.3" Left Decimal
Full specification displays also available as above
Red @ 98p each
Green and Yellow @ £1.35 each.
Data supplied with full spec. displays only.

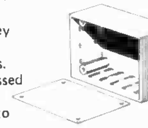
Quantity quotations on request

P.P. Note Unless included in price add 25p Post & Packing for orders totalling under £10. All prices include VAT and are valid in UK only for 2 months from journal issue date

Michael Williams Electronics

47 Vicarage Av. Cheadle Hulme, Cheshire SK8 7JP

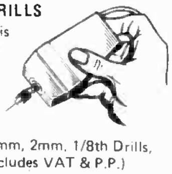
SC BOXES (square corners)



Easily drilled or punched, orange, blue, black and grey ABS. Incorporate slots for holding 1.5mm thick pcb's. Aluminium panel sits recessed into front of the box and held by screws running into integral brass bushes.

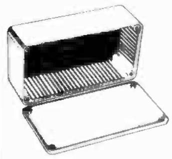
SC 85 x 56 x 35mm 80p (1-9) 77p (10+)
SC 111 x 71 x 48mm £1.07 (1-9) £1.04 (10+)
SC 161 x 96 x 59mm £1.49 (1-9) £1.46 (10+)
Add 25p per £1 order value for Post & Packing

240 VOLTS MINI HAND DRILLS



Ideal for drilling pcb's, chassis etc as well as model making. Supplied with 3 collets that accept tools and drills with 1mm, 2mm and 1/8" dia shanks.
£9.72 (includes VAT & P.P.)
Accessory tools... 5 Burrs, 1mm, 2mm, 1/8th Drills, 3/32" Collet Price £1.75 (Includes VAT & P.P.)

RC BOXES (round corners)



Easily drilled or punched, orange, blue, black and grey ABS. Incorporate slots for holding 1.5mm thick pcb's. Close fitting flanged lids held by screws running into integral brass bushes.

RC 100 x 50 x 25mm 51p (1-9) 49p (10+)
RC 112 x 62 x 31mm 59p (1-9) 52p (10+)
RC 120 x 65 x 40mm 68p (1-9) 62p (10+)
RC 150 x 80 x 50mm 77p (1-9) 74p (10+)
RC 190 x 110 x 60mm £1.33 (1-9) £1.30 (10+)

Polystyrene version

in grey only with no slots, no integral brass bushes
RC(P) 112 x 61 x 31mm 35p (1-9) 32p (10+)
Add 25p per £1 order value for Post & Packing

TRANSFORMERS

ALL EX-STOCK—SAME DAY DESPATCH

AUTO TRANSFORMERS

Ref	VA (Watts)	Auto Taps	£
113	20	0-115-210-240	2·81
64	75	0-115-210-240	4·65
4	150	0-115-200-220-240	6·24
66	300	0-115-200-220-240	8·62
67	500	0-115-200-220-240	13·10
84	1000	0-115-200-220-240	19·70
93	1500	0-115-200-220-240	23·62†
95	2000	0-115-200-220-240	31·56†
73	3000	0-115-200-220-240	45·76†

CASED AUTO TRANSFORMERS

240V cable in and U.S.A. 2 pin outlet

20VA	£4·95	Ref 113W
150VA	£8·94	Ref 4W
500VA	£15·11	Ref 67W
1000VA	£22·84†	Ref 84W
2000VA	£35·66†	Ref 95W

60 VOLT RANGE

Prim. 220–240V
Sec. 0–24–30–40–48–60V

Ref.	Amps	£
124	0·5	3·94
126	1·0	5·43
127	2·0	7·65
125	3·0	11·00
123	4·0	13·07
40	5·0	14·20
120	6·0	16·64
121	8·0	19·56†
122	10·0	24·09†
189	12·0	25·16†

SCREENED MINIATURES

Ref mA	Volts	£
238 200	3-0-3	2·50
212 1A, 1A	0-6, 0-6	2·97
13 100	9-0-9	2·28
235 330, 330	0-9, 0-9	2·39
207 500, 500	0-8-9, 0-8-9	3·14
208 1A, 1A	0-8-9, 0-8-9	4·51
236 200, 200	0-15, 0-15	2·28
214 300, 300	0-20, 0-20	3·22
221 700 (DC)	20-12-0-12-20	3·66
206 1A, 1A	0-15-20, 0-15-20	5·37
203 500, 500	0-15-27, 0-15-27	4·77
204 1A, 1A	0–15-27, 0-15-27	6·00
S112 500	12, 15, 20, 24, 30	3·15

MAINS ISOLATING

PRI. 220/240V
SEC. 120/240V
CENTRE TAP WITH SCREEN

Ref	VA(Watts)	£
07*	20	4·57
149	60	6·68
150	100	7·65
151	200	11·95
152	250	14·47
153	350	17·14
154	500	19·73
155	750	27·25†
156	1000	37·97†
157	1500	43·33†
158	2000	48·34†
159	3000	76·36†

*115V or 240V Sec. only.

12 and or 24 Volt

PRIMARY 220–240 VOLTS

Ref.	Amps 12V	Amps 24V	£
111	0·5	0·25	2·30
213	1·0	0·5	3·01
71	2	1	3·69
68	3	–	5·10
18	4	2	4·56
85	5	–	5·61
70	6	3	6·36
108	8	4	7·34
72	10	5	7·86
116	12	6	8·39
17	16	8	10·48
115	20	10	15·42
187	30	15	19·50
226	60	30	21·94†

50 VOLT RANGE

Prim. 200-240V
Sec. 0-19-25-33-40-50V

Ref No.	Amps	£
102	0·5	4·07
103	1·0	5·27
104	2·0	7·17
105	3·0	8·77
106	4·0	11·26
107	6·0	17·29
118	8·0	18·62
119	10·0	22·04†

30 VOLT RANGE

Prim. 220–240V
Sec. 0–12–15–20–24–20V

Ref.	Amps	£
112	0·5	3·15
79	1·0	4·00
3	2·0	5·55
20	3·0	6·87
21	4·0	7·93
51	5·0	9·55
117	6·0	10·69
88	8·0	14·15
89	10·0	14·51

TEST METERS

AVO 8 MK5	£67·33
AVO 72	£26·86
AVO TT 169	£28·94
AVO MM5	£23·48
U4315 (USSR) inc steel carry case	£16·52

PLUS

DECS SOLDERLESS BREAD-BOARDING

S Dec 70 contacts	£2·41
T Dec 208 contacts	£3·92
U Dec "A" for I.C.s, etc.	£4·58
U Dec "B" for I.C.s, etc.	£7·82

HIGH VOLTAGE

Mains Isolating
Prim. 200/220 *or* 400/440
Sec. 100/120 *or* 200/240

VA	Ref.	£
60	243	6·62
350	247	15·23
1000	250	32·68†
2000	252	54·80†

BRIDGE RECTIFIERS

		£
200V	2A	0·67
400V	2A	0·72
200V	4A	0·89
500V	10A	2·70

POWER UNITS

CC12–05, 3-4·5-6-7·5-9-12V at 500mA £5·18
STABILISED 3-6-7·5-9V at 400mA £6·98
3300 fits into 13A socket 6-7·5-9V 300mA £3·59
Plugs direct into 13A 3-pin socket, 6-7·5-9V 300mA with multi-plug £3·59

T.I. MINI-MULTIMETER

D.C.—1,000V, A.C.—1,000V, 1,000Ω/V.
D.C 1—100mA, Res.—150kΩ.
BARGAIN AT £6·21

AUDIO KIT 25W

2 + 25W Amplifiers, 1 + Pre-Amp
1 + Power supply, 1 + Transformer
1 + Front Panel
1 + Kit of parts to include on/off switch, neon ind. Stereo headphone socket
Plus Instructions book £32·18.

TEAK AUDIO KIT 25W

Teak veneered cabinet
Aluminium chassis, heat sink and front panel brackets plus back panel and sockets etc. £11·21.

STEREO FM TUNER WITH PHASE-LOCK LOOP

4 Pre-selected stations supply 20-35V. 90mA Max. £24·21

ELECTRONIC CONSTRUCTION KIT

10 projects (including Electronic Organ). Ideal gift at £8·63 (no soldering)

COMPONENT PACKS

200 Mixed value resistors (count by weight)
150 Mixed value capacitors (count by weight)
30 Mixed value precision resistors ¼W 2 %
15 Assorted pots and pre-sets
10 Reed switches
3 Micro switches
15 Wire wound resistors—mixed wattage
1 Pack wire 50 metres, assorted colours
PLEASE STATE PACK REQUIRED 90p PER PACK

NEW STEREO 30

Complete Stereo Chassis inc.
7 + 7W RMS, Amp, Pre-amp, Power Supply, Front Panel, Knobs (only needs Mains Trans.).
Stereo 30 £18·99 Mains Trans £3·89. Teak veneered cab. £4·54.

HIGH QUALITY MODULES

5 Watt RMS AMPLIFIER	£3·59
10 Watt RMS AMPLIFIER	£3·98
25 Watt RMS AMPLIFIER	£4·94
125W RMS AMPLIFIER	£17·61
PRE-AMP for 3-5-10W	£8·09
PRE-AMP for 25W	£15·57
POWER SUPPLIES 3-5-10W	£1·72
POWER SUPPLIES 25W	£4·43
TRANSFORMER 5-10W	£3·89
TRANSFORMER 25W	£5·74

ANTEX SOLDERING IRONS

15W £4·08 18W £4·08 25W £3·80
SOLDERING IRON KIT £5·66
STAND FOR ABOVE £1·84

CARTRIDGES

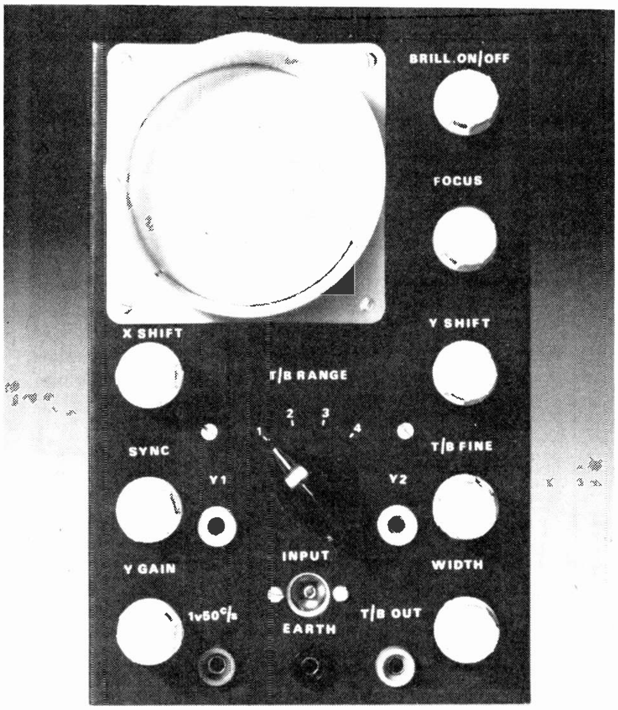
AT55	£3·93
SONOTONE	
V100	£4·87
9TAHC	£3·01
ACOS	
GP93–1	£2·50
GP96–1	£2·92
B.S.R.	
SX6M	£2·75
SC12M	£3·50
GOLDRING	
G800	£5·96
G850	£4·44
SHORE	
M75–65	£12·50
M55E	£14·19

Prices include VAT and P. & P. except † where carriage will be according to weight and distance
Electrosil Resistors, Semiconductors, Multi-meters
Wide range of panel meters audio accessories. Send stamp for lists
Prices correct at 21st January 1977

Barrie Electronics Ltd.

3, THE MINORIES, LONDON EC3N 1BJ
TELEPHONE: 01-488 3316/7/8
NEAREST TUBE STATIONS: ALDGATE & LIVERPOOL ST.

Bring 'scope' to your interest.

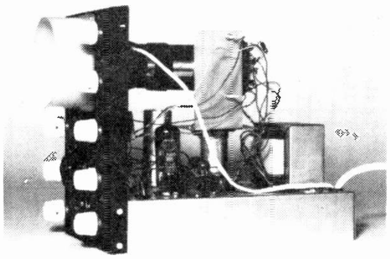


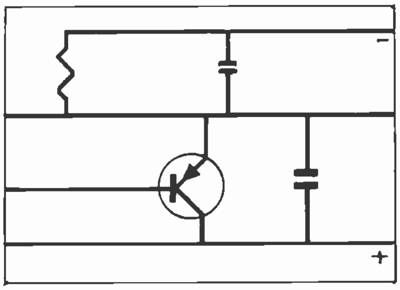
'There's only one way to master electronics... to see what is going on and learn by doing.'

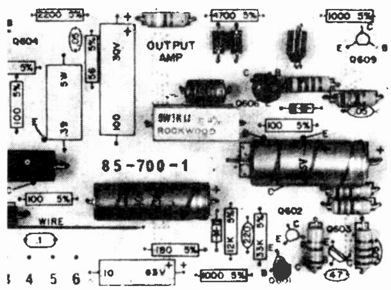
This new style course will enable anyone to have a real understanding of electronics by a modern, practical and visual method. No previous knowledge is required, no maths, and an absolute minimum of theory.

You learn the practical way in easy steps mastering all the essentials of your hobby or to further your career in electronics or as a self-employed electronics engineer.

All the training can be carried out in the comfort of your own home and at your own pace. A tutor is available to whom you can write, at any time, for advice or help during your work. A Certificate is given at the end of every course.







1 Build an oscilloscope.

As the first stage of your training, you actually build your own Cathode ray oscilloscope! This is no toy, but a test instrument that you will need not only for the course's practical experiments, but also later if you decide to develop your knowledge and enter the profession. It remains your property and represents a very large saving over buying a similar piece of essential equipment.

2 Read, draw and understand circuit diagrams.

In a short time you will be able to read and draw circuit diagrams, understand the very fundamentals of television, radio, computors and countless other electronic devices and their servicing procedures.

3 Carry out over 40 experiments on basic circuits.

We show you how to conduct experiments on a wide variety of different circuits and turn the information gained into a working knowledge of testing, servicing and maintaining all types of electronic equipment, radio, t.v. etc.

All students enrolling in our courses receive a free circuit board originating from a computer and containing many different components that can be used in experiments and provide an excellent example of current electronic practice.

To find out more about how to learn electronics in a new, exciting and absorbing way, just clip the coupon for a free colour brochure and full details of enrolment.

Write to:- British National Radio & Electronics School, P.O. Box 156, Jersey, Channel Islands.

NAME ______________________

ADDRESS ______________________

PEB 4/7

SEMICONDUCTORS—COMPONENTS

DIODES

Type	Price	Type	Price	Type	Price	Type	Price
AA129	£0·08	BY100	£0·16	BYZ11	£0·31	OA91	£0·07
AAY30	£0·09	BY107	£0·12	BYZ12	£0·31	OA95	£0·07
AAZ13	£0·10	BY105	£0·18	BYZ13	£0·26	OA182	£0·07
AAZ17	£0·10	BY114	£0·12	BYZ16	£0·41	OA200	£0·08
BA100	£0·10	BY124	*£0·12	BYZ17	£0·36	OA202	£0·08
BA102	£0·32	BY126	*£0·15	BYZ18	£0·36	SD10	£0·06
BA148	£0·15	BY127	*£0·16	BYZ19	£0·28	SD19	£0·06
BA154	£0·12	BY128	£0·16	OA10	£0·35	IN34	£0·07
BA155	£0·14	BY130	*£0·17	OA47	£0·07	IN34A	£0·07
BA156	£0·14	BY133	*£0·21	OA70	£0·07	IN914	£0·06
BA173	£0·15	BY164	£0·51	OA79	£0·07	IN916	£0·06
BB104	£0·15	BY176	*£0·75	OA81	£0·07	IN4148	£0·06
BAX13	£0·07	BY206	£0000	OA85	£0·09	IS44	£0·05
BAX16	£0·08	BYZ10	£0·36	OA90	£0·07	IS920	£0·06

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Type	Price	Type	Price	Type	Price	Type	Price
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IS922	£0·08	IN4005	£0·09	IS023	£0·13	IN5401	£0·15
IS923	£0·09	IN4006	£0·10	IS025	£0·14	IN5402	£0·16
IS924	£0·10	IN4007	£0·11	IS027	£0·16	IN5404	£0·17
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IN4002	£0·06					IN5407	£0·25

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200	TR12A/200	£0·51
400	TR12A/400	£0·71

10 AMP TO48 CASE

Volts	No.	Price
100	TR110A/100	£0·77
200	TR110A/200	£0·92
400	TR110A/400	£1·12

6 AMP TO66 CASE

Volts	No.	Price
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200	TR16A/200	£0·61
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Volts	No.	Price
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600mA TO18 CASE

Volts	No.	Price
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50	THY600/50	£0·22
100	THY600/100	£0·25
200	THY600/200	£0·38
400	THY600/400	£0·45

7 AMP TO48 CASE

Volts	No.	Price
50	THY7A/50	£0·48
100	THY7A/100	£0·51
200	THY7A/200	£0·57
400	THY7A/400	£0·62
600	THY7A/600	£0·78
800	THY7A/800	£0·92

1 AMP TO5 CASE

Volts	No.	Price
50	THY1A/50	£0·26
100	THY1A/100	£0·27
200	THY1A/200	£0·28
400	THY1A/400	£0·36
600	THY1A/600	£0·45
800	THY1A/800	£0·58

10 AMP TO48 CASE

Volts	No.	Price
50	THY10A/50	£0·51
100	THY10A/100	£0·57
200	THY10A/200	£0·62
400	THY10A/400	£0·71
600	THY10A/600	£0·99
800	THY10A/800	£1·22

3 AMP TO66 CASE

Volts	No.	Price
50	THY3A/50	£0·25
100	THY3A/100	£0·27
200	THY3A/200	£0·33
400	THY3A/400	£0·42
600	THY3A/600	£0·50
800	THY3A/800	£0·65

16 AMP TO48 CASE

Volts	No.	Price
50	THY16A/50	£0·54
100	THY16A/100	£0·58
200	THY16A/200	£0·62
400	THY16A/400	£0·77
600	THY16A/600	£0·90
800	THY16A/800	£1·39

5 AMP TO66 CASE

Volts	No.	Price
50	THY5A/50	£0·36
100	THY5A/100	£0·48
200	THY5A/200	£0·50
400	THY5A/400	£0·57
600	THY5A/600	£0·69
800	THY5A/800	£0·81

30 AMP TO94 CASE

Volts	No.	Price
50	THY30A/50	£1·18
100	THY30A/100	£1·43
200	THY30A/200	£1·63
400	THY30A/400	£1·79
600	THY30A/600	£3·50

5 AMP TO220 CASE

Volts	No.	Price
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600	THY5A/600P	£0·69
800	THY5A/800P	£0·81

No.	Price
BT101/500R	£0·80
BT102/500R	£0·80
BT106	£1·25
BT107	£0·93
BT108	£0·98
2N3228	£0·70
2N3525	£0·77
BTX30/50L	£0·33
BTX30/400L	£0·46
C106/4	£0·60

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U53	150	Diodes 75mA 1N4148	16133	£0·60
U54	50	Sil rect top hat 750mA	16134	£0·60
U55	20	Sil rect stud type 3 amp	16135	£0·60
U56	50	400mW zeners DO7 case	16136	£0·60
U57	30	NPN trans BC107/8 plastic	16137	*£0·60
U58	30	PNP trans BC177/178 plastic	16138	*£0·60
U59	25	NPN TO39 2N697/2N1711 silicon	16139	£0·60
U60	25	PNP TO59 2N2905 silicon	16140	£0·60
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U68	20	Unijunction trans TIS43	16148	£0·60
U69	10	1 amp SCR TO39	16149	£1·20
U70	8	3 amp SCR TO66 case	16150	£1·20

Code Nos. mentioned above are given as a guide to the type of device in the pak. The devices themselves are normally unmarked.

COMPONENT PAKS

Pak No.	Qty		Order No	Price
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C3	50	Precision resistors. Mixed values	16166	£0·60
C4	80	⅛W resistors mixed preferred values	16167	*£0·60
C5	5	Pieces assorted ferrite rods	16168	*£0·60
C6	2	Tuning gangs. MW/1W VHF	16169	*£0·60
C7	1	Pack wire 50 metres assorted colours single strand	16170	£0·60
C8	10	Reed switches	16171	*£0·60
C9	3	Micro switches	16172	*£0·60
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C12	30	Paper condensers preferred types mixed values	16175	*£0·60
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C20	1	Pak, copper laminate approx. 200 sq.in	16183	£0·60
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C23	60	¼ watt resistors mixed preferred values	16188	*£0·60
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MC3	24	miniature ceramic capacitors, 3 of each value—470pF, 560pF, 680pF, 820pF, 1,000pF, 1,500pF, 2,200pF and 3,300pF	16162	*£0·60
MC4	21	miniature ceramic capacitors, 3 of each value—4,700pF, 6,800pF, 0·01µF, 0·015µF, 0·022µF, 0·033µF and 0·047µF	16163	*£0·60

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R3—60 mixed ⅛W 10–82kΩ.
ORDER No. 16215 *60p

R4—60 mixed ⅛W 100–820kΩ.
ORDER No. 16216 *60p

R5—40 mixed ½W 100–820Ω.
ORDER No. 16217 *60p

R6—40 mixed ½W 1–8·2kΩ.
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R7—40 mixed ½W 10–82kΩ.
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R8—40 mixed ½W 100–820kΩ.
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PE

THE ESSENCE OF CONSTRUCTING

ONE dare hardly take one's eyes off the semiconductor industry these days. Blink, and the arrival upon the electronics scene of some fabulous new chip or discrete might well be missed. So it is not at all surprising that other important matters, less exciting or glamorous maybe but still essential for our purposes as constructors of electronic equipment, are rather neglected or taken for granted.

Putting It Together is the title of our special supplement this month and the phrase describes in plain unadorned language what it's really all about. The practical realisation of a circuit is the central activity for constructors, and everything else is subservient to this end. The skills and techniques involved in building electronic equipment have no particular mystic attached to them and they are readily acquired and applied. This is not to suggest that in contrast to circuit developments, the mechanics of assembly and wiring of components are standardised, and unaffected by changes in electronic technology. The reverse is of course true.

We have all learnt to appreciate the blessings of solid state, for the lightening of labours concerned with assembly operations. Nowadays assembly work is performed on a miniature scale approaching that of the instrument maker. And present indications are that the nature of this work will become further refined. Some traditional methods may be replaced. For example, the soldering iron may have to give way to the wire wrapping tool in certain applications, notably where microprocessor chips are involved.

Another thing we have become accustomed to is the higher standard of appearance of projects now possible thanks to the wide range of housings available on the market. Plastics has come into its own here, providing wide choice in small cases and cabinets which are natural homes for many self-contained electronic gadgets and instruments. Metal cases are also offered in variety and meet the requirements of larger equipments or for applications where a metal enclosure is an advantage if not an actual necessity. Ready made cases and cabinets make the constructor's task easier and give his handiwork an attractive and acceptable appearance for all manner of environments.

Though "metal bashing" has largely disappeared from the scene, along with the valve, some experience in working with sheet metal remains a valuable attribute for any electronics constructor. There is always the possibility of special or unusual requirements arising that cannot be met by using ready-made items. Even if not for fabricating in the entire, some elementary knowledge and skill appertaining to metal working in general is desirable, if only for modifying existing articles or making accessories such as special brackets and the like.

The essence of constructing will be found in this month's supplement: from the mounting of components and their wiring up, to the enclosure of the completed circuit assembly within an appropriate housing and the final embellishing of its outer surface. Newcomers to electronics and also those many regular followers of P.E. who enjoy reading about electronics but have yet to become practically involved should find *Putting It Together* of especial interest and value.

F.E.B.

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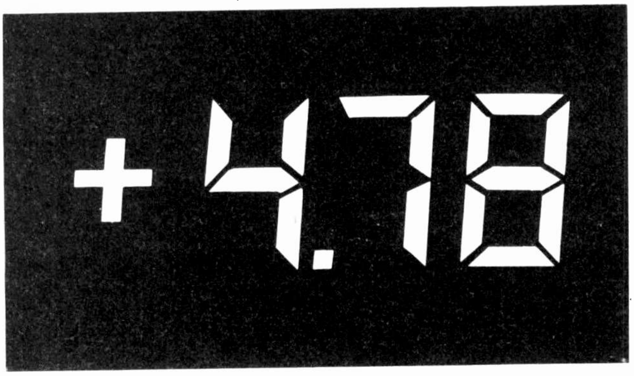
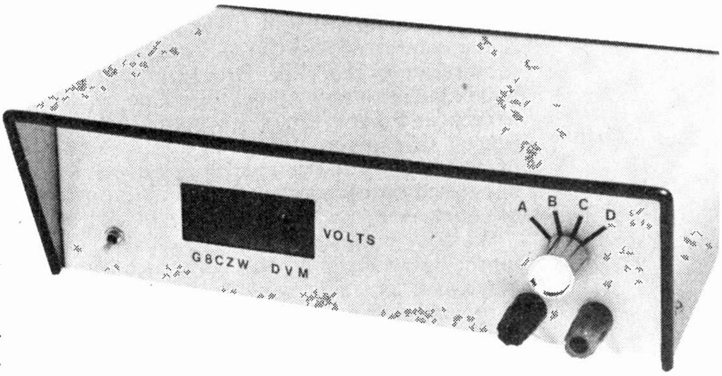


DIGITAL VOLTMETER

By A. J. Buxton

THIS article describes the operation and construction of a 3½-digit digital volt meter using an integrated circuit made by Ferranti. The ZNA116 is a standard product application of the Ferranti Uncommitted Logic Array (ULA) and provides all the logic functions necessary for a ±1999 range DVM. The dual slope integration technique of measurement is used, thus eliminating the need for a high stability capacitor and oscillator. The circuit is contained in an attractive steel cabinet, which provides a degree of r.f. protection. Most of the components are mounted on two printed circuit boards, the power supply and input attenuator being the only free mounted parts.

The construction and calibration of this instrument is very simple. The only test instrument required for fault finding is a multimeter. Providing reliable components are used, no problems should be experienced, the only difficulty may be in obtaining an accurate standard.



THE ZNA116 INTEGRATED CIRCUIT

The ZNA116 is a 24-lead DVM logic circuit. The system diagram is shown in Fig. 1. This integrated circuit features:

3½ decade drivers (±1999 maximum reading).
Automatic polarity detection and indication.
Leading zero suppression.
Overload indication.
Multiplexed BCD outputs.
External input to blank display.
Internal adjustable oscillator.
Single five volt rail operation with a supply current of only 10mA.

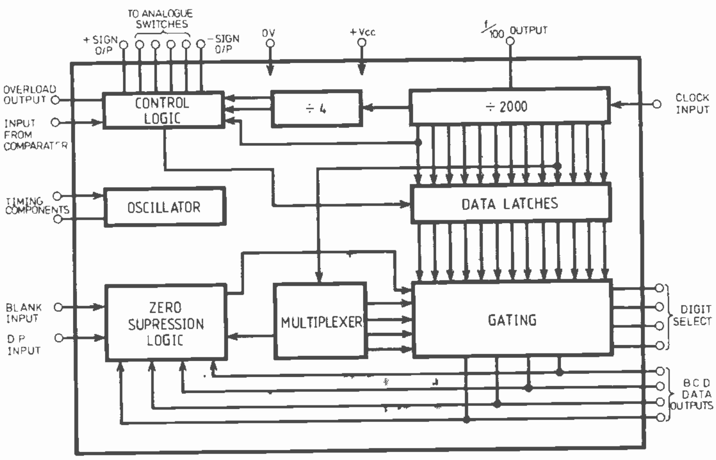


Fig. 1. System diagram of the ZNA116 DVM chip

SPECIFICATION . . .

Maximum Display Reading:	±1999
Readings Per Second:	2½ typical
Typical Accuracy: (1 volt range)	0·1% per °C
Input Impedance:	100kΩ for 1 volt range 200kΩ for 10 volt range 2MΩ for 100 volt range 20MΩ for 1,000 volt range
Total Supply Current: (all segments on)	200mA typical

Table 1 gives all the pin details and operational functions of the ZNA116.

The dual slope integration method can be described best by referring to Fig. 2. At a time T1, S2, S3 and S4 are open and S1 closes to apply an input voltage, Vin to the integrator. The integrator capacitor C charges up linearly until time T2 which is 4,000 clock pulses after T1. The voltage at the integrator output, Vx at time T2 is proportional to Vin.

At time T2, S1 is opened and either S2 or S3 is closed, to apply a reference voltage of opposite polarity to Vin, to the integrator. Thus C is made to discharge at a constant rate and at time T3 the output voltage of the integrator will again be zero. This is detected by the comparator and the reference voltage is now switched off and the number of clock pulses corresponding to Tx will be transferred to latches and displayed. This number is proportional to Vx and hence is proportional to Vin. If Tx exceeds 2,000 clock pulses, an overload condition is indicated.

At a time T4, which is 3,000 clock pulses after T2, S4 closes to completely discharge the capacitor. At time T5, which is 4,000 clock periods after T2, S4 opens and the cycle is repeated.

Table 1: PINNING AND FUNCTIONAL DETAILS—ZNA116

Pin	Name	Function
1	Earth	Supply 0 volts
2	f/100 output	Output at 1/100 of clock frequency
3	Clock input	External clock input, or link to pin 14 for internal clock
4	M1	Digit drive output, M.S.D.
5	M2	Digit drive output, 2nd M.S.D.
6	M3	Digit drive output, 3rd M.S.D.
7	M4	Digit drive output, L.S.D.
8	Blank input	Hold at logic 1 to blank display
9	D.P. input	Hold at logic 1 to blank leading zeros
10	A	2^0 BCD data output
11	B	2^1 BCD data output
12	C	2^2 BCD data output
13	D	2^3 BCD data output
14	Oscillator output	Link to pin 3 for internal clock
15	Oscillator input	External components, connected to this pin, control clock frequency
16	+VE reference switch output	When at logic 1, connects +ve reference voltage to the integrator
17	−VE reference switch output	When at logic 1, connects −ve reference voltage to the integrator
18	−Sign output	Goes to logic 1 when measuring −ve input
19	+Sign output	Goes to logic 1 when measuring +ve input
20	Comparator input	Signal from the external comparator
21	Signal switch output	When at logic 1, connects voltage to be measured into the integrator
22	V_{cc}	Supply +5 volts
23	Reset switch output	When at logic 1, turns on switch to completely discharge integrator capacitor
24	Overload output	Goes to logic 1 if count exceeds 2,000

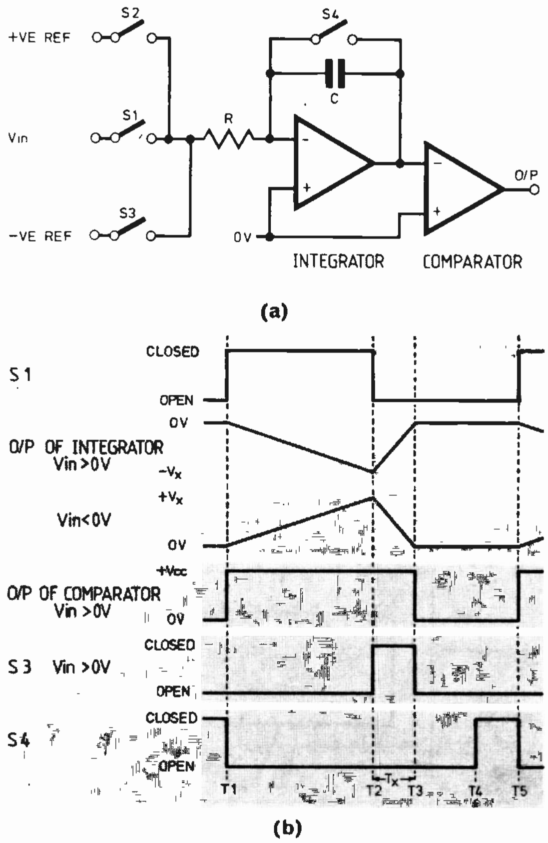


Fig. 2. Dual slope integration technique.
(a) Basic circuit diagram
(b) Waveforms produced during measurement cycle

If S1 is closed for a time which is a multiple of 20ms, any 50Hz mains ripple superimposed on Vin will be integrated to zero and thus good mains rejection is obtained. The integrating capacitor, C, and oscillator only need good short term stability to achieve high accuracy.

THE PRACTICAL DVM

The explanation of the dual slope system can be related to the practical circuit of Fig. 3. The integrator and comparator are ZN424 linear amplifiers which only need a single five volt power rail. The reference voltages are derived from the ZN423 precision voltage reference source. The switches are transistors operated by outputs from the ZNA116.

The measuring sequence is as follows:

A. Pin 23 goes to logic 0, the capacitor C7 has been fully discharged and is ready for integration.

B. Pin 21 goes to logic 1, the input signal is connected to the integrator for 4,000 clock periods.

C. Pin 21 goes to logic 0, disconnecting the input signal. Pin 16 or 17 goes to logic 1. This connects either the positive or negative reference to the integrator. The output from the comparator during (B) determines which one. Clock pulses are counted until the comparator changes state when pin 16 or pin 17 returns to logic 0.

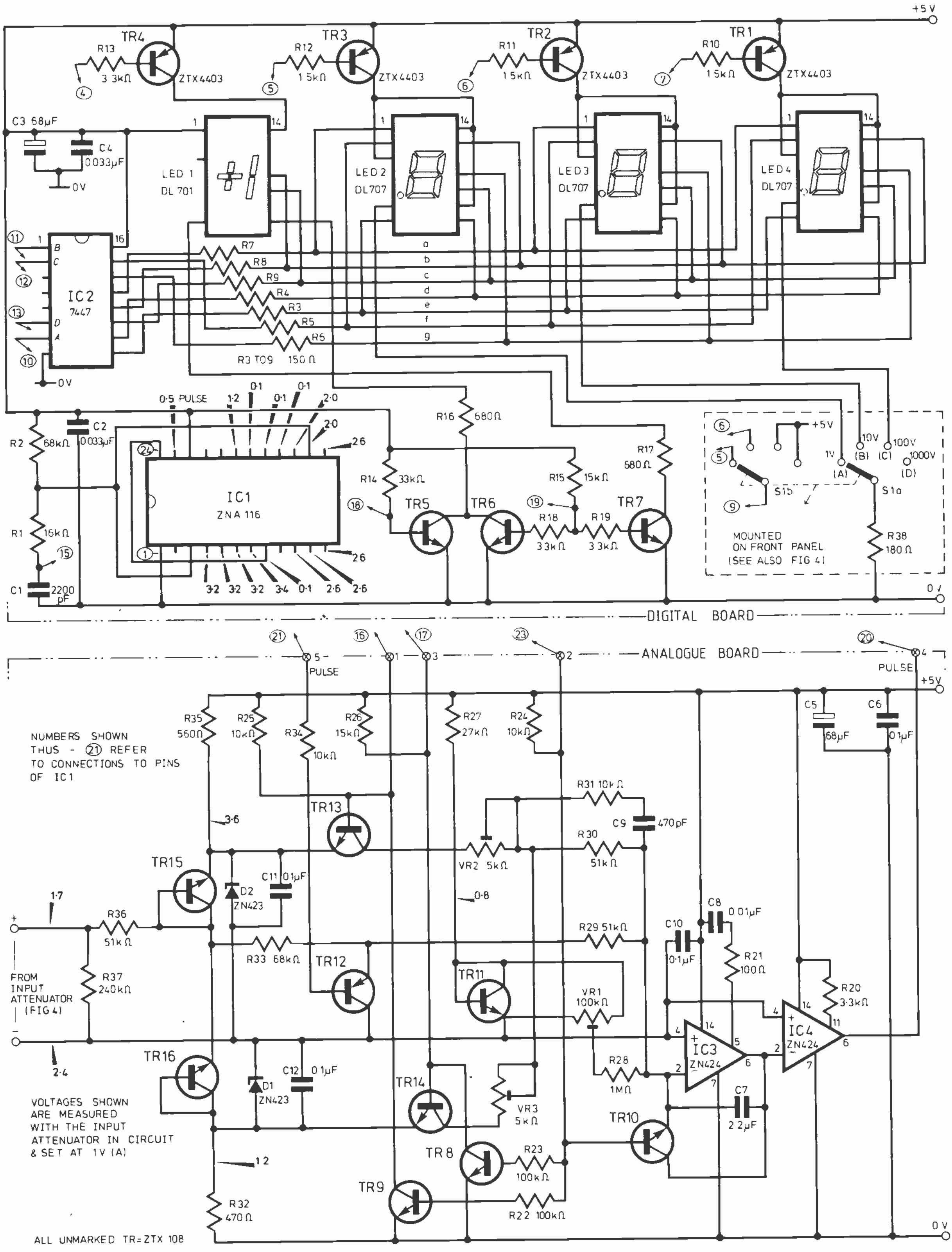


Fig. 3. Circuit diagram of the complete instrument, excluding input attenuator and power supply

COMPONENTS . . .

Resistors

R1	16kΩ 2% hi-stab.
R2, R33	68kΩ 2% hi-stab.
R3–R9	150Ω (7 off)
R10–R12	1·5kΩ (3 off)
R13, R18, R19, R20	3·3kΩ
R14	33kΩ
R15, R26	15kΩ
R16, R17	680Ω
R21	100Ω
R22, R23	100kΩ
R24, R25, R31	10kΩ
R27	27kΩ
R28	1MΩ 2% hi-stab.
R29, R30, R36	51kΩ 2% hi-stab.
R32	470Ω
R34	10kΩ 2% hi-stab.
R35	560Ω
R37	240kΩ 2% hi-stab.
R38	180Ω
R39, R40	10MΩ 2% hi-stab.
R41	2MΩ 2% hi-stab.
R42	180kΩ 2% hi-stab.
R43	22kΩ 2% hi-stab.

All resistors 10% ¼W carbon except where indicated

Potentiometers

VR1	100kΩ Bourns 3009P	0·75in Helical Trim
VR2, VR3	5kΩ Bourns 3009P	
VR4, VR5, VR6	4·7kΩ Carbon Pre-Set	

Capacitors

C1	2,200pF ±2·5%
C2, C4	0·033μF ±20%
C3, C5	68μF 10VW elect.
C6, C10, C11, C12, C14	0·1μF ±20%
C7	2·2μF ±10%
C8	0·01μF ±20%
C9	470pF ±20%
C13	2,200μF 25VW elect.

Transistors and Diodes

TR1, TR2, TR3, TR4	ZTX4403 (4 off)
TR5–TR11, TR13–TR16	ZTX108 (11 off)
TR12	ZTX213
D1, D2	ZN423
D3, D4	ZS170

Integrated Circuits

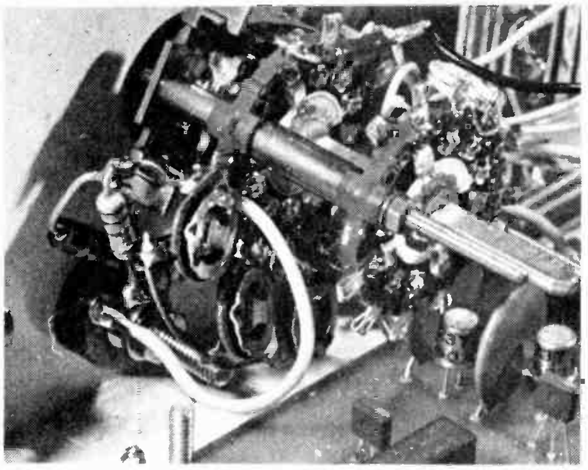
IC1	ZNA116
IC2	ZN7447
IC3, IC4	ZN424 (2 off)
IC5	78M05 5V 500mA regulator

Displays

LED1	DL701
LED2, 3, 4	DL707

Miscellaneous

S1 4-way 4-pole wafer switch
S2 d.p.s.t. mains switch
T1 8-0-8V 500mA mains transformer
SK1, SK2 4mm sockets (2 off)
FS1 2A 20mm fuse and holder
8-way tag strip, i.c. sockets (soldercon pins used for IC1), printed circuit boards, case, nuts, bolts, washers, standoffs, brackets (Electrovalue R4002), insulator and mica washer for regulator IC5, circularly polarised filter for display



D. On the next negative edge of the clock pulse, the count is transferred to the latches. The display is multiplexed at one fortieth of the clock frequency.

E. 7,000 clock periods after the sequence start pin 21 goes to logic 1 for 1,000 clock periods. This discharges the capacitor and the sequence starts again.

The output from the ZNA116 is in BCD format. This is converted to seven-segment code by a 7447 which also drives the display. The display is multiplexed which means that only one of the seven-segment displays is driven at a time. The display to be driven is determined by the state of pins 4, 5, 6 and 7 of IC1. For instance if pin 5 is at logic 0, TR3 is turned on. This allows current to flow through any driven segment of the second display, LED2. Pin 5 will then go high and pin 6 low, which will allow the third display to be driven. This sequence is carried out at 500 times a second so the human eye sees all the displays constantly lit.

The DVM has leading zero suppression which is accomplished by connecting logic levels to pin 9 of the ZNA116. On the 1 volt range, pin 5 is connected to pin 9 of the ZNA116 and will cause ±·000 to be displayed. On the 10 volt range, pin 6 is connected to pin 9 which will cause ±·00 to be displayed with no input. On the 100 volt range and 1,000 volt range, only the last zero will be displayed. The decimal point is selected by the range switch.

The input attenuator is shown in Fig. 4. This is hard-wired on the range switch which is a four-way, four-pole rotary switch. The 5kΩ variable resistors are miniature skeleton presets. The input impedance is 100kΩ on the 1 volt range and 20kΩ per volt on the other ranges.

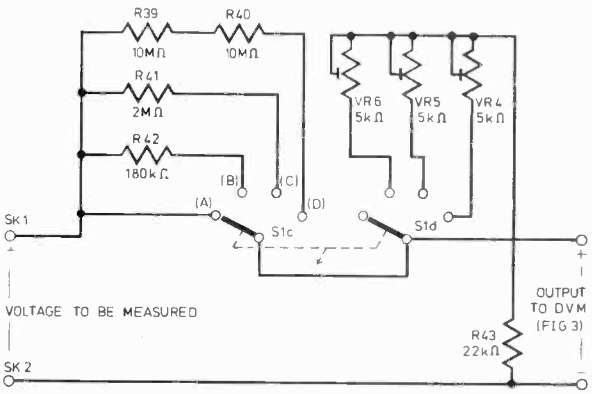


Fig. 4. Circuit of input attenuator

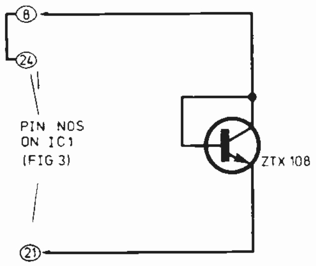
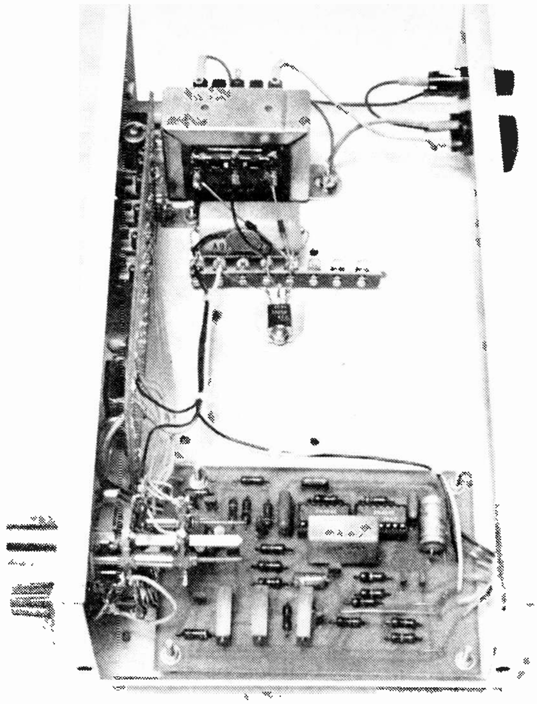


Fig. 5. A flashing "over-range" indication can be incorporated by adding this circuit

If the instrument is trying to measure a voltage that is greater than the range limit an overload condition is seen. Pin 24 will go to logic 1. This instrument has the overload indicator output wired to the blank display input (pin 24 to pin 8). This will blank the display on overload. The display can be made to flash if a diode is connected from pin 8/pin 24 to pin 21, as shown in Fig. 5.

The ZNA116 has an internal oscillator, the frequency of which is set by R1, R2 and C1. This instrument has an oscillator frequency of 20kHz, giving 2·5 readings per second and an integration time of 200ms. As 200ms is a multiple of mains frequency, any mains ripple on the input during measurements is cancelled out.

The power supply shown in Fig. 6 consists of an 8-0-8 volts, 500mA transformer, a full wave rectifier and an integrated circuit regulator. The 78M05 provides a stable 5 volt rail to enhance the linear circuit performance.



Internal view of author's prototype DVM, showing power supply components mounted on bottom of case

ASSEMBLY

The boards used in the DVM are shown in Figs. 7, 8, 9 and 10. The assembly should be carried out in the following order: wire links, i.c. sockets, resistors, capacitors, transistors and finally diodes. Do this on both boards, then wire the interconnecting leads, power supply leads and decimal point leads. When this is finished, check the soldering and then insert the i.c.s and displays in their sockets. The Analogue board is kept clear of the case floor by 12mm spacers on the fixing bolts. The Digital board is secured by means of two small angle brackets. The range switch is better wired before mounting on the box. Cut the leads to it to the correct length and then solder to the switch lugs. The attenuator resistors can be mounted directly onto the switch tags.

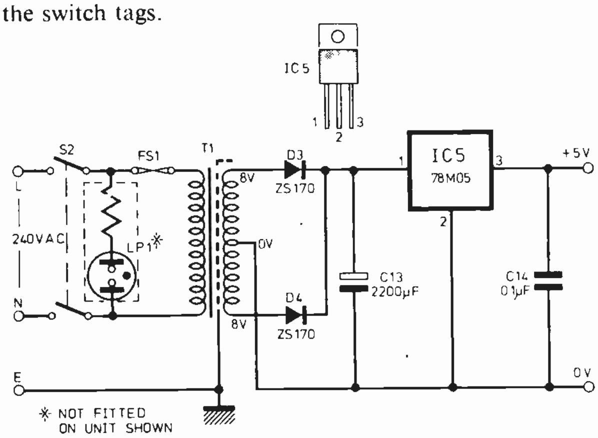
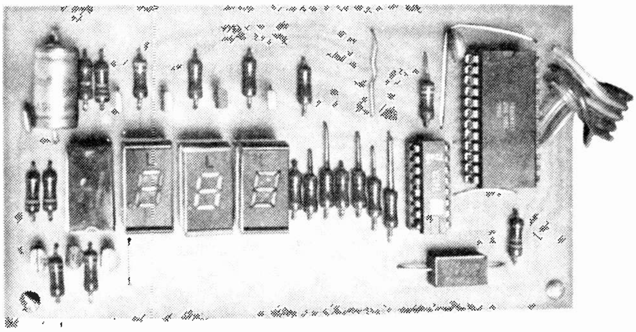


Fig. 6. Power supply circuit. Note that the d.c. supply is isolated from chassis

The cabinet used for the DVM is a standard instrument case drilled as shown in the photographs. After drilling remove all burrs, especially around the regulator fixing hole.

Before mounting the boards in the box, mount the input sockets, mains switch and fuse and the power supply components. NOTE: THE REGULATOR MUST BE ISOLATED FROM EARTH. The power supply is isolated from earth so that a full positive and negative range can be realised. Wire up the power supply and test for 5V ±0·2V output. If the supply leads are made long the boards may be tested outside the box. This may make checking and correcting mistakes a little easier.

When all connections are made check the wiring carefully including the external links on the two boards. There should be five on the analogue board and 12 on the digital board.



Front view of the Digital and Display board

ANALOGUE BOARD

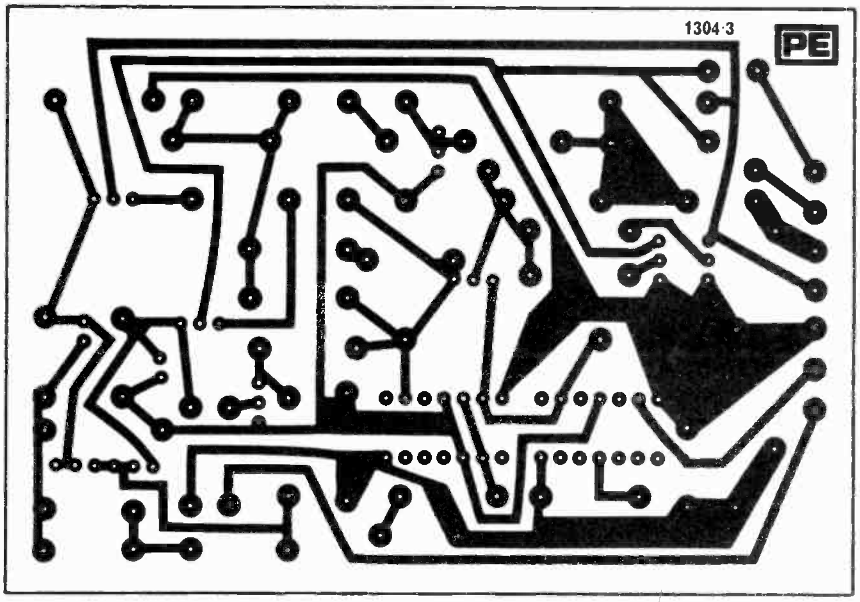


Fig. 7. Printed circuit board track layout, shown full size

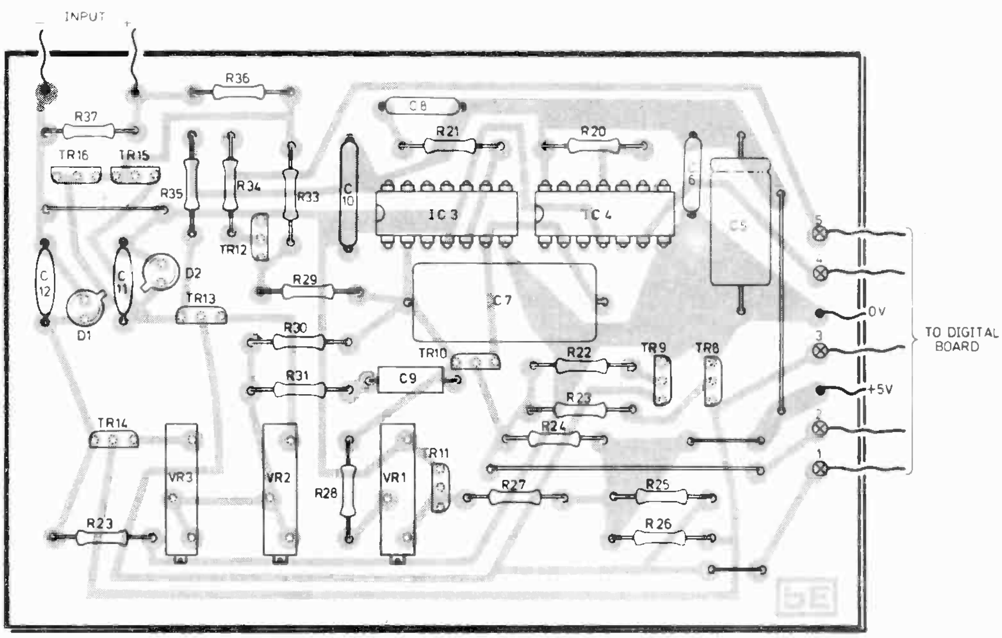


Fig. 8. Component layout and external connections

DIGITAL AND DISPLAY BOARD

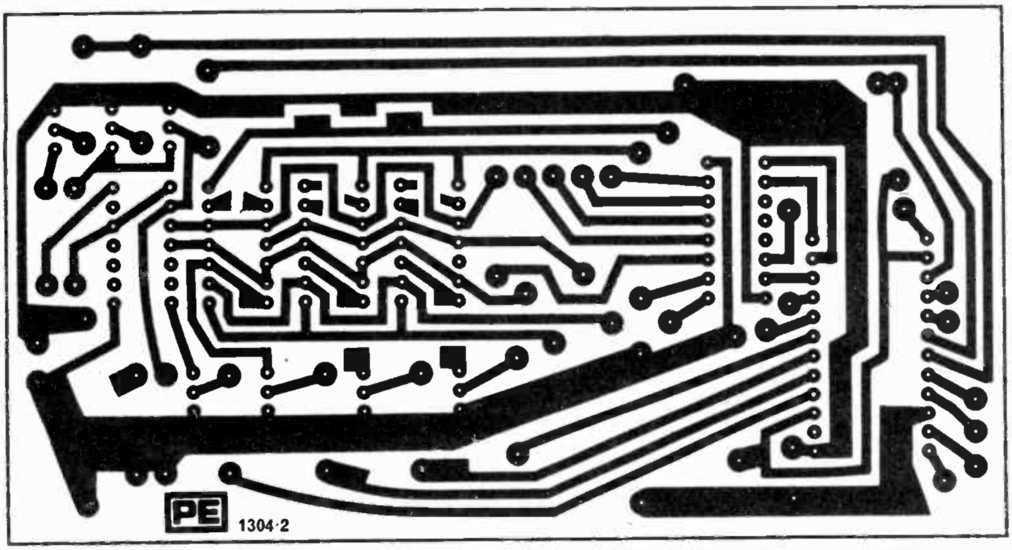


Fig. 9. Printed circuit board track layout, shown full size

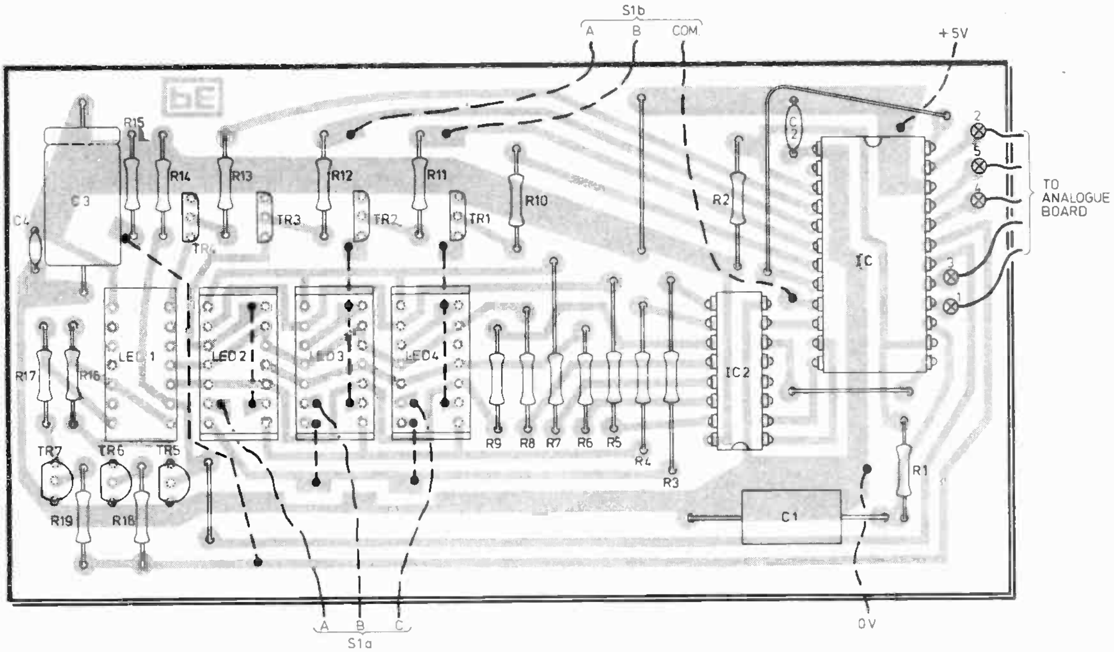


Fig. 10. Component layout and external connections, Links and connections shown in broken line are made on the copper side of the board

continued on page 276

SEMICONDUCTOR UPDATE ... By R.W. COLES

AY-3-8500

VMP2

4151

FUN AND GAMES

By now everyone must be familiar with the new generation of TV games units on sale as kits, ready made units and even advertised on the back of the breakfast cereal package! Unlike previous games which had limited facilities and used large numbers of TTL i.c.s the new games all used that great equaliser, an MOS LSI chip which provides an interesting variety of games at a low cost!

You may have been thinking that the manufacturers of these new games units must have developed their own chip design and are probably sitting on it very tightly, but this is not so, and in fact of the various games available, most use a common chip made by General Instrument Microelectronics (G.I.M.) and coded the **AY-3-8500.**

As far as I can see, there is no reason why these chips should not be freely available to amateurs apart from the fact that the games manufacturers are gobbling up all that G.I.M. can produce, making them as rare as the proverbial rocking-horse droppings for the moment at least! If you can't wait (by the time this appears you may not need to) it *is* possible to obtain a chip at a price of £10 from Videomaster who offer them as spare parts for their own series of "Superscore" games, but I rather suspect that the open-market price will be less than this if you can hang on for a while.

Making a games unit with the AY-3-8500 is not difficult since all the clever bits occur inside the portals of the 24-pin plastic package, the only other major component required being a v.h.f. or u.h.f. modulator, which is available ready built at a reasonable price if you do not want to build one.

Just to whet your appetite, the AY-3-8500 provides six game types, three for two people, i.e. football, tennis and squash, and three for one person, i.e. solo and rifle shooting 1 and 2 which requires a photo-cell type rifle attachment.

The ball games have a variety of switchable options including ball speed and bat size, and all games feature on screen numerical scoring and an audio output to drive a speaker for realistic "Hit" sounds. The control of bat position can be achieved with a couple of slider pots, and the whole unit will run from a 9V battery.

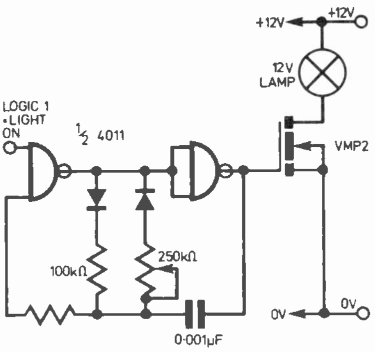


Fig. 1. An efficient lamp dimmer using the VMP2

MORE VMOS

Recently, I featured the VMP1 from Siliconix, a breakthrough which brings power handling capability to the other well known advantages of MOS technology. The VMP1 was packaged in a TO3 can and could switch 1 amp in just 4 nanoseconds, without risk from the usual bipolar nasties of second breakdown, thermal runaway or minority carrier storage.

The VMP1 just had to be the forerunner of what will become a standard power device family and already Siliconix have announced "Son of VMP1", and some variation on the theme.

"Son of VMP1" is the **VMP2** which comes in a TO39 can but can still switch currents of 1 amp or so in a few nanoseconds making it just about perfect for the interface of CMOS logic to the real world of hefty relays, thirsty lamps and strident speakers!

Variations on the theme are provided by the VMP11 and VMP12, which have higher drain to source voltages (60V and 90V respectively) than the VMP1, and the VMP21 and VMP22 which have the same attributes but in the smaller VMP2 type package.

Siliconix have produced an application note (AN76-3) titled "VMOS—A Breakthrough in Power Mosfet Technology" which describes the unique vertical channel construction of the VMP devices and is stuffed with interesting applications ranging from the simple CMOS driven switch to a 40W hi-fi amplifier and a 144 to 146MHz linear 5W r.f. amplifier. The wide application spectrum and the simplicity of the supporting circuitry necessary when using VMOS devices gets it my vote for the technology most likely to succeed in 1977, and I feel that this is an area to keep an eye on!

REAL PROSPECT

Well it had to happen I suppose. Raytheon have gone and put a voltage to frequency converter into an 8-pin mini-dip package making those recently exotic devices a real prospect for a multitude of amateur projects.

The diddy V to F, coded Raytheon **4151**, is no mini when it comes to performance though it offers up to $\pm 0{\cdot}05\%$ linearity and 100ppm/°C temperature coefficient, and can be wired as a frequency to voltage converter too.

If you can settle for 1 per cent linearity it is possible to use the 4151 with a single supply but for the 0·05 per cent specification you will need an extra op. amp. and split supplies.

The V to F's can be used with counters as analogue to digital converters, used to record d.c. signals on to audio tape recorders, with a companion F to V as an analogue data transmission channel or for all kinds of electronic music applications which set the mind a boggling.

The 4151 can be programmed for a wide range of scale factors (volts in versus frequency out) from 1Hz to 100kHz per volt, and its output is open collector to simplify interface to TTL or CMOS.

Electronic DAY INDICATOR

By M. H. George

ALTHOUGH one might find various odd applications for this device, the main intention in its design was to help an elderly person, as it is often more important for such a person to know the day of the week, than the exact date. The routine of a senior citizen's life often revolves on a weekly basis, with, for example, a regular visit to a day centre, or a call from the home help. An elderly person can be very absent minded, and may forget what has been said within minutes, and so it is hoped that this device will provide a graphic visual stimulus more easily remembered, and also be around to prompt the memory when necessary.

The mechanical design of the unit is specifically intended to give an easy action, with a microswitch pushbutton, and a clear l.e.d. display against large lettering. For safety, the unit is powered by a battery of manganese-alkaline cells rather than mains. This gives a life of at least one year, although it may be possible to improve on this, using mercury hearing aid cells.

LOGIC

The device makes use of CMOS integrated circuit logic to achieve extremely low power consumption, the display being enabled only by the pushbutton when viewing is required. The generation of one pulse per

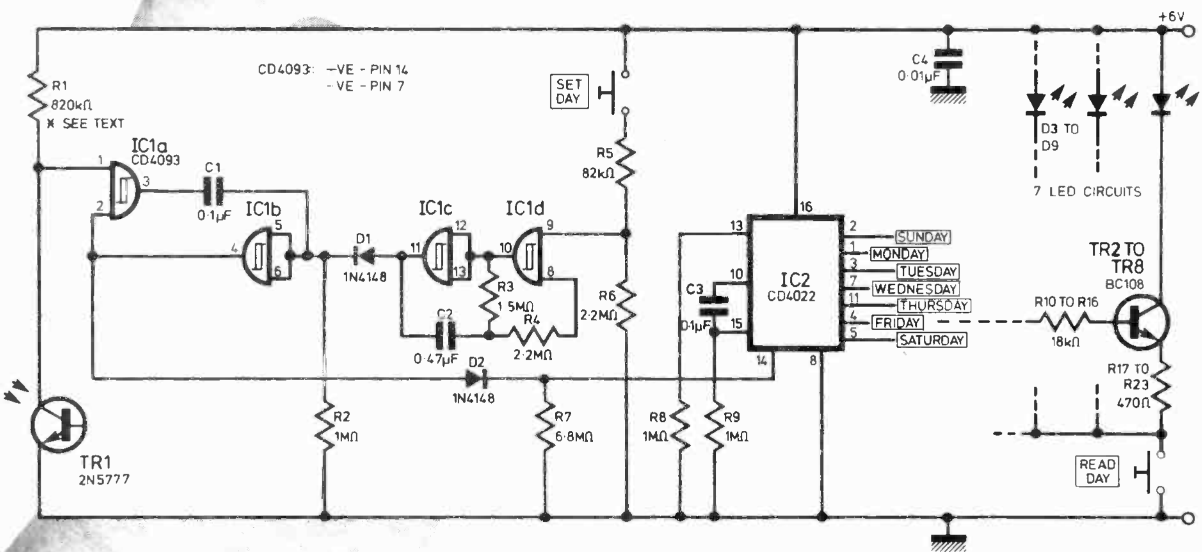


Fig. 1. Day indicator circuit diagram. No on/off switch is used, as the low current unit remains on permanent standby

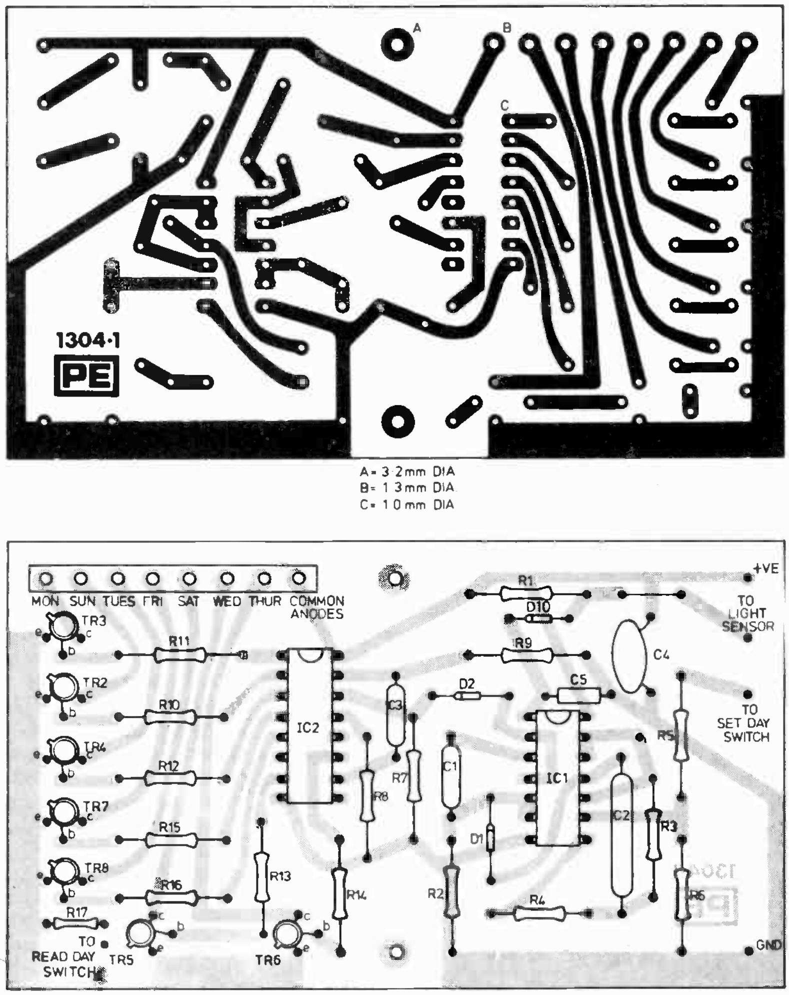


Fig. 2. Printed circuit and component layout of prototype. Note that on the prototype, resistors R18 to R23 have been eliminated by placing R17 in series with the Read Day switch.

COMPONENTS . . .

Resistors

R1	820kΩ*	R7	6·8MΩ
R2	1MΩ	R8	1MΩ
R3	1·5MΩ	R9	1MΩ
R4	2·2MΩ	R10–R16	18kΩ (7 off)
R5	82kΩ	R17–R23	470Ω (7 off)
R6	2·2MΩ		

All resistors $\frac{1}{8}$W 10%. *see text.

Capacitors

C1	0·1μF	C5	0·01μF*
C2	0·47μF		
C3	0·1μF		
C4	0·01μF disc type		

Semiconductors

TR1	2N5777
TR2–TR8	BC108 (or equivalent) (7 off)
D1–D2	1N4148
D3–D9	TIL209 l.e.d. (7 off)
*D10	1N4148

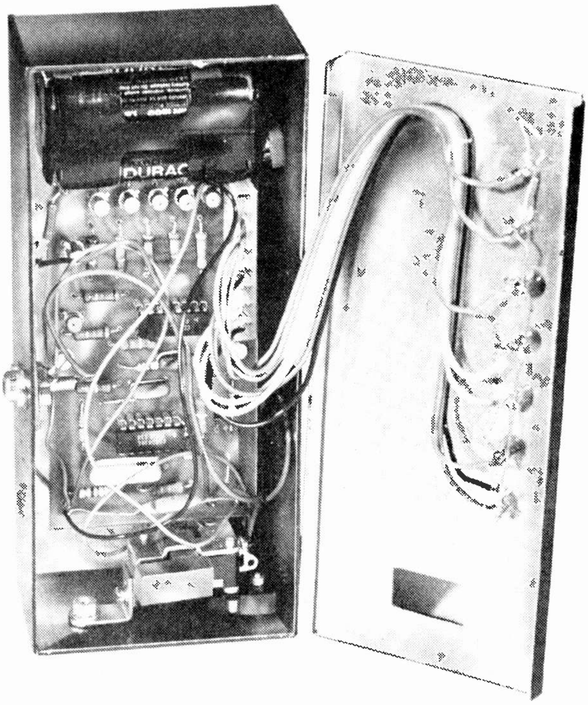
Integrated Circuits

IC1	CD4093
IC2	CD4022

Miscellaneous

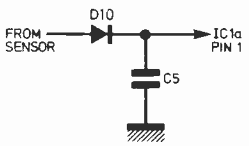
Metal box 164×74×50mm.
Microswitch pushbutton
Microswitch (to mount internally)
Battery holder
4×MN 1500 (HP 7 size) cells
Printed circuit board
Eight way printed circuit connector, or Veropins
14 way d.i.l. socket
16 way d.i.l. socket
Two way connector (for sensor)*

*see text



day is effected by observing the dark to light transition at dawn. Phototransistor TR1 forms a potential divider with R1, and the switching level is set by a Schmitt trigger. This in turn feeds a monostable which provides a short pulse output during the dark to light transition. This pulse advances a ring of seven counter, as can be seen in Fig. 1. Provision is also made for presetting the day, with an internal pushbutton.

Because of the exceptionally high input resistance of CMOS devices, a small capacitor, isolated by a diode at the Schmitt trigger input, immunises the input from transient phenomena such as lightning flashes. On the prototype, the use of a 0·01μF capacitor gave an input time delay of 15 seconds.



CONSTRUCTION

All the components except the l.e.d.s are mounted on a fibreglass printed circuit board, the layout of which is shown in Fig. 2. The CMOS integrated circuits should be fitted last, preferably in sockets, observing all the usual precautions when handling these devices. The eight way printed circuit connector is a convenient way of coupling to the front panel display, but may well be replaced by Veropins. It is preferable that the case be isolated from the circuit, although not essential. Practically any connector can be used to plug in the light sensor unit, but some will automatically earth the box, as in the case of the prototype, which used a phono plug and socket. The *press to display* pushbutton should be an easy action microswitch with a large button, and the *press to set day* switch is a microswitch which should be mounted where it cannot be operated accidentally. The general layout of the prototype is shown in the photograph.

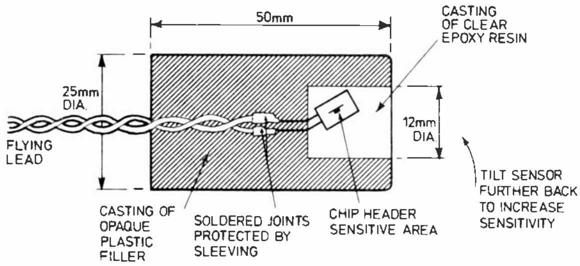


Fig. 3. Light sensor unit construction

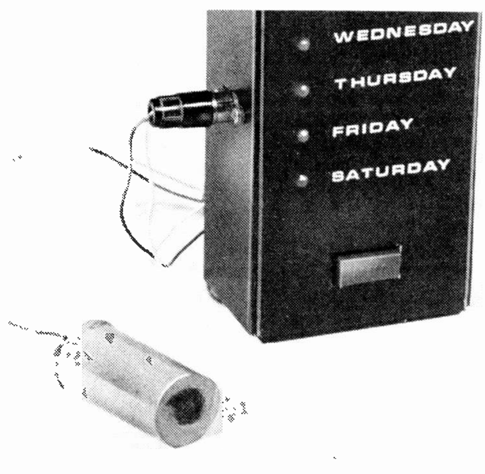
In the prototype, the light sensor (2N5777) had two flying leads soldered to it, and was cast in clear epoxy resin. This was then cast into an opaque body filler such as Plastic Padding, to complete the assembly. As can be seen in Fig. 3, for maximum sensitivity, the sensor transistor had to be mounted at a slight angle to expose the sensitive area to incident light.

SETTING UP

The main problem concerns the value of resistor R1. This will depend upon the location of the sensor, its encapsulation, and the transfer voltage of the CMOS gate. Initial tests with the 2N5777 showed that it might be too sensitive, and the original method of encapsulation was to reduce this sensitivity. But under freak weather conditions when the sun rose early in the morning, followed by a thick cloud build-up, and then the day finally brightening up once more, the gadget recorded two days, indicating a lack of sensitivity. In the prototype, this was cured by increasing R1 to 5·6MΩ, but a more satisfactory method is to tilt the sensor in its casting, so that the sensitive area "looks out" at an oblique angle (as in Fig. 3). R1 should not be reduced below 680kΩ in order to minimise battery drain. Care should also be taken to see that the device does not respond to bright moonlight.

The Day Indicator has been in successful use for some months, and even on dark mornings the reading was found to advance at about 8.30 a.m. A good direction to aim the sensor is East, but it certainly should be pointed well away from artificial sources of light.

Once the device has been preset to the correct day, operation simply consists of pressing the pushbutton and observing which l.e.d. lights up. ★



FASTER AND FASTER

The Sun has been turning faster and faster on its axis. Since 1967 its rotational speed has increased by about 5 per cent. According to Dr R. Howard of Hale Observatory the acceleration is greatest at about 15 degrees on each side of the equator getting less toward the poles. He is suggesting that the changes are only affecting the photosphere and not the lower levels of the Sun.

Since the Sun is a gaseous body the different sectors rotate at different speeds. It could be the magnetic fields cause the energy differentials needed to accelerate the surface gas. If the speeding up is part of the sunspot cycle process it may be that there will be a slowing period to follow. It so happens that the quiet period of the sunspot cycle has lasted much longer with fewer events and it may be that this cycle will exceed the normal 11 years.

It is during these special lulls in the cycle that other effects have been noted. Some of these involve changes in the solar atmosphere and a greater number of particles penetrating the solar system.

The method used by Dr Howard to determine the speeding up, was that of the frequency shift of spectral lines due to the Doppler shift as one edge of the Sun recedes and the other approaches the observer.

SPACE SPYING

It is not the custom to use *Spacewatch* as a political news medium. However, the techniques of space spying are of interest *per se* and some details are now given. The operations have been going on for some 5 years though very little information has been made public.

The satellites used for these activities have extremely sophisticated cameras. These cameras built by Perkin-Elmer have exceptional resolution. It is claimed that from a height of 160km individuals can be revealed to a degree which allows discrimination in dress. In other words military personnel can be distinguished from civilians. This is, of course, dependent on the air conditions being still and the cameras directed vertically downwards.

Some thirteen of these *Big Bird* missions have been operated. The launching used *Titan IIIB's* from the site at Vandenberg. The satellites have a diameter of 3 metres and a length of 15 metres and the weight at launching is between 12,000 and 13,000 kilograms. The orbits have a

BY FRANK W. HYDE

perigee of 160km and an apogee of 270km. The orbital period is initially 88·8 minutes. The inclination of the orbit is 96 degrees.

PICTURES

As the orbits are sychronous with the Sun the satellites pass over the surface of the Earth at the same time, that is local time, each day. The lighting conditions are therefore reasonably constant and repeat pictures can be obtained. Thus any changes during the time between revolutions can be determined. This enables much easier interpretation of these changes. The progress of building or marshalling can be observed on an hourly basis.

The use of the low perigee is necessary to obtain the high resolution but brings some disadvantages. This is shown in the greatly increased drag and consequently rapid decay of the orbit. Very frequent use is therefore necessary of the manœuvring engines to maintain the correct levels. Enough fuel is carried by the satellites for an operational mission of 150 days. These satellites are not permitted to enter and burn up in the atmosphere but are destroyed at command from the ground.

The field of view of the cameras is a very narrow one. Films are normally stored in small canisters and these are ejected into the atmosphere periodically. They descend by parachute toward the Pacific and are "snatched" by trapeze-carrying Hercules aircraft. If they are missed recovery is possible by frogmen.

Since these satellites have such narrow fields another type of satellite is required to take the "wide angle" view. These satellites are low resolution search and find craft. They carry video equipment for transmission direct to Earth. Because of their primary "search" and "find" facility they are also used for back up missions. They are about 4,000 kilogram payload vehicles with an operational life of something of the order of two months.

Another back up system particularly for meteorological information is the Defence Meteorological Satellite System (*DMSS*).

RUSSIAN READY FOR MORE EVA

It would seem that the failure of the *Soyuz/Salyut* mission in 1975 resulted in a change of plan in respect of *EVA* (Extra Vehicular Activity). There was to have been an attempt at *EVA* after a long break during the 1975 mission.

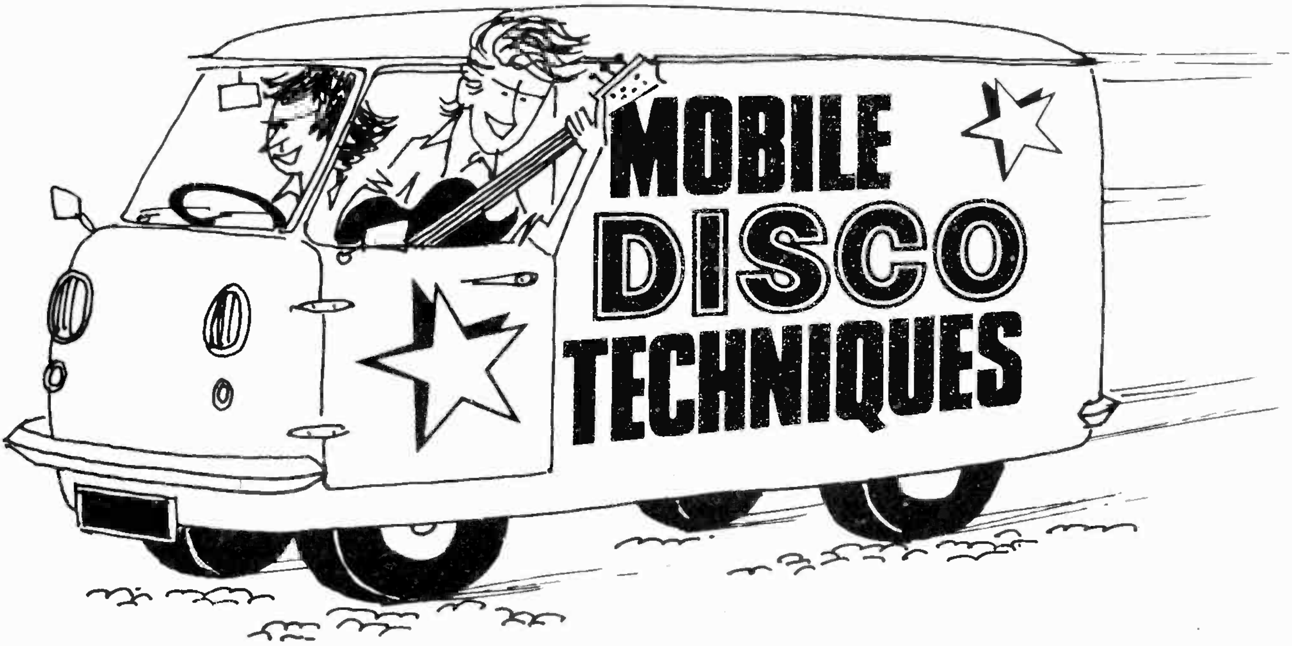
The first ever space walk was carried out in 1965. The Soviet cosmonauts have not attempted one since 1969 though America has walked space and the Moon since then. That this was to have restarted with the 1975 mission of *Soyuz/Salyut* was revealed by a Russian cosmonaut.

There has been some information about the Soviet attempts to acquire space suits of the American type but the order was blocked from a high level. Since 1971 an emergency garment has been worn at critical phases of a mission.

This suit is a very simple one and is pressure sealed by a thin rubber layer. This is fastened to the wrists and ankles by twisting the rubber up in the hand and taping off. These knots are then sealed off under an outer garment. There is no sanitary system and such a suit would hardly do for normal *EVA*.

It is clear from the programmes of special training that have gone on recently in the Soviet Union and the personnel involved (one is a naval officer with four years as a commander of deep water divers in the Baltic) that something may be imminent.*

**Since the copy was received the Russians have announced the launching of a two man Soyuz space vehicle. Speculation is that they will link-up with their space laboratory for a prolonged stay.—Ed.*



By N. McLeod

FUNDAMENTALLY, a mobile discotheque consists of a light show and a sound system. The light show may consist of various medium powered spot-bulbs, controlled sequentially, flashing randomly or made to pulse with the music, and possibly strobe lights or ultra-violet bulbs for extra effect.

The sound system will comprise two turntables with cartridges, some form of mixer, a microphone, a power amplifier or two, and a number (usually two) of loudspeaker cabinets. (The use of two loudspeakers, in addition to spreading the source of sound, is sufficient to convince most of the listeners that the music is stereophonic, whether it actually is or not, and is therefore to be recommended!) Let us examine all these items in turn, starting with the sound system.

TURNTABLES

You need two turntables to produce a continuous flow of music. As one record finishes, the next one bursts forth, bang on time, at exactly the right level.

It is essential to be able to control the turntable in order to achieve this; anything else is a secondary consideration. For example, singles are recorded at such high modulation levels as to make most rumble relatively inaudible. Delicate arms, with pretty little weights dangling on nylon cords, are going to be wrecked. Automatic lift-off is tiresome and quite unnecessary, since it takes the deck out of your control while it performs its function. Cueing arms, which lift and lower the pickup onto the record are just a joke, unless you don't mind your records arriving in a rather haphazard manner. Besides, if you have a shaky hand, disco work is not really for you. All you want is a basic turntable that will revolve your records at the desired speed, and that will start and stop quickly without causing the stylus to jump grooves.

MOUNTING

Normally record decks are supplied with springy clips to absorb the vibrations caused by movement near to the player. However, when they are used in a disco console this springy suspension, unless it is very stiff, can be more of a hindrance than a help, as any attempt to touch the deck causes the stylus to bounce merrily over the grooves.

The best idea is to bolt the decks down securely; provided the console rests on a solid table, and the hall in which you are playing doesn't have a bouncy wooden floor, you should have few problems with records jumping unless someone actually collides with you.

CUEING

Before you play a record on your disco you must cue it. To do this you will need a pair of headphones and some means of switching them to the output from either turntable regardless of whether it is turned up on the control panel. Check the speed, start the turntable and place the stylus at the beginning of the record. As soon as you hear the first few notes, stop the turntable and wind back to the beginning, plus a further quarter of a turn to give the turntable time to run up to speed when you start it again.

Should you miss the start by a few grooves, go back and start again. Winding a record backwards under a stylus does neither much good, but as a necessary evil it should be kept to a minimum. Note that when this operation is completed, the whole mechanism should be at rest. It should just wait there until it is needed. Nor should you have to sit there holding anything; your hands should be completely free.

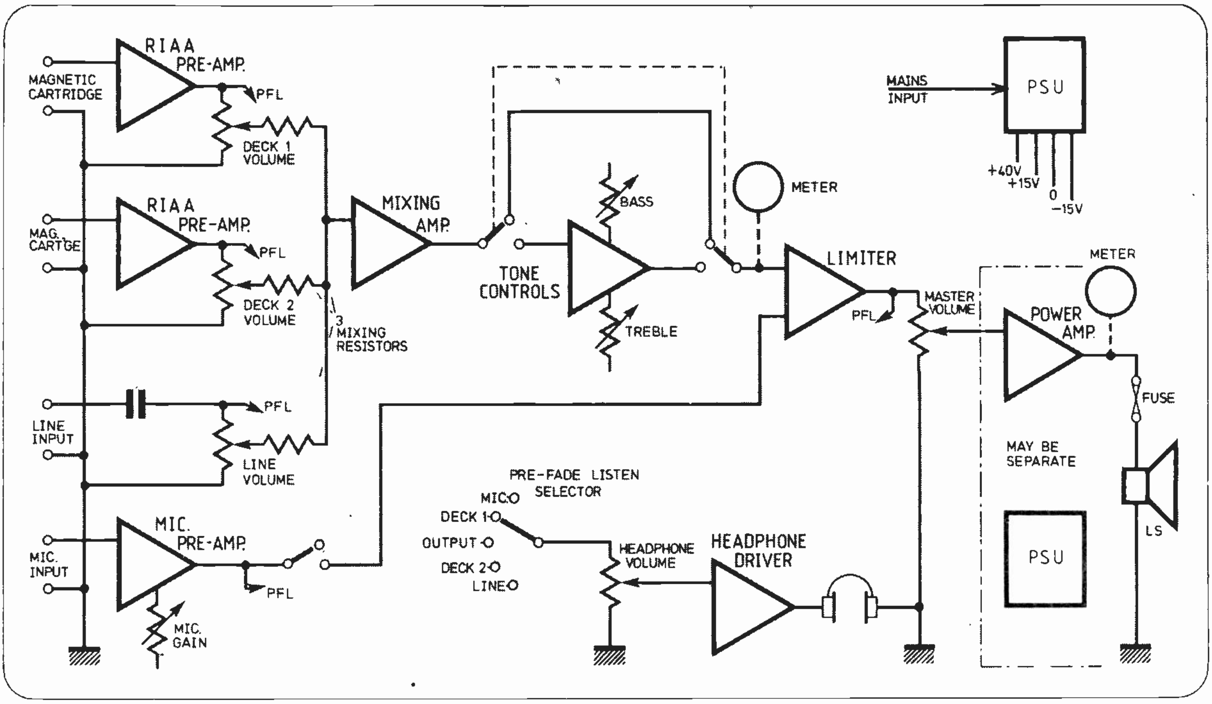


Fig. 1. Representative quality disco console

THE SLIP MAT

Many operators use the slip-mat technique, which is very useful within its limitations. The slip-mat is a piece of felt slightly larger than an LP, with a hole in the middle to fit the centre spindle of the record deck. It is placed (not glued) on the turntable between the platter and the record, allowing the record to be wound back over the felt while the platter is braked. When the record is about to be played, the turntable is started and run up to speed while the operator holds the mat (not the record!). At the appropriate moment he releases the mat and off it goes.

This can be a very effective technique, particularly suited to heavy transcription turntables such as the Garrard 401. It does have the disadvantage, however, that you still have to hold something, namely the mat, until the instant when the record is due to go.

"QUICK-START" MODIFICATIONS

A method which works very well with cheaper idler-driven decks such as the Garrard SP25 is the modification of the mechanism for "quick-start" operation. First the motor switch operated by the on-off lever is shorted out so that the motor is running all the time. Then the notch on the "Off-Man" section of the operating lever should be filed smooth to prevent possible jarring of the turntable as the switch lever is operated.

Finally, any automatic mechanisms should be removed and discarded, as they are of little value in a disco system, leaving a lever which engages and disengages the rubber wheel coupling the motor shaft to the turntable platter, and, of course, the original speed-change arrangements. An idler deck modified in this manner will generally start up to full speed in less than a second, requiring only about a quarter of a turn of "back-cueing". A switch may be fitted to the front panel to rest the motor when the deck is not in use, if required.

CARTRIDGES

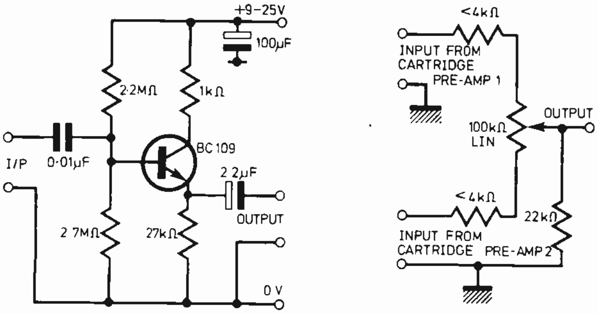
Unfortunately, both for the records and the sound quality, many ready-made units come equipped with ceramic cartridges better suited to highly budget conscious stereo systems than to equipment with any pretensions to quality sound. Ceramic cartridges have the advantage of being cheap to buy, and cheap to keep in stylii. They have the advantage, too, of requiring very little circuitry before the pre-fade and mixer circuits, but they require a heavy tracking weight, generally around four to five grams, with consequent record wear.

Magnetic cartridges are only a little more expensive, certainly compared to the cost of a total system. They track at less than half the stylus pressure and with a suitable RIAA preamplifier provide greatly superior sound quality. Something like the Shure M75-B or a Goldring G800 would suit systems using a deck of the calibre of the Garrard SP25, McDonald MP60 or similar.

Choose a cartridge for which you can obtain spare stylii easily and cheaply, and always take one with you.

INDIVIDUAL TONE CONTROLS

After the preamplifier you will have a signal which is "flat", that is with all the frequencies of the original recording in their correct proportions. You may, however, wish to equalise it by boosting or attenuating the bass, treble, or a selected part of the frequency



(a) (b)

Fig. 2. (a) Impedance converter for ceramic cartridges. (b) "crossfade" control, typical arrangement

range to compensate for deficiencies either in your reproducing equipment or in the record itself. This will require tone controls or filters, of a complexity largely determined by the contents of your wallet.

Generally speaking, though, it should not be necessary to equalise each channel independently. Any records which are of really atrocious quality should not be played, and those with minor shortcomings, together with the limitations of your speakers, can be adequately taken care of by one set of tone controls after the mixing stage.

THE MIXER

The mixer is shown in block form in Fig. 1. There are, of course, many variations, but I have tried to show most of the facilities that can be usefully employed. The RIAA pre-amps are more usually contained within the mixer circuitry itself. A ceramic cartridge requires less of a pre-amp, but an impedance converter (Fig. 2a) is most useful to enable it to be used with the usual values of faders. Note that I have shown each record deck as having its own fader, capable of being independently controlled from maximum gain to zero. I prefer this arrangement to the other, common technique of using a single control with signals fed in at each end, the output being taken from the slider, the so-called "crossfade" control (Fig. 2b).

The trouble with the crossfade arrangement is that you can only do just that; it may not be what you want to do. You cannot compensate for differing modulation levels on your discs with a crossfade control without introducing crosstalk from the other deck. Doing it with the master control is abusing its purpose, as will be explained later, and the only other way is to have a separate "Grams Gain" control, or whatever you decide to call it.

Now if you're going to have two controls for the record decks you may as well have them working like all the other inputs or life is going to get very confusing, and it's bad enough already!

Both record deck faders are taken via mixing resistors to the mixing amplifier. Also feeding the mixing amplifier I have shown a line input, which can be driven by a tape recorder to supply jingles or records you do not personally possess. The use of a tape recorder in this latter manner is even more illegal than using it to tape the records in the first place, and of course I am not encouraging you to do this. Far better to use it for jingles and announcements to expand the entertainment.

THE MICROPHONE

I have been to a large number of discos where the records are recognisable for their tunes, but the intervening announcements have consisted of a totally unintelligible squawking noise. Do not use a microphone at a disco unless it is clearly audible. With the GPO telephone lines the frequency response is limited to between 300 and 3,000Hz, yet speech is usually quite intelligible even in the presence of interference. These, then, are the frequencies that count. An extension of the bass response gives fullness to the voice, but if overdone makes the sound muddy, and greatly increases the noise produced by handling or touching the microphone.

Extending the treble response makes the voice crisper and sharper unless taken to the extent where it is impossible to increase the gain above a very low level without a squeal of feedback. Generally, with a good microphone, the pre-amp should have a flat response from 300Hz upwards and a steady bass roll-off below that frequency.

It is vital to use the microphone properly. Do not let other people make their own announcements; either they will nearly swallow the microphone while shouting at the top of their voice or they will hold it at waist level and murmur to themselves, both being equally disastrous. If you can obtain a "pop-shield" which fits over the top of the microphone, buy one and use it so that you can speak right up against it without introducing the characteristic "popping" sound. Failing that, speak directly into the mike from about three inches away, clearly and distinctly. You should not have to shout; if you do, you have the wrong microphone.

CHOOSING A MICROPHONE

There is a vast number of obscure oriental microphones around whose quality is not reflected by their appearance or price. If it was, they would be held together with string and exchanged for goldfish and plastic windmills at the fair.

Do not buy a microphone you have never heard of before until you have actually tried it in operation. Failing that, buy from a maker with a proven reputation for good microphones, like Shure or AKG. The AKG D190 is an excellent, though pricey, microphone for disco use with its smooth uncoloured sound and robust construction, while the Sony range of electret microphones produce a clear, crisp sound that is hard to beat at the price.

One warning about electret microphones; do remember to take the battery out when not in use. It doesn't last for ever, and when it leaks it makes a horrible mess. It is advisable to mount your microphone on a flexible "gooseneck" attached to your console so that you can adjust it to a position convenient for use, while leaving your hands free to work the controls.

THE MICROPHONE PREAMPLIFIER

The most important characteristics of a microphone pre-amp are a good overload margin and a reasonable noise level. A versatile design, which uses negative feedback to adjust the gain over a wide range, is shown in Fig. 3. It includes a switch to roll-off the bass

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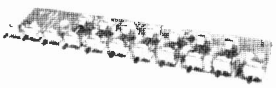

Printed circuit module assembled & tested with all components ready mounted.

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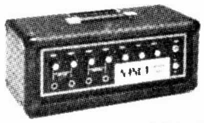

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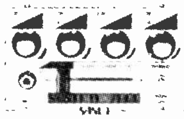

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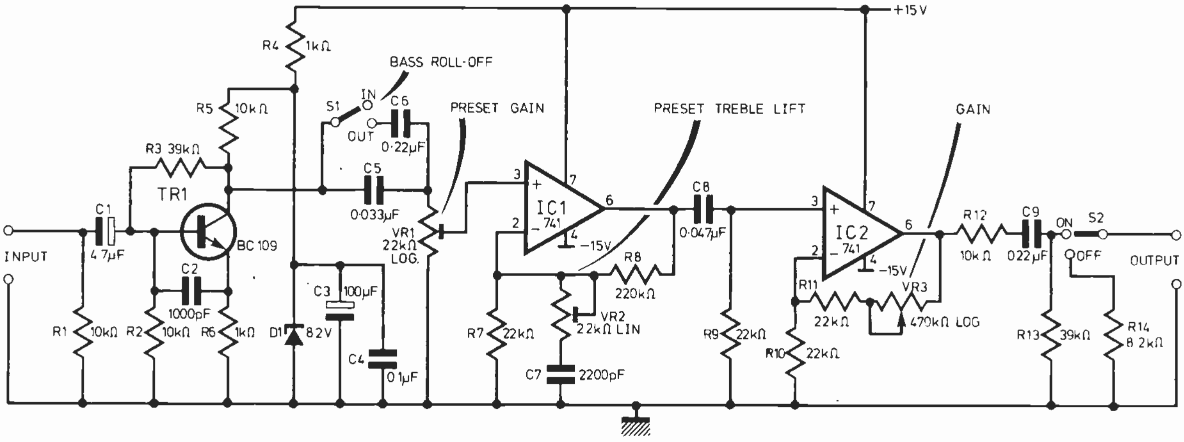


Fig. 3. Circuit of versatile microphone preamplifier for disco use. It requires ±15V at not more than 25mA. The input and output impedances are unaffected by the settings of the controls. VR1 should be set for sufficient output from the circuit with VR3 in mid-position, and VR2 should be adjusted for the best tonal balance at the output of the whole system

response and an adjustment to improve the treble gain. It also includes a preset gain control to match the sensitivity of almost any microphone.

Note that the output is switched on and off, so that the panel gain control can be preset at a level just below that which causes feedback and then forgotten about, with the switch used to turn the microphone on and off when required.

GROUPING AND AUTOMATIC "DUCKING"

All the inputs, from records, microphone or tape recorder are fed into the mixing amplifier. This is just a fairly straightforward amplifier with enough gain to allow for the losses in the fader circuits with a bit to spare, a low input impedance and a low noise level, since any noise it generates will pass into the rest of the system.

If you want to have one of those arrangements where the music "ducks" down automatically whenever you speak, then the music inputs must be grouped together and then the output from the microphone preamp used to control the gain of that group and to feed the output separately. When tone controls are used, it is also a good idea to have the microphone feeding the output separately to avoid it being affected by the settings of the tone controls when they are used to correct deficient recordings (see Fig. 1).

LIMITER

Of all the circuits devised for use with my disco set-up the limiter is far and away the most useful. Its purpose is to control the output in such a way that it will never exceed a certain level, however large the input. Used properly it will eliminate most of the dynamic range of any material played. Why is this a good idea?

In Fig. 4 the vertical axis is scaled in sound level, the further up you go, the louder the environment. The slightly wavy line near the bottom of the graph is intended to show the residual noise produced in the hall by people talking and dancing, together with any

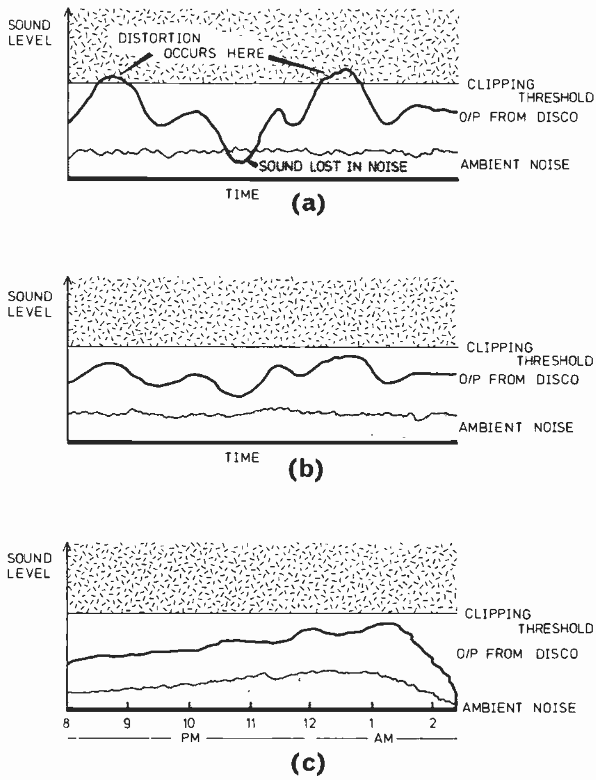


Fig. 4. Running a disco without compression (a) may result in the system running into distortion, or in the output from a very soft part of a recording being lost in noise.

Compressing the dynamic range (b) makes it easier to keep the equipment and the audience happy. A long, but not untypical evening's entertainment is shown in (c). Note that at no time is the disco short of power

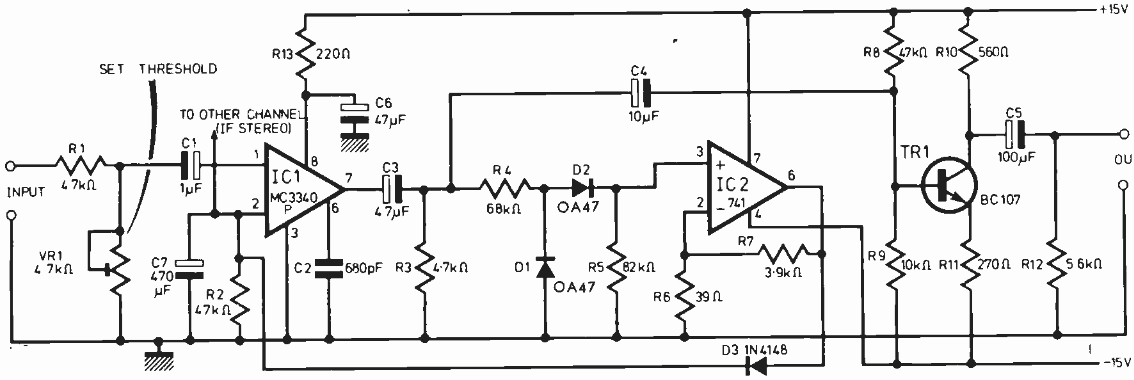


Fig. 5. Limiter circuit to reduce dynamic range. Output around 250mV r.m.s. maximum for inputs above limiting threshold set by VR1. Requires ± 15V at less than 50mA

other sources of background noise. The straight line above it shows the maximum sound level produced by your equipment when it is working at the maximum volume it can produce without undue distortion.

Between, and in the first instance occasionally crossing the two, is a jagged line indicating the level actually produced by your equipment; in the first diagram without the limiter/compressor, in the second one with it connected in circuit. When the line crosses the top one, your equipment is running into distortion, and if it crosses the bottom one you are no longer properly audible.

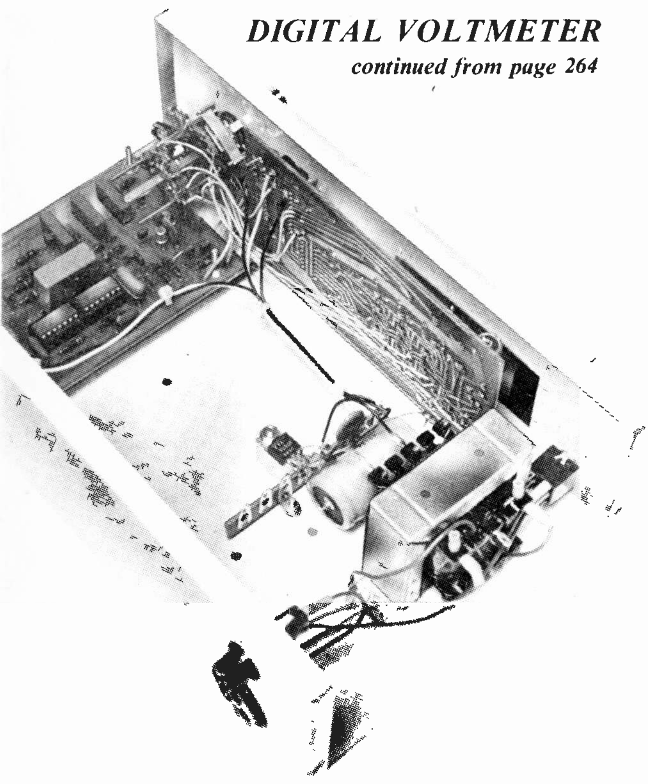
Now although modern records contain a good deal of compression already, it is very advantageous to compress them still further for disco work to ensure that your amplifiers and speakers are always working well within their power limits, and that excessive settings of the input controls do not really matter very much. The less discriminating of disco DJs quite often manage to obtain a limiting effect by driving their power amplifiers into clipping, but because this produces enormous amounts of distortion in addition to threatening the life of the output transistors this method is definitely out for anyone who cares in the least about his sound quality.

The construction of the limiter (Fig. 5) is not critical; 0·1in matrix Veroboard is most suitable. For stereo use, link together the gain control lines (pin 2 of IC1) in the two channels.

Next month: More on choosing and using disco equipment

DIGITAL VOLTMETER

continued from page 264



CALIBRATION

Set the range switch in the 1 VOLT position (A) and short together the input terminals. The SET ZERO preset VR1 should be adjusted until the display just flickers between +0 and −0. (If this won't work swap the ZN424s and try again. If still no success, see the section on testing.)

A known positive voltage between one and two volts should now be connected to the input terminals and VR3 adjusted until this voltage is displayed. The input voltage should be reversed and VR2 adjusted until the display is again correct. VR1, VR2 and VR3 are now correctly set and should not need altering again. The three input attenuators are set up with an appropriate voltage in their range. The accuracy of the calibration depends on the reference instrument used, this should preferably be another DVM. The calibration is now complete and the instrument can be used.

TESTING AND FAULT FINDING

Every fault on a piece of electrical equipment is an individual case. It is not possible to anticipate every condition and cause of faults. Experience gained from previous articles show that most faults are caused by missing components and interconnections or by mounting components the wrong way round.

As an aid to fault finding the circuit diagram shows voltages at certain nodes, measured using a standard AVO 8. These voltages are measured with respect to 0 volts. ★

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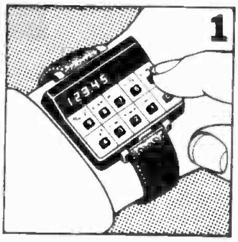
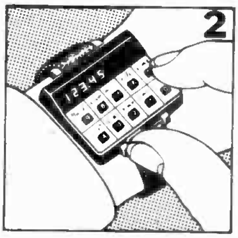
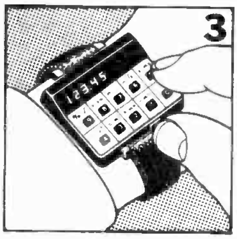


1. The switch in its normal, central position. With the switch centred, numbers – which make up the vast majority of key-strokes – are tapped in the normal way



2. Hold the switch to the left to use the functions to the left above the keys...



3. and hold it to the right to use the functions to the right above the keys.

The display uses 8 full-size red LED digits, and the calculator runs on readily-available hearing-aid batteries to give weeks of normal use.

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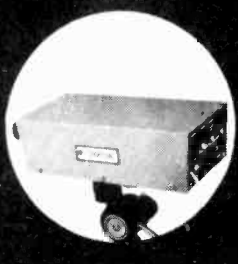

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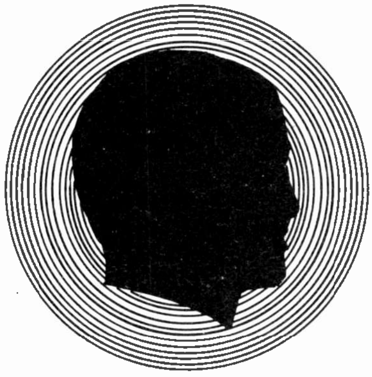

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THE circuit in Fig. 1 gives precise control of the speed of a miniature d.c. motor.

Ignoring inductive effects, the d.c. motor equation is:

$$Vm = IaRa + Eb$$

Where the back e.m.f. is exactly proportional to speed.

A dummy resistor (R3) equal to the armature resistance is used to find IaRa. The operational amplifier and TR1 produce an output of 2(IaRa) − Vc.

Therefore the voltage across the motor is:

$$Vm = IaRa - Vc$$

The control voltage is then equal in magnitude to the back e.m.f., and is proportional to motor running speed.

A control range of −0·1 volts up to −5·0 volts gives a typical speed range of 40 to 2,000 r.p.m. independent of supply voltage and load variations.

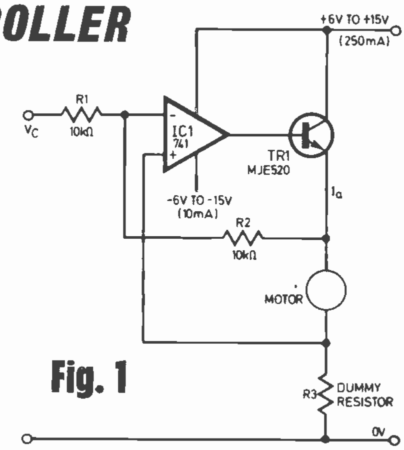


Fig. 1

J. Lidster, Darlington, Co. Durham.

INITIAL RESET

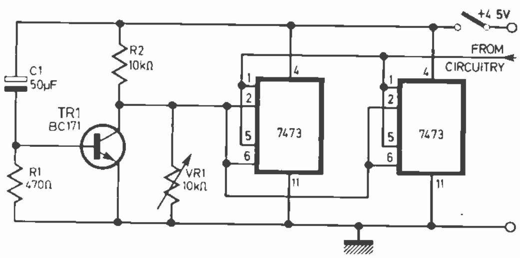


Fig. 1

THIS network operates a self-clear for logic systems when initially switched on, thus inducing a condition which would otherwise be rather improbable, due to the switch-on transient.

Master-slave flip-flops are shown as an example in Fig. 1, where the initial state will occur when all flip-flop outputs are at logical zero. The initial reset network consists of TR1 and its associated discrete components. Resistors R2 and VR1 are arranged as a potential divider, the latter being shunted by non linear load TR1, whose value depends on the voltage developed across R1. Only during the switch-on transient of the supply will C1 produce a voltage across R1, and turn on the reset transistor. The resistor VR1 was chosen to be variable to make the design less critical.

E. V. Dias,
Lisbon,
Portugal.

BISTABLE TOUCH SWITCH

THE circuit of Fig. 1 can be used to control mains equipment and is not prone to spurious triggering from too light a touch or a double touch.

The device works off the induced a.c. mains field which surrounds the human body when in a building containing a.c. mains wiring. When the touch plate is touched, the stray voltage is applied to the gate of TR1, which acts as an impedance buffer. The a.c. voltage on the drain is half-wave rectified by D1 and applied to capacitor C1. The value of C1 is selected so that there is a slight delay between the plate being touched and the bistable changing state, so preventing false triggering.

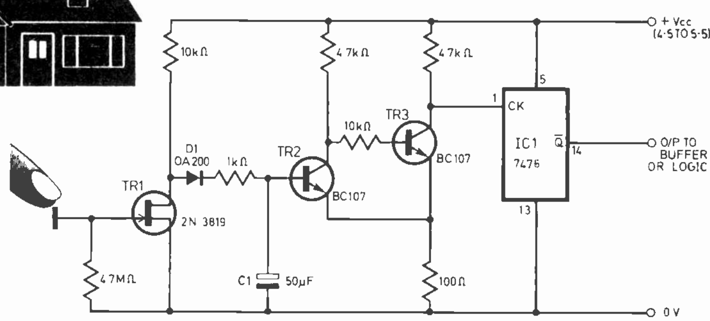


Fig. 1

The voltage across C1 is applied to a Schmitt trigger formed by TR2 and TR3. When the trigger threshold is reached the collector of TR3 will go high, triggering the bistable IC1.

Output $\bar{Q}$ at pin 14 of IC1 is fed to a buffer stage driving a suitable relay.

P. S. Robinson,
Tyldesley,
Lancs.

Part 2 — THE MPU CHIP

MICROPROCESSORS explained

By R.W.Coles

The focal point of a microprocessor system is the MPU chip itself, and this is reflected in the way complete microprocessor systems are often referred to by the MPU chip name or number, regardless of the fact that numerous other chips are involved and are quite essential for system operation.

The MPU chip is of course in charge of the overall system and spends its time reading instructions from program memory, interpreting them, and then manipulating the system buses so as to carry out the wishes of the programmer. The MPU chip is in effect the "Foreman" of the system, reading the "Plans" provided by the "Architect" or programmer and making sure the "Workforce" in the form of peripheral chips like I/O ports, do as they are required by the "Plan" or program.

We must not take an analogy of this sort too far, because some of the "Workforce" are actually embodied in the MPU chip itself, but perhaps this could be explained by assuming that the "Foreman" has a "Calculator" and "Notebook" in his pocket for use where appropriate when following the "Plan".

One thing is certain, and that is that the "Foreman" will never act on his own initiative, and will always follow his instructions to the letter, even if they are wrong, a fact which puts a heavy burden on the programmer. The "Foreman" will be quite happy to start building operations in a "Bog" or to put doors on the 10th storey which lead out into "mid air"—if instructed to do so by an incompetent "Architect"!

THE MPU chip is a collection of system components which exist inside a single package, and the decisions as to which components should be included and which not, have to be taken by the semiconductor manufacturers themselves, and, needless to say, they do not always agree on where the boundary should be drawn. Fortunately for us, there is a large measure of agreement on the main MPU components, and this makes it possible to consider a "Typical" chip and the building blocks within.

A TYPICAL MPU

Fig. 2.1 shows a block diagram of a typical MPU chip. This will be used to examine the function of each of the most important internal building blocks in a dynamic, rather than a functionally static, way.

We can start with the assumption that the MPU chip has just been "reset" by means of a signal applied to its RESET input either manually (from a switch) or automatically, from a power-on reset circuit. The reset causes the internal MPU REGISTERS to be cleared of information so that they contain all zeros, and the particular register of initial importance is the PROGRAM COUNTER because this is connected to the ADDRESS BUS which in turn is connected to an external program store such as the PROM mentioned last month.

With the address input to the PROM being all zeros, the very first instruction word is accessed, and this PROM output data is connected back to the MPU via the DATA BUS. What this first instruction word actually is, has of course been determined by the programmer who is happy in the knowledge that when the MPU "wakes up" it always starts in the right place, as required.

INSTRUCTION REGISTER

The first (and subsequent) instruction words is (are) latched by the MPU in the INSTRUCTION REGISTER, the outputs of which are decoded by the INSTRUCTION DECODER into a series of control signals which configure the MPU to perform the operation specified by opening and closing gates and generating clock or shift pulses via the TIMING and CONTROL circuits.

Let us assume that the first instruction was a *LOAD IMMEDIATE*—which means that a constant stored in PROM in close association with the instruction itself is to be loaded into the MPU ACCUMULATOR register.

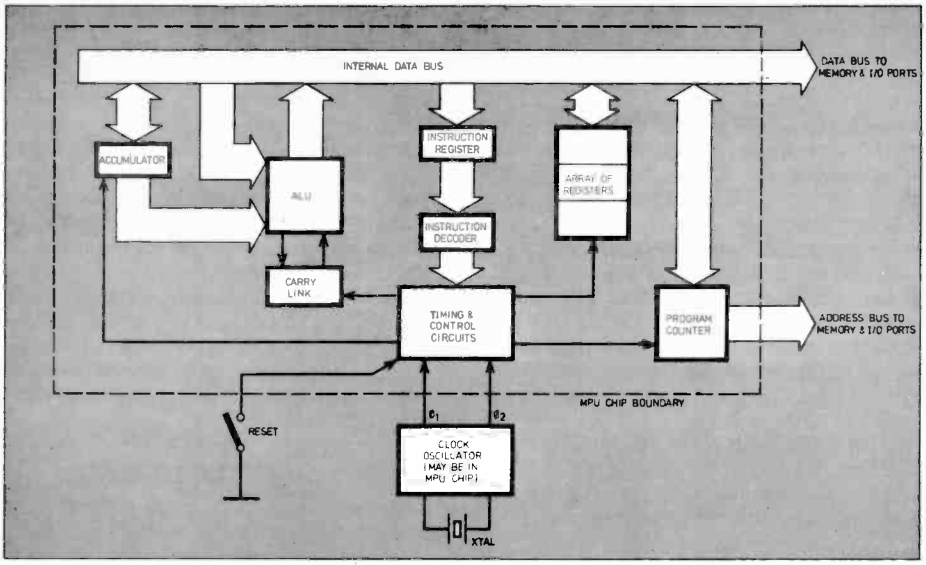


Fig. 2.1. A simplified block diagram of a "typical" MPU chip

The accumulator is a very important part of the MPU. Most instructions use the storage and manipulative functions it provides and it is always used to store the result of an arithmetic or logical operation.

Working data which is stored in, or retrieved from, external RAM memory is always routed through the accumulator, as is data intended for Output Ports or read from Input Ports. The number of binary bits which can be stored by this register is determined by the word-length of the particular MPU chip in use, and so for example, an eight-bit MPU can store eight bits in its accumulator.

Once the *LOAD IMMEDIATE* instruction has been completed the program counter is incremented to address the next instruction in the PROM which is interpreted as before by the instruction decoder. Let us assume that the programmer intends to perform an addition sum with the data loaded in step one and some other word to be loaded later.

REGISTERS

To make way for the second data word it is necessary to store the first word away somewhere, and to make this easy MPUs are provided with a set of internal

Glossary of Terms

ACCUMULATOR—A storage register, where arithmetic and logical results are held. A majority of MPU instructions operate on, or test, the accumulator content.

ADDRESS BUS—A parallel group of connections used to carry binary addresses *from* the MPU chip *to* memory.

ALU—Arithmetic and Logic Unit. An essential part of a microprocessor where arithmetic and logical operations are performed.

CLOCK—An oscillator which provides the basic timing reference for the MPU chip. The clock is often crystal controlled.

DATA BUS—A general purpose bus, or group of parallel connections, used to carry instructions and data to *and* from the MPU chip.

HARDWARE—All the electronic components, including the MPU chip, which go to make up a microprocessor system (contrast with *Software*).

INSTRUCTION DECODER—A logic gating array or small ROM *internal* to the MPU chip used to interpret instructions fetched from memory.

INSTRUCTION REGISTER—A register in the MPU chip used to hold instructions fetched from memory.

JUMP—A class of MPU instruction which causes the program to leap forwards (or backwards), either by a specified amount, or to a specified location.

LINK—A single-bit register used primarily to hold the carry out of the accumulator register during arithmetic operations.

MICROPROGRAM—A program, usually stored *inside* the MPU chip which controls the MPU during the basic fetch/execute sequence.

PROGRAM COUNTER—A special register which holds the current memory address. The register can be incremented or have its contents replaced during jump instructions.

REGISTER—A general purpose storage location which will hold one MPU "Word".

SOFTWARE—MPU programs stored on any media: even handbooks (and this article) came under this broad heading. Programs in ROM are sometimes called "*Firmware*".

STACK—A last-in-first-out store made up of registers or main memory locations and used to store, for example, subroutine return addresses.

SUBROUTINE—A sequence of instructions which perform an often required function, coded so that it can be called from any location in the main program.

registers which vary in number, in name, and in the facilities provided depending upon the type of MPU; but in every case they can be used for temporary data storage.

The second instruction in our program, then, would be an *EXCHANGE* instruction which exchanges the contents of the accumulator with a chosen register, effectively storing away the data loaded by instruction number one for future reference.

At this point the program counter is incremented once more, and the third instruction is placed in the instruction register, ready for execution. The third instruction might be another *LOAD IMMEDIATE* which loads a constant associated with the instruction into the accumulator, after which the program counter is again incremented and the fourth instruction read into the MPU.

Let's say the fourth instruction is an *ADD* instruction which will add the first data word (in the register) to the second data word (in the accumulator) to produce an answer which is stored back into the accumulator.

ARITHMETIC LOGIC UNIT

To perform the addition we need another MPU component termed the ARITHMETIC LOGIC UNIT (or ALU) and using our "Building Site" analogy the ALU is the calculator in the "Foreman's" pocket, which can be used to solve problems of an arithmetic, or logical nature.

The operation of the ALU is parallel in nature, which is to say that it is presented with two parallel binary words on which it performs an addition, subtraction, logical AND, logical OR, or one of a number of special "party tricks" which particular MPUs usually boast, as commanded by the decoded instruction.

In arithmetic operations it is necessary to produce a *CARRY* or a *BORROW* output to allow arithmetic operations to be cascaded to give a longer effective word length and hence greater precision in the result.

For example, an eight-bit MPU can carry out 32 bit arithmetic by using four, eight-bit operations in series in the program with the *CARRY* or *BORROW* acting as the link between the cascaded program steps to ensure continuity. The *CARRY/BORROW* bit is stored in a flip-flop or register stage which is closely associated with the accumulator and which is often termed the LINK for obvious reasons.

NO MULTIPLY OR DIVIDE

A thing to notice about the ALU is that multiplication and division are not normally included in its capabilities, and these operations have to be provided by a program sequence which controls the MPU in an *ADD* and *SHIFT* or *SUBTRACT* and *SHIFT* routine to produce the product or dividend after a number of repetitive operations.

This is a good example of HARDWARE versus SOFTWARE. Addition and subtraction are relatively simple and so can be easily performed by hardware (the ALU), but although multiplication and division *can* be performed by hardware, a large logic array is necessary and it becomes much more economic to use a software program to achieve the required result, even though it takes longer.

CLOCK OSCILLATOR

Our four-step program has now finished the simple addition and has used all the major MPU building blocks, though by no means all the facilities available of course. It is now time to consider the way the MPU coordinated its actions so that it was able to control the input of instructions and output of data on its internal and external data bus and yet avoid conflict.

The MPU keeps in step in true military fashion, and with a precision which would bring tears to the eyes of any nostalgic Sergeant Major, not by using the regular beat of a military band but by using the regular beat of a crystal controlled clock oscillator which may be entirely external to the MPU chip or may have only the crystal itself external.

The MPU uses the CLOCK input as a reference to synchronise the sending of address information to the memory, the reading of the instruction from the memory, and any subsequent use of the data bus and address bus called for during the execution of the instruction itself.

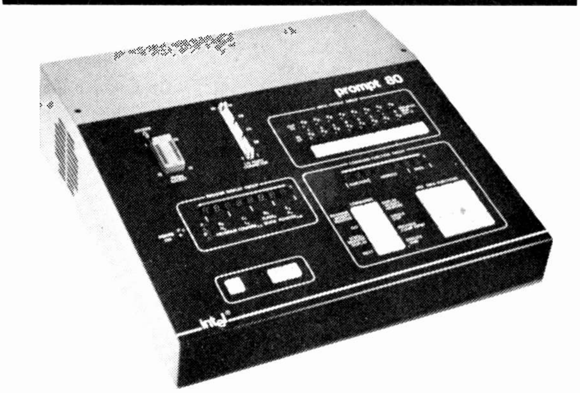
THE FETCH-EXECUTE CYCLE

The MPU, you may have noticed, has to carry out some operations in the absence of specific instructions from memory, and in fact it has its own internal MICROPROGRAM through which it continuously cycles when power is applied, and which is intended to instruct the MPU to read user programs from memory and carry them out in an orderly fashion.

The sequence of operations controlled by this microprogram is called the *FETCH-EXECUTE CYCLE* and this cycle is carried out at least once for each instruction in the user program. We say at least once, because most MPU instruction sets include multiple-word instructions which have to be read, or "fetched" from memory one word at a time.

In eight-bit MPU systems a word is termed a BYTE, and the *LOAD IMMEDIATE* instruction used in our four-step example would normally be a "two-byte" instruction requiring two loops of the *FETCH-EXECUTE CYCLE* microprogram for operation. The first byte would inform the MPU that it was a *LOAD IMMEDIATE* and that it required a further memory read to fetch the data byte from the next PROM location in sequence. Note that this also requires the program counter to be incremented twice, a point ignored in the earlier example because in some MPUs a *LOAD IMMEDIATE can* be achieved with only one instruction word.

DESIGN AID



The Prompt 80, a new microcomputer design aid from Intel incorporating a complete microcomputer with input keyboard and switches, output displays, a powerful 3k byte monitor and a complete EPROM programmer

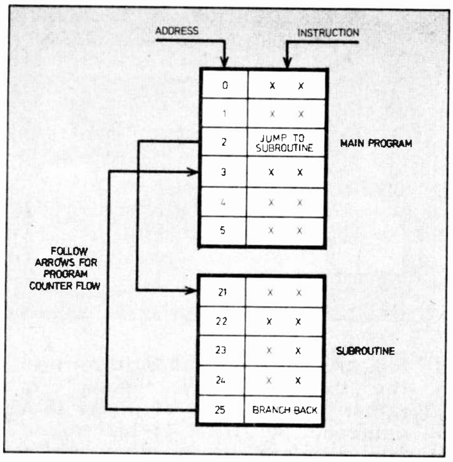


Fig. 2.2. Single level subroutine operation

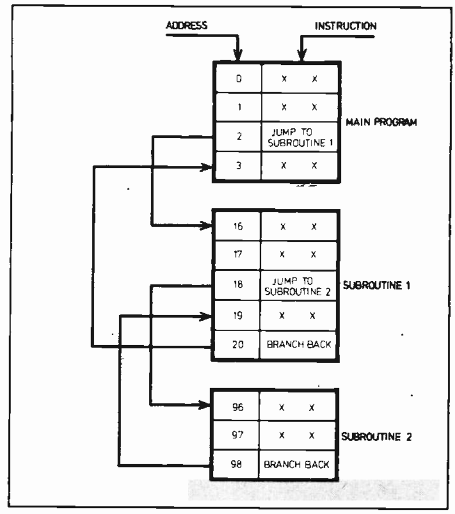


Fig. 2.3. A two level "nested" subroutine operation

PROGRAM JUMPS

In our treatment of the MPU chip so far, it has been implicitly assumed that after reset the MPU starts executing instructions at address zero, and then continues on through the program by incrementing the program counter until it runs out of instructions to execute or is reset, or comes to a *HALT* instruction.

This treatment is adequate to get a "feel" for the way an MPU goes about its business, but there is a big improvement to be made, and all practical devices incorporate this useful facility which is the ability to change the program counter address not just by incrementing it but also by direct substitution of a new address word under program control.

Changing the program counter contents causes the program to continue at an address which may be quite unrelated to the step-by-step sequence followed up to that point, and is not unnaturally called a *JUMP*.

The ways in which various MPU chips execute *JUMPS* and the internal MPU hardware provided to facilitate the operation is different in each case, but every MPU has a complement of *JUMP* or *TRANSFER* instructions in its instruction set and they can be used to make decisions (*JUMP IF POSITIVE, JUMP IF CARRY SET*) or to avoid repeated coding of often used program sequences (*JUMP TO SUBROUTINE*). See Fig. 2.2.

JUMP TO SUBROUTINE

The *JUMP TO SUBROUTINE* instruction type is particularly worthy of note because it has interesting hardware and software implications and is a very powerful tool in the hands of the programmer.

It was mentioned earlier that multiplication had to be achieved by means of a program sequence of *ADDS* and *SHIFTS*, and let's face it, this ends up as quite a lengthy and cumbersome section of program which you wouldn't want to write out in full each time a multiplication was necessary. With the aid of a *JUMP TO SUBROUTINE* it is possible to write the sequence just once and put it in a set of locations which can be accessed as a *SUBROUTINE* whenever necessary.

The *SUBROUTINE* can be "called" from any location in memory by putting its start address in the program counter with a *JUMP TO SUBROUTINE* instruction and then letting it perform the multiplication before returning to the main program where it left off by restoring the original contents of the program counter + 1.

The action of returning to the main program "undoes" the subroutine jump in effect, and most MPUs have special instructions to achieve this, typically *RETURN FROM SUBROUTINE* or *BRANCH BACK*. Notice that it is necessary to store the current contents of the program counter before a *JUMP TO SUBROUTINE* so that the subroutine can be called from anywhere in the main program and on completion a return to the correct instruction can be achieved even though the subroutine may be called many times in a particular program.

PAUSE FOR BREATH

If you are a newcomer to microprocessors you will probably have found the previous paragraphs on subroutine jumps quite hard going, and in this case you should, for the moment anyway, skip the next section which is intended for those who feel a reasonable familiarity with the aims of programming an MPU and can see the usefulness of subroutines and visualise what takes place when they are called.

NESTED SUBROUTINES

Subroutines are such a useful programming tool that they are used a great deal, and many programs are written with a short main program consisting almost entirely of subroutine calls, and backed by a "Library" made up of the subroutines themselves.

Sometimes a subroutine itself may call another subroutine, and this is where a problem can arise if the implications are not carefully examined. See Fig. 2.3.

When the main program calls the first subroutine a new address is loaded into the program counter and the original content of the counter is stored in (say) a register within the MPU so that it can be used by the subroutine to return to the main program. If the subroutine calls a further subroutine then the contents of the program counter must be changed again, and again its original contents must be saved so that the second subroutine knows how to get back to subroutine one.

If the program counter were to be saved in some fixed area in the MPU, like a register, then calling the second subroutine would overwrite the return address for subroutine one in this register and the net result would be that the program would get lost, probably ending its days in an infinite loop from which it could never exit.

What is required is some kind of storage area which could be used to store a number of these return address words, and some mechanism which takes the last address stored as the first return address, the last but one as the second return address and so on, so that without going to any special trouble in writing the program, nested subroutines are easily possible and do not require a lot of mental gymnastics in their preparation.

THE STACK

The type of store just described is termed a STACK in microprocessor parlance and most MPU chips have, or can use, a store of this type to save subroutine return addresses. See Fig. 2.4. The Intel 4040 MPU, for example, has a "Hardware" stack which can store seven return addresses without the direct involvement of the programmer, and without the need for external RAM memory.

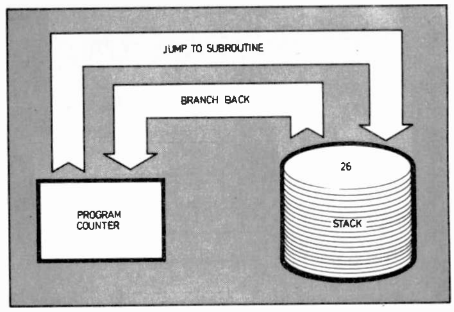
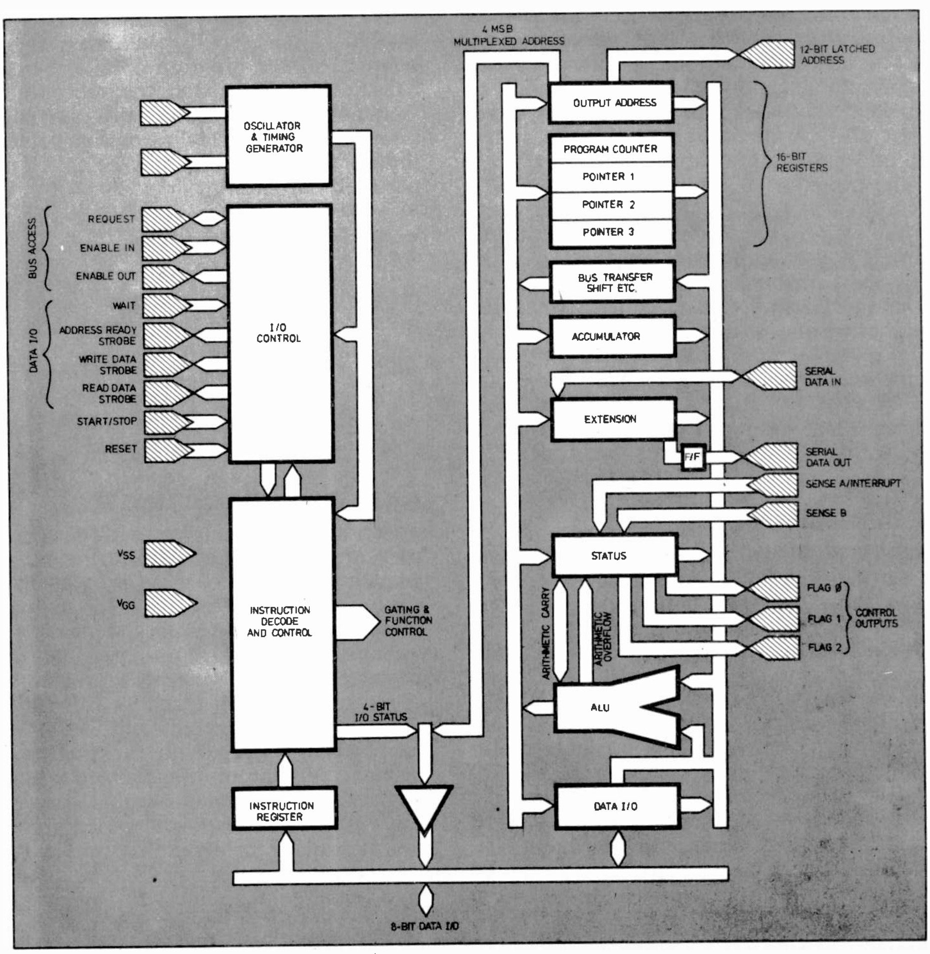


Fig. 2.4. Nested subroutines and the "stack". The "stack" is rather like a stack of plates in a canteen. A JUMP to subroutine puts a "plate" *on* the stack, and a BRANCH BACK takes a "plate" *off*. The "plates" are, of course, Memory Addresses. If many subroutines are nested, the stack grows upwards

Fig. 2.5. The SC/MP MPU chip organisation or flow chart



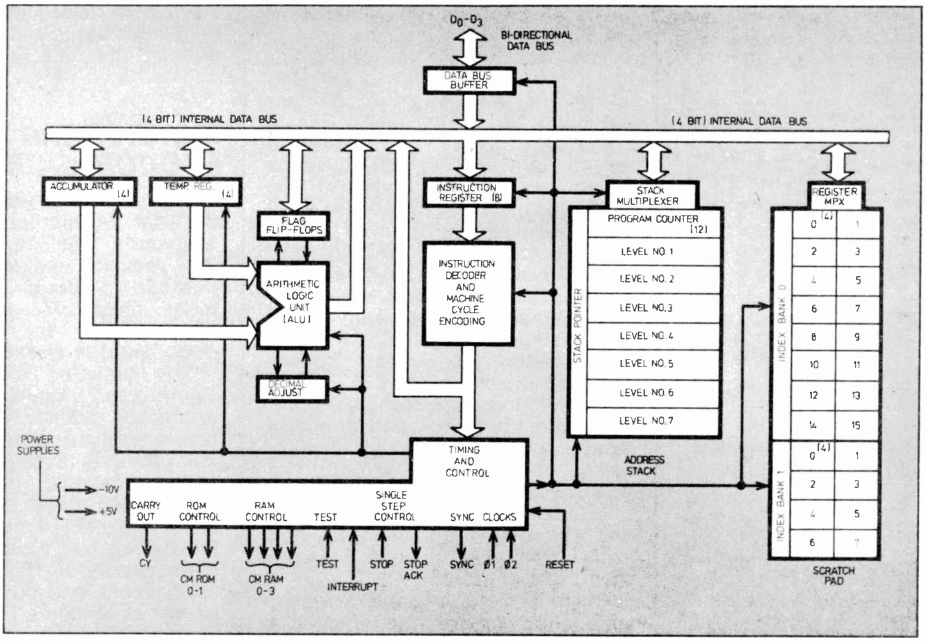


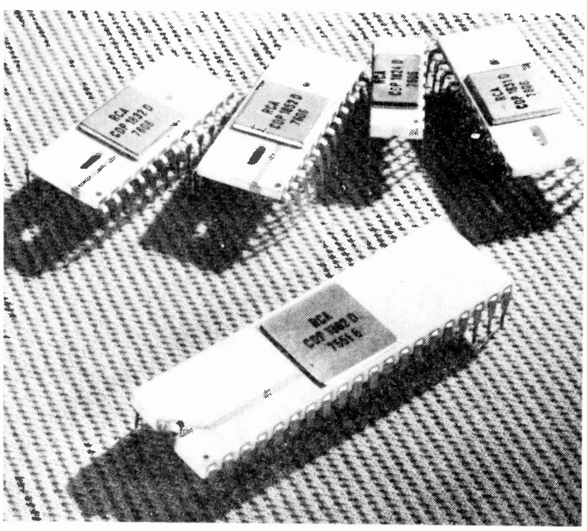
Fig. 2.6. The 4040 MPU chip organisation

An internal stack of this type is simple and effective but is limited in its extent so in larger systems such as the Intel 8080 a stack is created in RAM and the address of the top of the stack is indicated by a register in the MPU called a stack pointer. With this arrangement a return address is stored in external RAM at the location pointed to by the stack pointer which is then incremented to point to the next available stack level ready for further subroutine calls. A *RETURN FROM SUBROUTINE* causes the stack pointer to be decremented and the data last stored to be retrieved and put in the program counter.

The SC/MP microprocessor falls into a unique category because as it comes it can only run subroutines to one level, having no register stack and no automatic stack manipulations for making a subroutine call or return. With a few instructions, however, it is possible to create one's own stack in RAM which will provide all the facilities of the 8080 system for the outlay of a little extra software.

This type of stack is called a SOFTWARE STACK and because it is created by the programmer, it can be used for other jobs too, which makes it a very versatile tool indeed when writing programs of the "Data-Processing" variety.

CHIP FAMILY



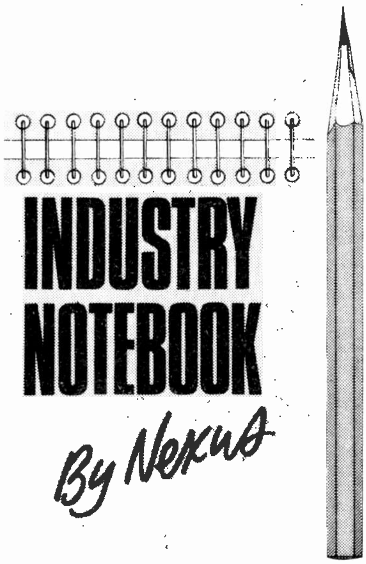
The RCA CDP 1802 single chip CMOS microprocessor and some of the input/output and memory support circuits

HEAVY GOING

This Part of "Microprocessors Explained" has, in all probability, been rather heavy going for some readers, but don't despair! If one can get a working familiarity with the major concepts introduced this month the rest of this Series should be fairly easy to digest, and let's face it, before long microprocessors will be a part of all our lives and so an early start will pay dividends!

If you now feel at home with the "Simplified MPU" (Fig. 2.1) you might like to have a go at finding your way around two "real" MPU chips, the National SC/MP (Fig. 2.5) and the Intel 4040 (Fig. 2.6).

NEXT MONTH: The Instruction Set and how to use it. Programming Techniques.



WHAT'S IT WORTH?

Pricing policy is the jungle in which many a marketing manager has perished. The golden rule is to charge what the market will bear which broadly speaking is what the customer is prepared to pay.

When a unique product is brought to the market it can command a good price. Later, when a competitive product appears, the original product is no longer unique and in order to maintain sales the downward price spiral starts. When lots of competitive products appear, prices can drop dramatically. Lowering of prices is often assisted by an increase in production giving lower unit costs as the product gains wider public acceptance.

The supreme example is electronic calculators which, since being manufactured by the million and with intense competition, have dropped in price for the simpler types by a factor of ten or more times since their introduction to the market. The same thing is happening with digital watches.

UNCONTROLLED

Unhappily, the system can easily get out of hand and we find manufacturers doubling production for half the profit and then doubling again for no profit and then making thumping losses. Then, when every tenth of a penny has been shaved off component prices and there are no more savings to be made on materials, the only thing left to be shaved is labour costs and production moves overseas to the Far East.

The horrors of the downward price spiral are vividly illustrated in the balance sheets of Sinclair Radionics. In 1973 there was a pre-tax profit of £306,200 on £1·8 million turnover. In 1974 with a more than doubled turnover the profit declined to £240,500. In 1975 with £6·2 million turnover profits dwindled to £45,000 and in 1976 with £5·6 million turnover there was a loss of over £350,000.

The losses last year were mainly attributable, says Sinclair, to the Black Watch, launched in November 1975. Having spent £200,000 on publicity there were technical problems with the watch and crippling delays in the supply of components from sub-contractors. The downward price spiral on calculators was already hurting badly and the Black Watch shows how costly bad luck or bad management, or both, can be.

Clive Sinclair remains irrepressible. As recently noted in this column, he went up-market with a nicely packaged calculator in rolled gold selling at £60 which did rather well. I have since discovered that he went further up-market with a solid gold model at £2,750 inclusive of VAT. Half a dozen were bought by a buyer from the Middle East. A gold ingot with a built-in calculator gives the buyer the advantage that he can instantly calculate the day-to-day value of his investment by reference to the daily gold prices.

UP-MARKET

There is a lot to be said for going for the high qualitv end of the market, providing you can find customers. I was interested to see that with watch prices tumbling as the digital craze develops, one real old-fashioned clockwork watch has appeared on the market with a price tag of £4,255. And not in solid gold or platinum. It hasn't even got a face, only a transparency through which you can see in motion a wonderfully delicate movement of great beauty. It tells the time, too.

The new Sinclair Microvision TV, launched with enormous publicity is also up-market. At 300 US dollars (£170 in the UK) it's not cheap but while unique it could hold the price. Meantime, Sinclair is staying in the mass market with calculators and watches although he has dropped out of hi-fi.

The popular Oxford range of calculators is made in a Sinclair-controlled plant in Hong Kong but the Cambridge range, digital watches (an upgraded model) and the Microvision are now being built in-house at St Ives. Sinclair is also staying in instruments with a 4½ digit multimeter scheduled for production later this year.

WHICH YEAR FOR MICROPROCESSORS?

The year 1975 was to have been the year for microprocessors. Then everybody was saying 1976 was the year of the microprocessor. Perhaps it could be 1977, but more likely 1978 before the big take-off. And yet the downward price spiral is already taking place.

The Managing Director of Warren Point Ltd., Geoff Evans, sees enormous activity but very little real action in applying microprocessor power to a staggering number of applications, over 20,000 in fact, which have been identified. But the expected stampede to use the device has turned out to be a mere doddle so far.

He thinks one of the reasons for slower acceptance than anticipated is the multiplicity of devices available and the mountain of literature supporting them. While lots of people are experimenting, few want to commit themselves in a big way on a microprocessor type which may, in the end, be only a half-way house or to a standard less than or possibly different from the final industry standard whenever that emerges.

The very fecundity of ideas in the business is, in fact, its own worst enemy. The situation should improve, says Evans, when one manufacturer achieves such dominance in the market that his device automatically becomes the industry standard. Meantime, the ding-dong continues with each contender claiming his device is best and with prices sinking as one way of establishing a market share which could lead to domination.

Eventually, the market leader, whoever it may be, will make a fortune. When, is a different question. But this could be a good year for specialist consultants, helping clients to thread their way through the maze of claims and counterclaims on specifications.

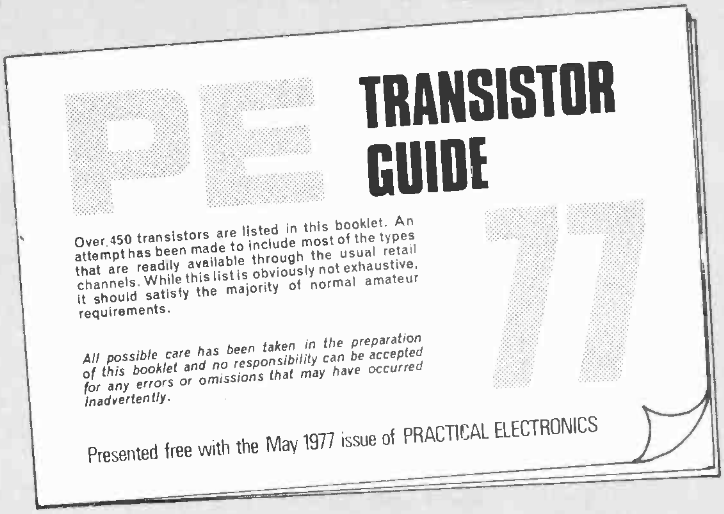
MORE CUTS

Apropos my opening paragraphs I note that Commodore Business Machines have slashed the price of the CBM 5000 5-function digital watch from £17·50 to £11·95 as a result of "mass production and decreased overheads". Models with fancy cases (gilt, chrome, etc.) get lesser reduction, suggesting that the jewellery on the outside already costs more than the works inside. The £5 digital watch will not be long coming.

IN NEXT MONTH'S ISSUE...

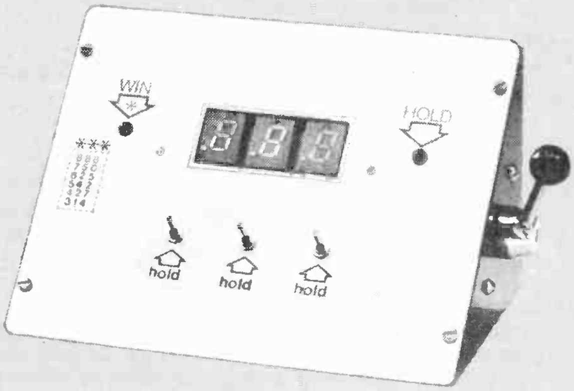
FREE!

Over 450 popular transistors are listed in this booklet with important parameters and comparables.



ONE ARM BANDIT

Make sure you get your own back by building this machine. It offers hours of entertainment with six selectable winning combinations and a hold facility with each display.



ORGAN TREMOLO

Phase modulates the output signal of an electronic organ to give the effect of a rotating cabinet extension.

DIGITAL DARKROOM TIMER

Satisfies a need for an accurate, reliable and repeatable timer for enlarger control or for timing various darkroom jobs.

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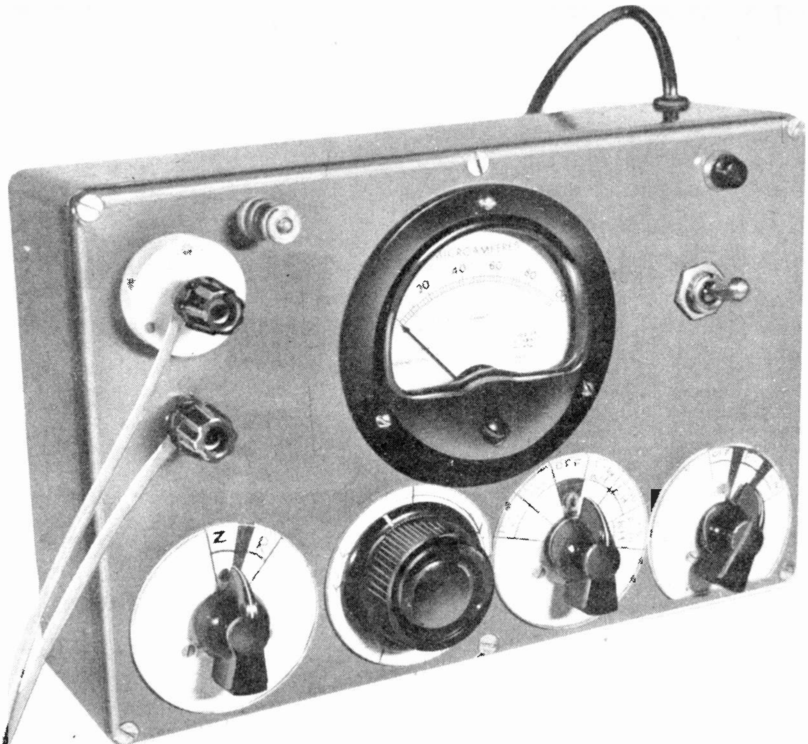
A sensitive amplified bridge design that ensures meaningful protection to your home or business.

Don't be disappointed — place a firm order with your newsagent *NOW*

PRACTICAL ELECTRONICS

OUR MAY ISSUE WILL BE PUBLISHED ON THURSDAY, APRIL 7, 1977



pH METER

By K. E. LANGFORD

THIS final part deals with the construction, standardising, and use of the pH meter.,

CONSTRUCTION

An early decision will have to be made as to which glass and calomel electrodes shall be used, by checking designs from manufacturers' drawings, since appropriate sockets will need to be fitted to the unit quite early on. Purchase the electrometer valve (if the valve version is to be built), and also the special ceramic or nylon rotary switch S1. Decide between using batteries or power pack for the supply, and then obtain a die cast box of suitable size. The much cheaper aluminium boxes with open corners are less satisfactory since screening is incomplete. The prototype instrument is housed in a die cast box 8·75in × 5·75in × 2·25in (222mm × 146mm × 57mm). Doram Standard Switch Kits (type 327428, 327440, plus spacers) are suitable for S1.

INPUT TERMINAL

Near the top left-hand corner of the lid, make a circular hole of 1 to 1·5in (25–38mm) in diameter, using an Abrafile or chassis punch. Clean the internal edges with a half-round file, finishing with emery paper. This will take input terminal I1, the assembly of which is shown in Fig. 5.

Obtain some new clean Perspex sheet $\frac{1}{16}$in (1·6mm) minimum thickness, and leaving the backing paper intact, cut out a circular hole of diameter half an inch greater than the diameter of the hole in the box lid. This will give a quarter of an inch (6·3mm) all around when the Perspex is placed concentrically over the hole. Drill three equally spaced (120°) holes around the Perspex, and three coincident holes around the lid hole, so that the Perspex can be mounted above or beneath the lid like a window. Size 6BA nuts and bolts (nylon is ideal) complete the fitting. Avoid leaving scratches in the Perspex, as these fill with impurities and make excellent conducting paths which ruin the input characteristics.

Next, centrally drill the Perspex to accept the socket appropriate to the glass electrode, and fix it in place. Having finished, strip off the backing paper, wash the "window" in tepid soapy water, swill thoroughly, dry in warm air, and store in a clean dry box with the valve and zero/read switch. These items comprise the input, and need not be fitted until all the rough work is completed, neither should they be fingered or contaminated, particularly the switch wafer.

A little below the lid window, drill the lid and mount the positive input socket for the calomel electrode lead. An ordinary four millimetre insulated terminal socket is satisfactory, and no special precautions are necessary apart from cleanliness. To the right of the input, an uninsulated earth terminal or socket is mounted in direct contact with the lid. Other items to be earthed will be connected to the underside of this.

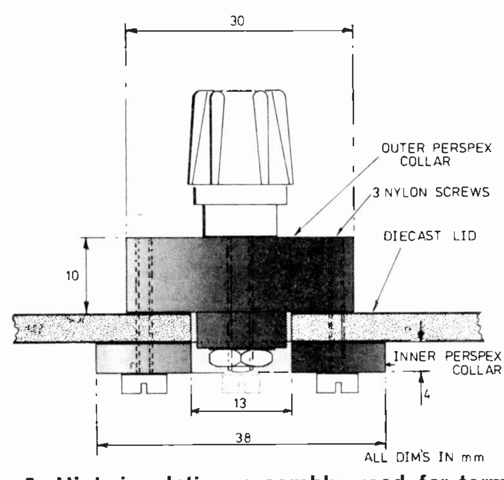


Fig. 5. High insulation assembly used for terminal I1 in the prototype instrument. A simplified version is described in the text

VALVE SCREENING

Next make a can for the electrometer valve, using a length of half inch diameter domestic copper hot water pipe. Cut off a 2·25in length (57mm), and to one end solder a disc made from copper foil. A piece of flattened copper tube, or even a small bronze coin will do. Clean up the edges with a file, wash to remove swarf and flux, and dry thoroughly.

The valve is located in the can either by wrapping it round with two inch wide clean polythene sheet to take up the slack between the inner diameter of the tube and the outside diameter of the valve, or by cutting two washers from foam nylon packing material. The outside diameter of the washer must be an easy push fit into the copper tube, while the centre hole takes the valve. Locate a washer at each end of the valve, and to prevent the glass contacting the cap end, insert a foam nylon disc or a few circles of polythene sheet cut to size. Using tweezers, carefully introduce the valve into its "snuggery" and store with the rest of the input components.

METER MOVEMENT

The meter ME1 should be a 0–100 micro-amp movement as any other range will make calibration exceedingly difficult. Shape or size is immaterial, providing the case will accept it, the resistance is about 1kΩ, and the accuracy is better than 3%.

Mount the meter on the lid a little above centre, and equidistant from each end. Leave space below for switch S1, the zero setting pot, the on/off switch S3, and the range switch S2. Make the holes for the meter and all the latter components, and work on the lid is almost complete. If a power pack is to be used, holes for a panel type mains switch and possibly a neon indicator will be required.

The power pack may be located at the top right-hand corner of the box itself. The transformer is fixed to the base of the box by 6BA countersunk screws from beneath. Other holes will be needed for the mains lead grommet and a brass saddle to anchor the lead, and for a three way barrier strip to terminate the mains. Mains earth is taken from the barrier strip to a solder lug fastened to one of the transformer bolts by an extra nut. The rest of the power pack components can be squeezed into the same corner, by mounting them on a piece of plain matrix board, and attaching to the side or base of the box with stand-off pillars. Extra flexible flying leads take the 18 volts d.c. from the power pack to the main circuit board rails.

CIRCUIT BOARD

Components for the main circuit are mounted on matrix board supported by the meter terminals. The valve assembly is mounted as near as possible to S1 and the input terminal, and arranged if possible so that no other leads cross the input to the grid. The valve may be located on the matrix board by making a copper or brass saddle to take the can, and drilling 6BA clearance holes at each end, then bolting to the board. To one end of the saddle, solder an earth wire, and take the other end of this to a solder lug fixed to the underside of the earth terminal. At some convenient point, take the negative supply rail down to the same connection. Sound earthing is essential to prevent inexplicable drift sometimes encountered when measuring pH at the alkaline end of the range.

No special component layout is called for on the main board, but arrange for resistors R8 to R12 to be readily accessible, as their values will have to be selected during calibration. The prototype layout is shown in Fig. 6.

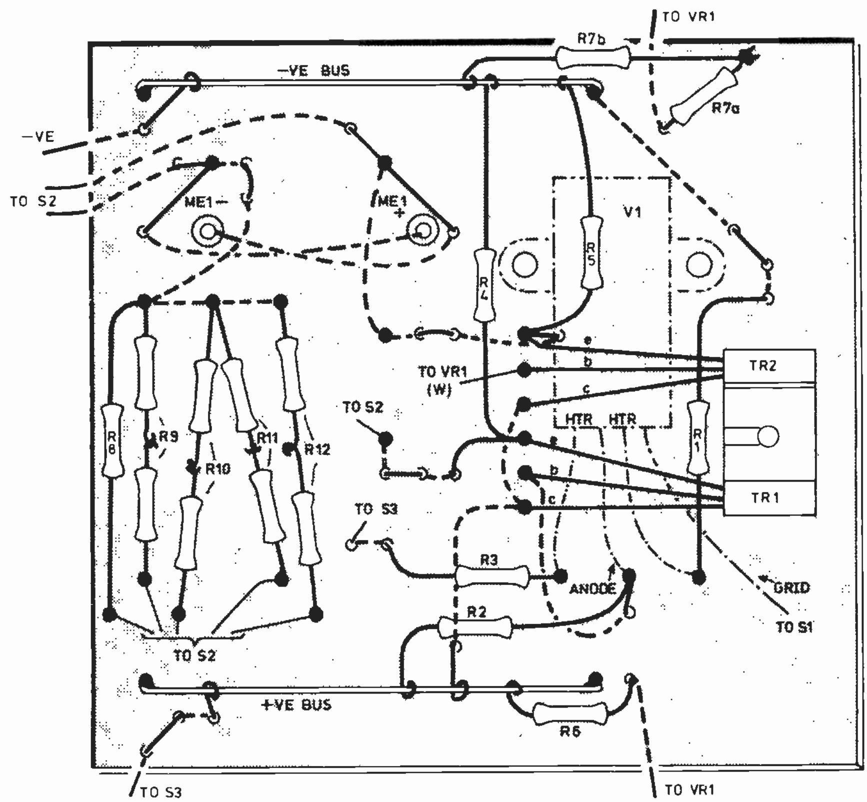


Fig. 6. Simplified board layout for the pH meter circuit, using 0·25in unclad matrix board secured by the meter terminals

When soldering the valve lead, use a heat shunt or pliers behind the joint. Never solder less than 15mm from the seal, and do not bend nearer than 2mm from this. Any extension to the grid lead is made with uninsulated stiff copper wire. The valve lead marked N.C. can be cut off at about 2mm from the seal, but *be sure the correct one is cut.*

CONTROLS

Dials for the various controls are left to individual choice. The prototype was labelled with paper scales marked in ink and covered by discs of Perspex fastened to the lid with three 8BA bolts, equally spaced around the centre hole, and concealed by the boss of the knobs. For S1, S2 and S3, pointer knobs were used, and a circular one for the zero setting pot VR1.

Before final assembly, remove all blobs of solder, finger marks, and any extraneous material from the box, lid, and matrix board, and thoroughly dry in warm air. Leave any painting of the box until calibration is complete, and the meter is seen to be functioning with satisfaction, then completely strip down and apply the final finish.

ACKNOWLEDGEMENT

The basic circuit of this instrument was published some years ago by Mullard Ltd., as a low voltage electrometer, and was modified by the author for use as a pH meter.

If a different type of indicating meter is fitted, it should be remembered that the current flow between X1 and X2 should not exceed one milliamp, to prevent overloading of the bridge.

The electrometer valve version has an input resistance of $10^{10}\Omega$ per volt, a maximum input voltage of 2 volts,

F.E.T. ALTERNATIVE INPUT STAGE by M. Abbott

It was decided to give the constructor an alternative, solid state front-end to the author's original design, and this is shown in Fig. 8. The input circuit is very simple, and would conveniently replace the valve at a later stage if required.

The i.c. is more expensive than the valve, but does give slightly improved linearity, and is available from Doram Electronics Ltd. (order code 305-456).

With the f.e.t. amplifier the input reference level is taken from the centre voltage of VR1, by means of the two 82kΩ resistors. This ensures that balancing the bridge to zero should automatically be near the centre of VR1. The input resistance of the i.c. and consequently the instrument as a whole, is 10^{14} ohms. The base of TR1 is driven directly from the amplifier output, and as can be seen, there is no voltage gain, as the circuit is a voltage follower. However, unlike the valve input stage, there is no 180° phase inversion, therefore the meter connections must be reversed. As expected, there is no warm up time with the f.e.t. version (not to be confused with the electrode equilibrium time), and the function of S3 can be reduced to simply "on" or "off". With the mains built unit, S3 can be eliminated altogether, leaving the on/off function to the mains switch alone.

CONSTRUCTION OF F.E.T. UNIT

Veroboard and other conventional component boards are unsuitable for mounting the f.e.t. device, as their surface resistance and conductor spacing would shunt

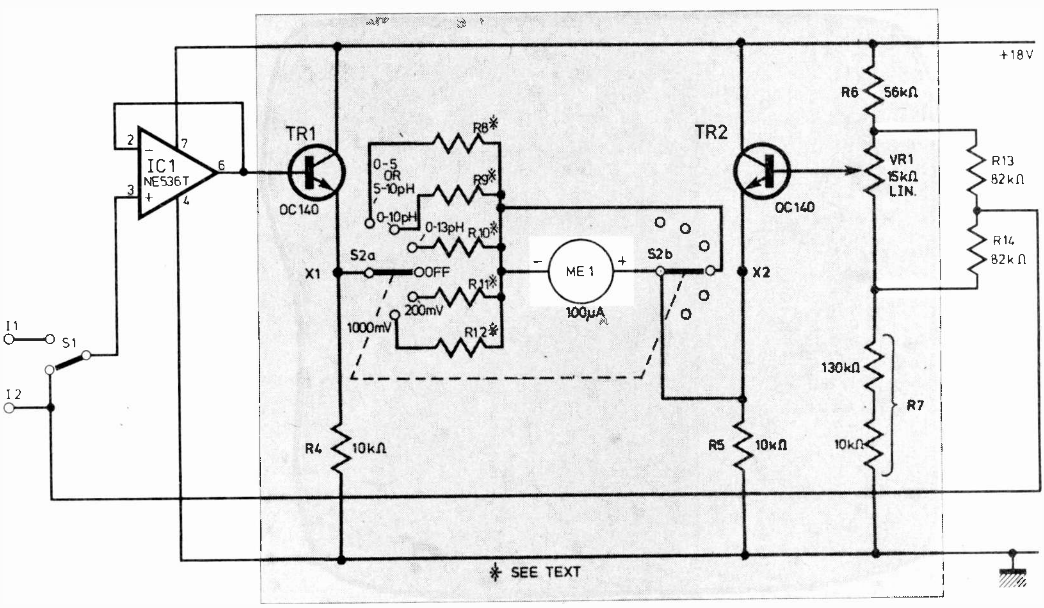


Fig. 8. Meter circuit with f.e.t. front end. The shaded area remains the same. Note the polarity reversal of ME1

and the minimum readable input is 0·5mV. A change of at least 0·02pH should be detectable.

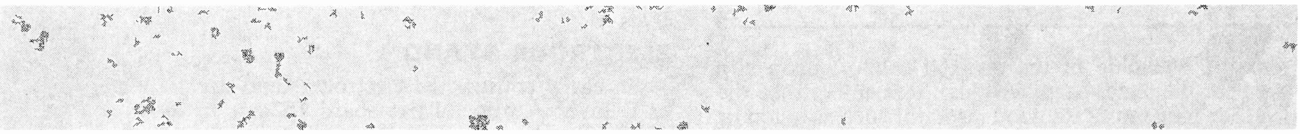
THE ELECTRODES

Both the pH sensitive glass electrode, and the calomel reference electrode will have to be purchased, and will constitute the most expensive single items. An experienced laboratory technician could fabricate a calomel electrode, but the purchasing and handling of scheduled poisons like mercury and calomel is not recommended for amateurs; furthermore, certain items would be difficult to obtain retail. Making a glass electrode is quite outside the scope of anyone except a scientific glass worker, even if the special glass and other materials were at hand.

The most suitable glass electrode for our use is the general purpose type, which works well in the range 0–13pH, but is not recommended for use at low temperatures. Since measurements will be taken at 25°C (explained later) this constitutes no hardship. The most convenient plug termination is either a 4mm plug or spade lug. Avoid fittings which will only enter a special adapter in the maker's own pH meter.

This type of electrode can be purchased as a separate unit, and also combined with a calomel reference as a dual electrode showing a price advantage, but it requires a special socket to take the two leads and earth. It also lacks versatility, and can turn out to be more expensive in cases of breakage, since the complete unit has to be replaced. Separate electrodes are preferable as the calomel standard can always be obtained with either spade or 4mm connections, and therefore easily adapted to the constructed meter.

If the glass electrode purchased calls for a double socket for lead and earth, then a 4mm plug can be substituted for the electrode lead, and earth taken

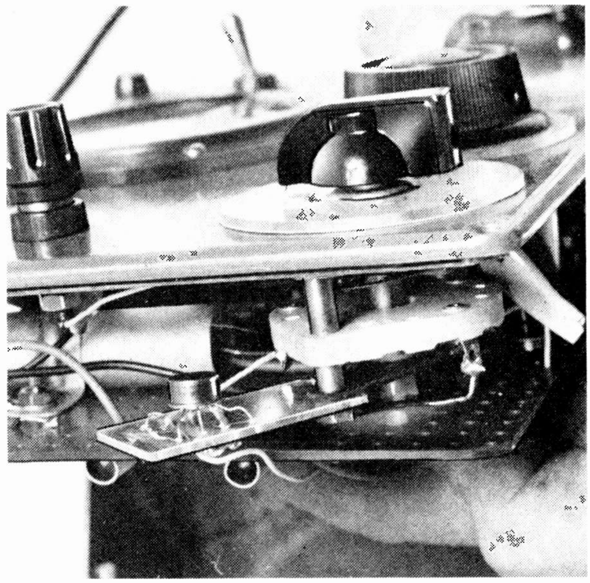


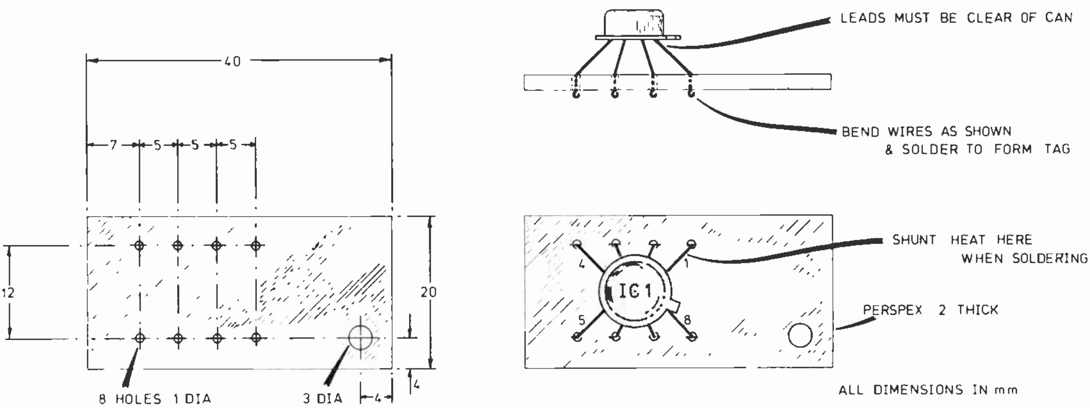
the input resistance of the amplifier. However, if a piece of Perspex is cut and drilled as detailed in Fig. 9a, the i.c. can be mounted on it, as shown in Fig. 9b, and the whole assembly could then be mounted at some convenient point.

Once the Perspex tablet has been constructed, it should be thoroughly cleaned with methylated spirit and wiped with clean dry tissue paper, before mounting the i.c. The integrated circuit should of course not be fingered too much around the lead-out area, to avoid contamination, and should **not** be cleaned with methylated spirit.

Location of the f.e.t. assembly should be as close to the input switch S1 as is practicable, so that all input leads can be short. In the prototype it was mounted on the end of one of the threaded retaining pillars of S1.

The only special points relating to wiring, are that solder joints to the i.c. should be relatively swift, a heat shunt being placed between the joint and the device. A pair of pliers with an elastic band around the handle can be used for this purpose. Stiff wire should be used for the input signal leads, as this can be encouraged to stay clear of other wires and objects more readily, which is a good idea even if it is insulated. ★





(a) **(b)**

Fig. 9. Physical construction of the optional f.e.t. module

ELECTRODE SUPPLIERS

Electronic Instruments Ltd.,
Hanworth Lane, Chertsey,
Surrey, KT16 9LF.

The E.I.L. "Laboratory Electrodes" catalogue can be obtained from the above address, and the most suitable electrodes are:

Series 1070 all-purpose **glass electrode**, 0–14pH STANDARD (1070–1)

For banana termination to suit the PE pH Meter order No 1070–120.

Refillable, ceramic junction **calomel reference electrode**. For spade terminal type, suitable for above, order No 1370–710.

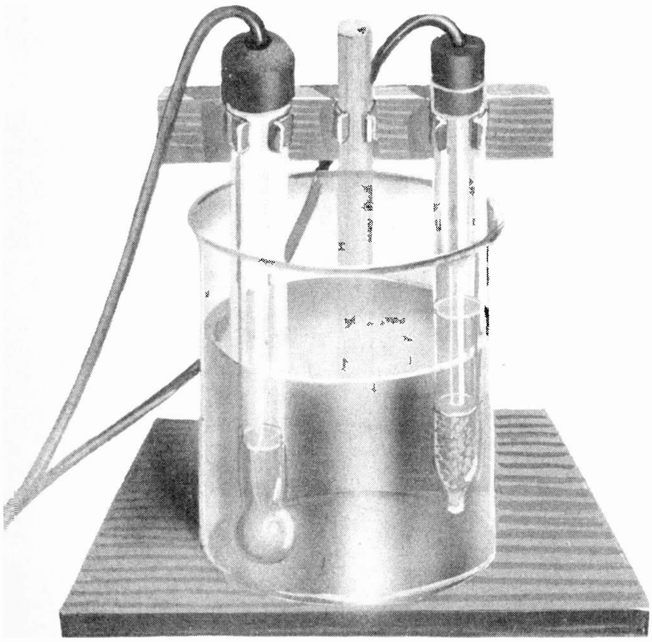
E.I.L. are also suppliers of buffer solutions and powders.

A. Gallenkamp & Co. Ltd.,
PO box 290, Technico House, London, EC2P 2ER.
Glass Electrode EJ–704 (0–12pH only)
Calomel electrode EJ–710

from the screening of the co-axial cable, with a clip wired for the meter earth terminal. Remember that the electrode plug must be a good insulator such as nylon or polythene, in order to preserve the high input resistance of the meter, by preventing a leak path between the electrode lead and earth sheath.

Glass electrodes need conditioning prior to use; usually by a twenty-four hour immersion in very dilute hydrochloric acid. Follow the maker's instructions. When not in use, the electrodes should be kept covered with clean distilled water to a depth of half an inch above the glass bulb. A small plastics container such as a 50 c.c. polythene beaker is ideal for this purpose. Repeated drying out and wetting of the electrode will drastically reduce its accurate working life.

Bulbs are very fragile, and if cleaning is needed to remove greasy films, immerse in tepid soapy water, and use an old tooth brush to assist the operation. Do not use household detergent, as this may temporarily upset the ion exchange characteristics and lead to inaccuracy.



After purchase, the calomel electrode will need filling with either distilled water, or saturated potassium chloride solution. The latter is made up from the analytical quality salt. This salt is a completely innocuous substance with no hazards attending its use. The salt bridge is represented by the porous plug at the end of the electrode, which allows a slight bleed of potassium chloride solution. During storage, this can be stopped by fitting the rubber cap usually supplied with the electrode. However, remember it must be removed before use, in order to achieve electrical continuity within the combined electrode system.

Maintenance consists of keeping the glass tube charged with potassium chloride solution, and an occasional wash down on the outside using distilled water. For pH work in general a worthwhile investment is a small three-hundred cubic centimetre polythene squeeze-type wash bottle, from which distilled water is quickly and conveniently delivered.

ELECTRODE STAND

An easily constructed electrode stand can be made as follows: A piece of flat board 152mm × 76mm × 19mm (floorboard) is centrally drilled to accommodate a length of 12mm dowelling, which is then glued into place. This centre rod can be 200mm long. An adjustable cross piece is cut from wood 127mm × 13mm × 6mm, into the flat side of which is screwed centrally a Terry clip giving a good sliding fit on the dowel.

A further two smaller clips, preferably polythene coated, to clasp the electrodes, are attached near one end of the cross piece 25mm apart. With this simple stand the electrodes are held conveniently side by side, and can be easily immersed in, or removed from the distilled water in which they are stored. The sample whose pH is required can then be introduced into the beaker, and the electrodes re-immersed. The stand may be rendered comparatively waterproof by two coats of polyurethane varnish.

STANDARDISING THE METER

To carry out the standardisation, an accurate source of potential is required. The classical approach is a Weston Standard Cell which in its commonest form consists of an H shaped glass tube, each limb of which houses a reference electrode, one positive and one negative, while the cross piece of the H forms a salt bridge connecting the two electrolytes. Connections are made by platinum wires sealed into the glass, the whole cell being sealed from the atmosphere. Its potential at 20°C is 1·0183± 0·0001 volts, and it has a negligible temperature coefficient. In the form described it is fragile and expensive.

A much smaller version exists, shaped like a large cartridge fuse which can be housed in a special holder, connections being made by the end caps. This cell is much less expensive than its glass counterpart, produces an identical voltage, and delivers a current which must not exceed ten micro-amps. One or other of these cells is often incorporated in commercial pH meters for carrying out standardisation.

For anyone seeking results of the highest possible accuracy, its use is recommended, but for our own purpose a cheaper alternative exists. The Mallory mercury cell will, after a short initial period of discharge, give a potential steady to within 0·01 volts on very light load.

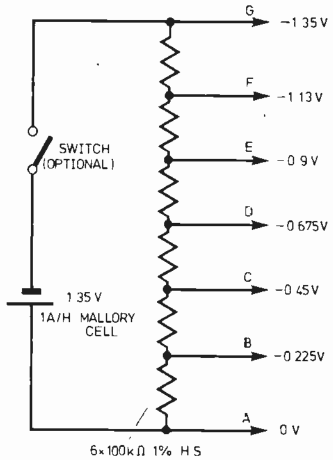


Fig. 7. Voltage reference source for standardising, using a Mallory PX1 cell

Type PX1 has a capacity of 1,000mA/hours, and a p.d. of 1·35 volts. When brand new the voltage is slightly above this figure, but on discharging it for twenty-four hours through a 1kΩ load, it steadies off at 1·35 volts.

This partially discharged cell, when connected into the potential divider illustrated in Fig. 7, serves admirably as a standard source of potentials for calibration purposes. The various voltages obtainable are accurate as long as the drain on the cell never exceeds about 12μA.

Table 1: METER CALIBRATION RESISTORS (100μA, 1kΩ movement) used on valve prototype

Range	Exact resistance
0–1 volt	13,750Ω
0–2 volt	28,800Ω
0–14pH	11,270Ω
0–10pH	7,420Ω
0–5pH	3,000Ω

RANGES

The prototype instrument was constructed with different ranges, partly as a challenge to ingenuity, and partly to exploit all the positions on the two-pole six-way rotary switch. The ranges are as follows: 0 to 5pH (or 5 to 10pH), 0 to 10pH, 0 to 13pH, OFF, 0 to 2 volts, 0 to 1 volt. This order was chosen to offer some sort of overload protection, since the two coarsest ranges are adjacent to the OFF position. By using one of the second set of poles on S2, the meter is arranged to be shorted out in the OFF position, which greatly reduces needle oscillation when the meter is moved. An alternative would be to bring out the meter leads to exterior terminals on the box, so that ME1 could be used as a simple micro-ammeter. When not in use the terminals could be linked across.

Since the current gain varies with components, no accurate values can be given for R8 through R12 since the exact resistance of ME1 is unknown. As a guide, the multiplier resistors used in the prototype using a Ferranti 0–100μA meter movement with 1kΩ resistance, are given in Table 1.

MILLIVOLT RANGES

For calibration of these ranges, across the appropriate contacts of S2 for the range concerned, place a preset potentiometer of approximately twice the resistance given for that range in Table 1. Move S1 to ZERO position and switch on the mains (power pack type). Then rotate S3 to the fully ON position, and allow five minutes for the instrument to warm up and stabilise. Set the preset to maximum resistance, and turn S2 to the 2,000mV range. Rotate VR1 until the meter reads zero, which ideally should be at centre position. If zero is found at an extreme setting, the relative values of R6 and R7 can be altered to correct this, but their sum value must remain the same.

Next connect the voltage source of Fig. 7 to inputs I1 and I2, observing polarity. Select −1·35 volts (output G), and switch S2 to the 2,000mV range. Zero ME1 again, then shift S1 to the read position. Adjust the preset in series with ME1 until the latter reads 67·5 micro-amps (i.e. 1/20th of 1,350mV). Return S1 to zero, and change the voltage source to −675mV (output D). With S1 back to read, check that ME1 reads 33·75 micro-amps. Slight divergence from this is most likely due to inaccuracies within the meter.

Now zero all switches, remove and measure the resistance of the preset, and using a series or parallel combination of standard fixed resistors, insert that resistance in place of the preset. That range will then be calibrated to the scale factor: micro-amps × 20 = millivolts.

Leaving R6 and R7 untouched, repeat the same steps to calibrate the 1,000mV range. Consult Table 1 for the preset value to be used, and set up using the voltage source outputs C, D, and E, relating these to the scale factor: micro-amps × 10 = mV.

With the instrument warmed up, drift should be small, but always zero the meter between operations.

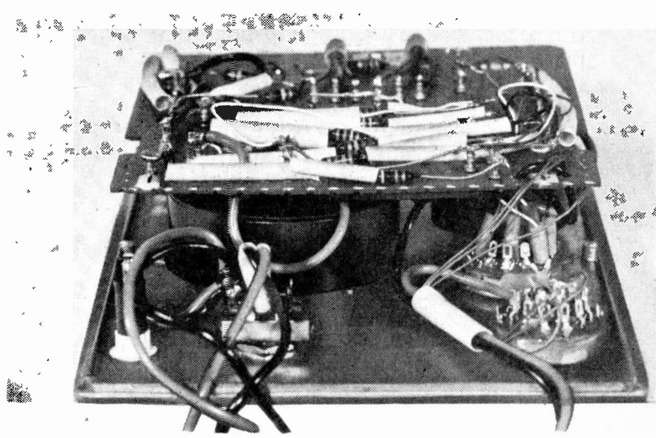
pH RANGES

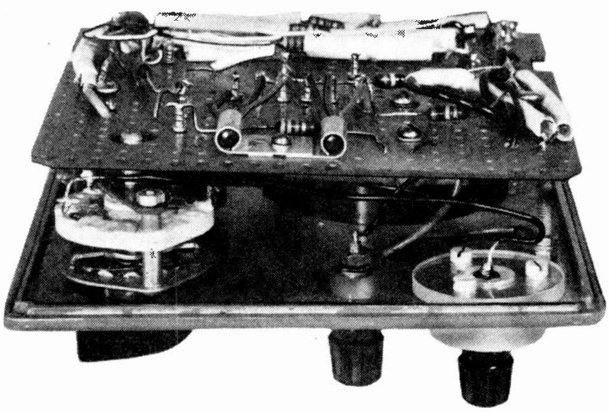
From the Nernst equation, the following data can be calculated:

At 25°C

1pH unit = 59·1mV
2pH ,, = 118·2mV
3pH ,, = 177·3mV
10pH ,, = 591·0mV

It is apparent that the relationship between electrolytic solution pressure (E.S.P. in mV) and pH is linear, all the E.S.P. voltages being direct multiples of 59·1mV.





The value of 1pH is temperature dependent; at 0°C it drops to 54·1mV, and at 30°C it rises to 60·1mV. Consequently pH measurement should be made at the original calibration temperature, which in our case is the above set of figures (25°C). Lower temperature values could be used, but the resistance of the glass electrode would increase sharply. More sophisticated commercial meters often have temperature compensation built in, but for this simple device the problem is resolved by always working at the convenient temperature of 25°C.

None of the exact pH voltages are obtainable from the reference voltage source, but since 10pH on the 10pH range should be 100 micro-amps for f.s.d., the equation:

$$\frac{225}{591} \times 100 = 38{\cdot}1\mu A$$

shows that output B (225mV) from the voltage source should read 38·1 micro-amps on the meter, which would be 3·81pH.

Similarly, for output C (450mV) of the voltage source:

$$\frac{450}{591} \times 100 = 76{\cdot}1\mu A\ (7{\cdot}61pH)$$

These two positions are nicely spaced for calibration, and it is only necessary to carry out the previously described procedure to find a suitable multiplier resistor to fix the scale at these two points.

Because of meter non-linearities, finding a series resistor giving the closest average result from **two** points on the scale, should minimise the chance of fixing calibration against a particularly bad deviation from ideal within the meter.

The range 0–14pH is rarely required by amateurs, but can be included as it is useful to quickly find the approximate pH of a sample before switching to a more convenient range. To utilise the maximum deflection of the meter on this range, assume that 98 micro-amps is f.s.d. instead of 100. This is divisible by 14 to give 7, so that 7 micro-amps is equal to 1pH unit, followed by multiples up to 98 micro-amps (14pH units).

As before, using voltage source B:

$$225mV \text{ must read } \frac{225}{59{\cdot}1} \times 7 = 26{\cdot}6\mu A\ (3{\cdot}8pH)$$

For the 0–5pH range, and by an artifice, the 5–10pH scale, proceed as for the 0–10pH scale, substituting 5pH units instead of 10pH, and modify the equation accordingly. For working between 5 and 10pH, the zero point has to be artificially offset to zero with a 5pH input level.

USING THE METER

The recommended basic operational procedure is as follows:

(1) Check that S1 is at zero, and S2 is off, along with S3.
(2) Earth the instrument (battery type), or plug in mains.
(3) Switch on mains (power pack type).
(4) Rotate S3 to fully on position (valve type).
(5) Allow five minutes to warm up (valve type).
(6) Observing polarity, connect in the source of potential to be measured.
(7) Select S2 range, or commence on highest range.
(8) Set meter to zero using VR1.
(9) Alter S1 to "Read".
(10) Take measurement.

When a different range is required always move S1 to zero, set S2 to the new range, zero meter, and finally move S1 to "Read" again.

To shut down:

(1) Set S1 to zero.
(2) Switch S2 off.
(3) Switch S3 off.
(4) Turn mains switch off.
(5) Remove source of potential.

For pH measurements, the glass and calomel electrodes are now used for the first time. The potential delivered by the glass electrode is produced by three separate elements: (a) the pH dependent voltage generated by the glass bulb, (b) the difference in potential generated where the silver chloride coated silver wire dips into the hydrochloric acid within the glass bulb and (c), a peculiar variable not fully understood, called the "asymmetric potential" which is of a few millivolts. The voltage generated by the inner wire is constant, but the asymmetric potential slowly varies, though it may be considered stable over the short period involved in taking measurements. Its origin is rather obscure, but may be related to discontinuities in the special glass where alkalis were removed during flame working, or to strains remaining after annealing. Although of small value, it is usual to allow for it if accurate work is contemplated.

PRECISION WORK

For precision work then, only the pH dependent voltage should be measured, and this is done using substances of known pH value, called "buffer solutions". Two such buffer solutions are used for most routine pH measurements, one to cover the range 0 to 7pH, and the other for the range 7 to 14pH. The acid range buffer (0–7) is a solution of potassium hydrogen phthalate, containing 10·12 grams per litre of the salt. At 25°C its pH is 4·01. The second buffer is a solution of sodium tetra-borate deca-hydrate (borax) used at a concentration of 3·8 grams per litre, and has a pH of 9·18 at 25°C. A litre bottle of each solution, together with saturated potassium chloride, make up part of the essential equipment for readers wishing to carry out pH measurements. The recommended technique for pH measurement is therefore as follows:

Carry out steps one to five of the operational procedure.

Immerse the glass and calomel electrodes in a suitable volume of the selected buffer, by raising the stand, removing the distilled water, and replacing by buffer solution.

Connect the electrodes to the input (glass negative and calomel positive).

Allow a minute or so for the glass electrode to come into equilibrium with the buffer.

Select a suitable pH range to cover the **sample** (not buffer) to be tested.

Set switch S2 accordingly.

Move S1 to "Read".

Using VR1, adjust the meter needle to the **value of the buffer** (not to zero).

Alter S1 to zero.

Remove the buffer solution and wash both electrodes with distilled water, and then immerse them in the **sample** whose pH is to be measured.

Follow steps nine and ten, after allowing a short time for the glass electrode to reach equilibrium.

After use, wash the electrodes and put them back in the distilled water in which they are kept. The small amount of buffer may be used again during a measuring session if it is not diluted by wash water, but **do not pour it back into the stock bottle.**

NOTE

Note that when measuring pH, the meter is never zeroed, and with S1 at zero, there is always a positive reading on the scale. Take note of this value, as it is the non pH dependent voltage, and may be restored if VR1 is accidentally moved during a session.

Buffer solutions left open will absorb atmospheric CO_2 (particularly borax) and alter slightly in value. Buffers should be sealed from air and stored in the dark.

POWER PACK

The circuit in Fig. 4 (last month) will provide 17 to 18 volts at about 50mA, and is recommended, as failing batteries when not checked will give rise to inaccurate results. The values of R1 and R2 are selected to maintain regulation during mains voltage variations, and produce a Zener diode current of four to five milliamps at nominal 240 volts a.c. input. On the prototype, the values of R1 and R2 were 20Ω and 290Ω respectively, and the output potential was 17·2 volts over mains variations from 215 to 255 volts.

SOIL

For soil pH measurement, accurate and comparable results are only obtained under certain prescribed conditions. For the official Ministry method, see Bulletin No. 209 "Fertilizer requirements" Appendix: Ministry of Agriculture, Food & Fisheries, available from H.M. Stationery Office.

Before testing, the soil is dried in an air oven at a fixed temperature. Then a definite amount is weighed out and mixed with the correct quantity of distilled water, and the electrodes inserted into the fine slurry obtained.

For field work, a mixture is made of 2½ volumes of soil to 1 volume of distilled water, and well stirred to produce a similar slurry. Results between the two methods vary by as much as ±0·2pH unit (sufficient to seriously affect the yield from a crop of barley!).

AQUARIUM WATERS

Measurement is best made by immersing the electrodes directly in the tank, avoiding air bubbles from the aerator. The pH of the water can then be adjusted while watching the meter. The small amount of KCl diffusing out of the calomel electrode during a test is insignificant. The temperature of the water will not be 25°C, but provided tests are carried out at the same temperature each time, results will be comparable.

Similar remarks apply to measurements made on nutrient solutions used in the water culture of plants (hydroponics), where acidity is very important.

PURE WATER AND BUFFERS

Wherever reference has been made to distilled water, the use of de-ionised water is equally good. Melted ice taken from the sides of a domestic deep freezer can be used, and is free from soluble salts, if not perhaps CO_2. If a large clean plastics container is filled with mains water, placed in a freezer, and occasionally stirred, the ice produced will be practically pure, provided some of the water remains unfrozen at the bottom. The product is quite suitable for making up buffer solutions.

Both phthalate and borate buffers can be purchased in the form of tablets and sachets containing definite weights of the chemical, which when dissolved in the correct quantity of water, will make a buffer solution.

AGEING

A glass electrode nearing the end of its life becomes sluggish, and often reads low at high pH levels. Check by buffering at 4·01 and 9·18. A very slow response, or a low reading at the second point suggests that a new electrode is needed.

Inorganic films on a glass electrode are best removed with hydrochloric acid (50% by volume), while grease is dealt with by clean soft tissue. Dehydrating solvents such as alcohol or acetone are not recommended, neither are household detergents or abrasives. Avoid using the glass electrode at temperatures above 50°C in solutions of high pH, since attack on the glass is accelerated.

OTHER USES FOR THE METER

Very small currents can be measured (down to 10^{-9} amp), by finding the voltage drop across a high resistance such as 1 megohm, through which the current is passing.

Potentials between dissimilar metals, a fertile source of corrosion, can be measured by connecting a lead to each metal, and moistening with water or weak brine.

Leaking capacitors can be detected or compared with a satisfactory component, by connecting them across the input, charging to, say, 1·5 volts, and finding the time required for the voltage to drop to half its initial value. Using a capacitor of low leakage characteristics will likewise give a check on the input resistance of the meter.

Another possibility is a pH controlled alarm, giving audible warning of pH rise or fall from some preset value. The use of a 741 i.c. as a voltage comparator is a method of doing this, and could give either blind control, or measurement and control together.

During the last ten years, new electrodes have been developed which are sensitive to ions other than hydrogen. These are fluoride, nitrate, sulphide, sodium and calcium. Using a specially adapted meter, these ions, some of which are difficult to determine chemically, could be measured using electrochemical methods.

However the instrument is employed, the inputs should be shorted together when not in use, to prevent any static charge accumulating. ★

TRANSIENT GENERATOR

By R. Gwinn

A LARGE number of acoustic musical instruments have an amplitude envelope which decays during the note, and it is the Transient Generator which synthesises this characteristic electronically. The basic envelope is illustrated in Fig. 1, and shows which components of the profile can be varied. As can be seen, first there is an attack up to a peak, then a decay down to a fixed sustain level, and then when the key is released there is a further decay to zero. The variable parameters are: *Attack* time, *initial decay* time, *sustain level*, and final *decay* time.

CIRCUIT DETAILS

The transient generator needs a TTL compatible input which is logical "1" when a key is depressed, and logical "0" when it is released. Referring to Fig. 2, IClc and ICld form an edge-triggered latch, which is set via C1 and can be reset via either C2 or TR1. When a key is pressed, the latch is set, and the output of IC1c goes high. TR2 and TR3 turn on, and C3 begins to charge via R6 and VR1, which controls the *attack* rate. The voltage on C3 goes to the emitter follower TR7, which provides a low impedance at the output on VR5.

This rising voltage is fed back via R3 to TR1, and when it gets to its peak of about 5 volts, TR1 passes enough current to reset the latch. This turns off the attack part of the circuit, and IC1b output goes to logical "0". TR6 turns off and TR5 turns on, causing C3 to discharge via R9 and VR3, the *initial decay* time control. This continues until C3 is at the same voltage as the wiper of VR4, setting the *sustain level*. The circuit remains stable in this state until the key is released. The output of IC1a goes high causing TR4 to turn on. Then C3 discharges to earth via R8 and VR2, the final *decay* control.

If the key is released before the *attack* and *initial decay* cycle has finished, the latch is reset by C2, and the circuit goes straight into the *decay* part of the envelope.

A Veroboard layout suitable for this circuit is shown in Fig. 3, which also includes the Keyboard Trigger circuitry of Fig. 5, overleaf.

COMPONENTS . . .

Resistors

R1	39kΩ	R8	100Ω
R2	15kΩ	R9	100Ω
R3	100kΩ	R10	18kΩ
R4	220Ω	R11	10kΩ
R5	3·3kΩ	R12	10kΩ
R6	100Ω	R13	1·8kΩ
R7	10kΩ	R14	470Ω ½W

All resistors are ⅛W 5% unless otherwise stated

Potentiometers

VR1	1MΩ log	VR4	1kΩ lin
VR2	1MΩ log	VR5	10kΩ lin
VR3	100kΩ log		

Capacitors

C1 0·047μF
C2 0·047μF
C3 10μF 15V elect.

Semiconductors

TR1, TR2, TR4, TR5, TR6 and TR7 BC108
TR3 BC158
IC1 SN7400
D1 5·1V 400mW Zener

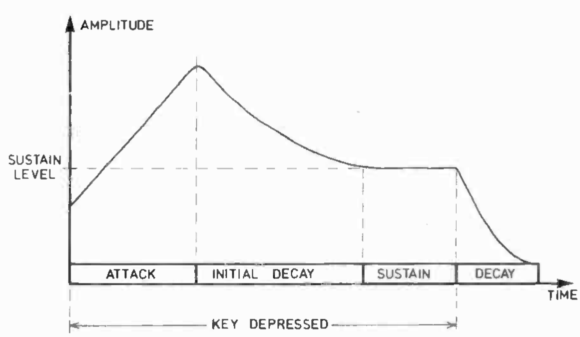


Fig. 1. The Transient Generator amplitude envelope

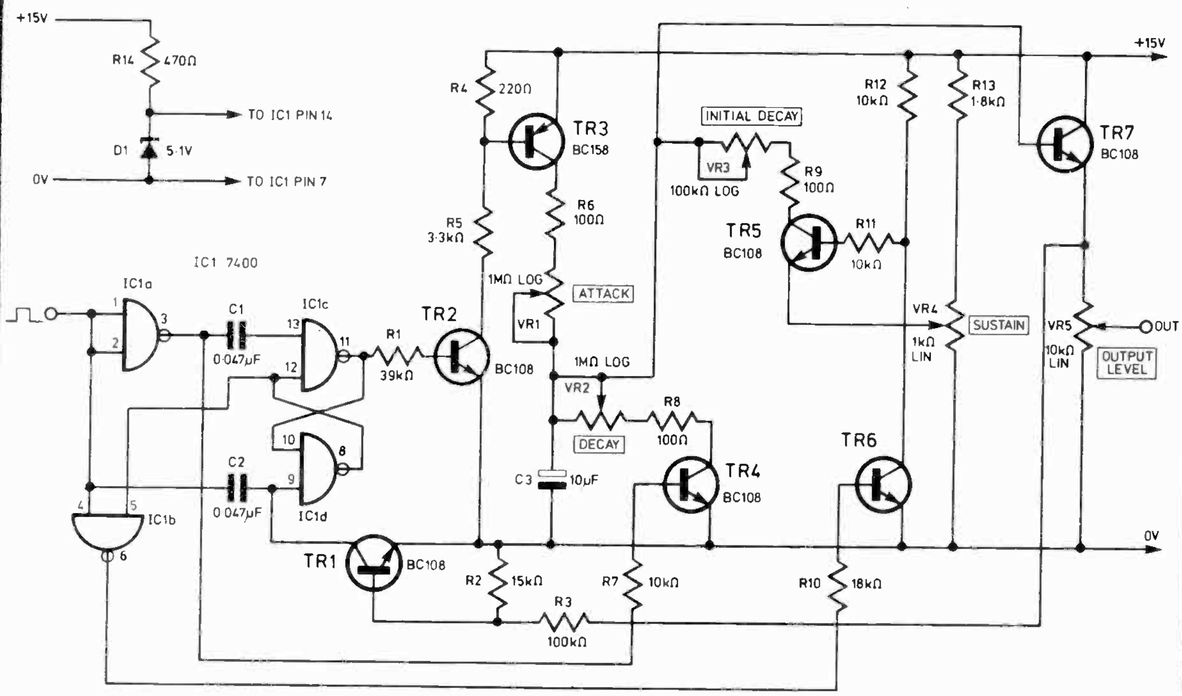


Fig. 2. Circuit diagram of the Transient Generator

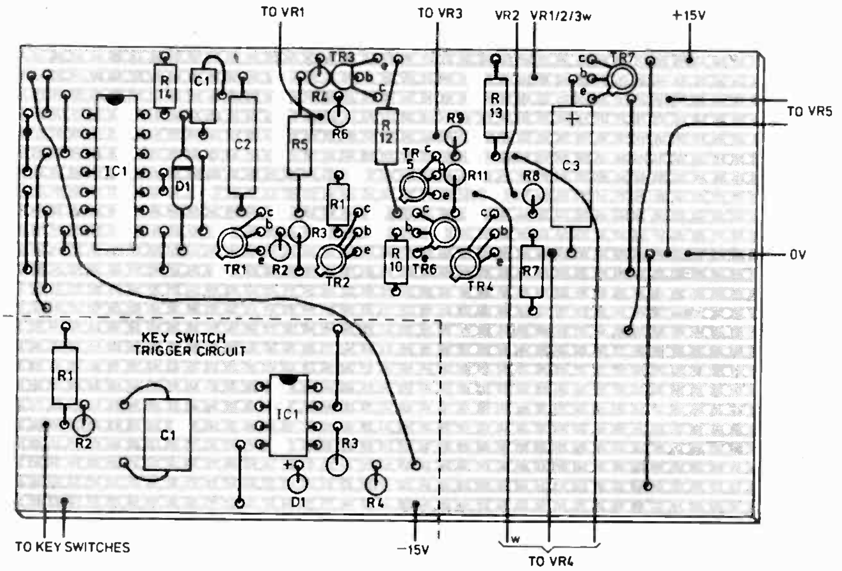


Fig. 3. Veroboard layout suitable for the Transient Generator and also the Key Switch Trigger circuit shown in Fig. 5

TRIGGER CIRCUIT

If the transient generator is being interfaced with an existing synthesiser, a trigger circuit such as the one shown in Fig. 4 should be used. The preset should be set to a voltage in between the voltages corresponding to "key up" and "key down", so that the comparator changes state to follow the input.

This circuit is wired for an input which has the "key down" voltage higher than the "key up". If the reverse is true, the inputs (pins 2 and 3) to the operational amplifier should be swopped over.

DIRECT KEYBOARD TRIGGERING

Keyboard switches can give considerable contact bounce problems, and a circuit giving immunity to this is shown in Fig. 5. R2 and C1 form a low-pass filter which reduces the switch-bounce voltages, and feeds the signal to IC1 which is wired as a Schmitt Trigger with a hysteresis of 28 volts. Using this circuit therefore, the transient generator could be run directly from a keyboard.

REPEAT EFFECT

The digital signal from either of these trigger circuits need not go straight to the transient generator. If it is put through an AND gate with an oscillator providing the other input, a repeat effect can be produced. A string of envelopes repeating at the frequency of the oscillator can be gated in by the keyboard. In imitating a mandolin for example, a short *decay* down to zero *sustain level* would be set up on the transient generator, and an oscillator frequency of about 5Hz would be used. A suitable repeat oscillator is shown in Fig. 6.

APPLICATION

The transient generator provides a voltage which is used to alter various parameters in a synthesiser. It was decided that this was more versatile than including a V.C.A. in the module. In its quiescent state, the output is at zero volts, and goes positive when triggered. The envelope generated during its operational cycle is then used to patch into a V.C.A. or V.C.F.

One transient generator, with a filter and, say, two oscillators, is perfectly adequate for a simple synthesiser. A bank of these units, however, with each set to control a different aspect of the note, would be extremely useful in a large system. ★

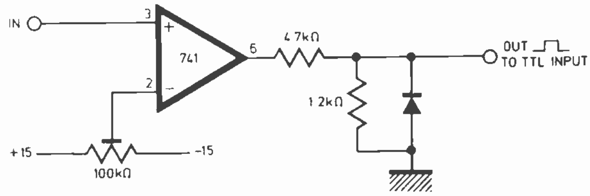


Fig. 4

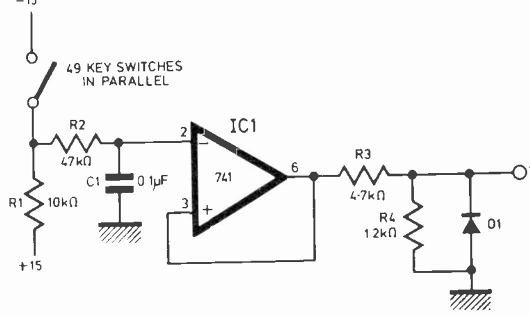


Fig. 5

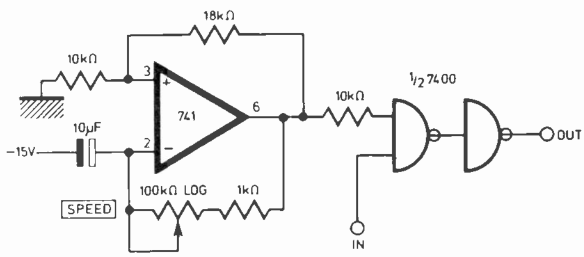


Fig. 6

NEWS BRIEFS

Alex Marshall

ALEXANDER Marshall, founder of A. Marshall (London) Ltd. died on Saturday, February 5, following a short illness. The new owner of this retail and trade component business is the wife of the deceased, Mrs J. L. Marshall. The existing management team remain.

The sad news of Alex Marshall's death (received just as this issue was going to press) was a shock, more especially because of the amicable relationship that had grown up between his firm and this magazine over the past 10 years.

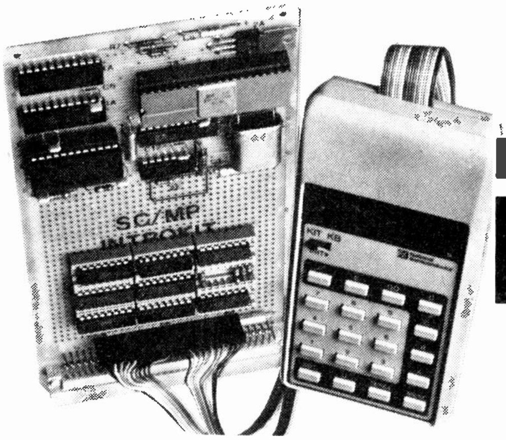
The firm was established in Cricklewood, London in the late 50's. Alex's business acumen was shown in the subsequent expansion of his business as evidenced by the increase in size of advertisements in P.E. from 1 column inch in February 1967 to whole pages in later years, reflecting the wide range of components stocked. The opening of additional shops in Glasgow, Bristol and Paris was part of this success story in the component supply business. Constructors have cause to be grateful to Alex for the high standard of service he instituted.

Recently Marshall's had been closely associated with P.E. in organising the Microprocessor Competition and Forum. Alex's tremendous personal enthusiasm for both projects and his bountiful gesture in providing prizes set an example and gave great encouragement to his co-sponsors, National Semiconductor and P.E. That he would not be there on February 26 to present the prizes was something we have never of course contemplated. Somehow it seems most unfair.

Our commiserations go to Mrs Marshall and family and to all members of the staff of their company in their tragic loss.

The genial countenance and radiating charm of this friendly Glaswegian will be greatly missed.

—*F.E.B.*



Programming a MICROPROCESSOR

By D. B. Johnson-Davies

With the arrival of low-cost development kits, the microprocessor is no longer just a pipe dream as far as the amateur is concerned. Last month the construction of one such kit was described: the National Semiconductor SC/MP Kit, and the following article explains in detail how to write and run simple programs which do what would otherwise require complex circuits of discrete components. The principles covered apply to any microprocessor, but the examples are specifically for the SC/MP and the article concludes with a program for a millisecond reaction timer.

THE heart of the microcomputer is the Central Processing Unit—CPU. In the SC/MP kit this is in a single 40-pin package, and costs on its own as little as £5 in quantity. The CPU has been called a "Highly Obedient Moron"—it slavishly fetches instructions, interprets them, and obeys them; this three-stage process being repeated over and over again. The CPU is in no sense intelligent, and it takes an intelligent programmer to make it appear to behave intelligently.

BINARY NOTATION

The instructions tell the CPU to perform certain operations on numbers, or data. Since the CPU is built out of logic circuits operating only with binary numbers it requires instructions and data to be presented in this form; therefore it is important to understand the concept of binary notation.

In decimal notation we seem to get by with using just the ten digits 0—9 for representing numbers as large as we please. This is achieved by giving the digits different values according to the column in which they occur; a 9 in the third column from the right in fact means 9×10^2.

Similarly in binary notation the two digits 0 and 1 can be used to represent any number, each *bit* (short for Binary Digit) denoting the absence or presence of a different power of two. Thus 1100_2 (the suffix 2 denoting binary notation) represents from right to left:

$$0\times2^0+0\times2^1+1\times2^2+1\times2^3=12_{10}$$

However strange binary may seem, reflect that 12_{10} cannot be said to be any nearer to reality (e.g. twelve objects) than can 1100_2; they are each just notations.

HEXADECIMAL

Binary numbers are so awkward to remember and use that it is often more convenient to put them into *hex* (short for hexadecimal) notation in which sixteen digits are used:

Decimal:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Hex:	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F

By grouping the digits of a binary number into fours (from the right) and converting each group into a single hex digit, the hex equivalent is instantly obtained. For example $11000100_2=C4_{16}$. Do not be put off by numbers such as DEAD! Unless otherwise stated, all numbers in this article will be in hex notation. Remember though that however the programmer chooses to represent them, the CPU deals only in *bits*.

Thus instructions and data are each just one or more 8-bit (2 hex digit) binary numbers. Each instruction corresponds to a different number; for example C4

OPCODE INDEX OF INSTRUCTIONS

Opcode	Mnemonic	Assembler Format	Operation
00	HALT		Pulse H-flag
01	XAE		Exchange AC and Extension
02	CCL		Clear Carry/Link
03	SCL		Set Carry/Link
04	DINT		Disable Interrupts
05	IEN		Enable Interrupts
06	CSA		Copy Status to AC
07	CAS		Copy AC to Status
08	NOP		No Operation
19	SIO		Serial Input/Output
1C	SR		Shift Right
1D	SRL		Shift Right with CY/L
1E	RR		Rotate Right
1F	RRL		Rotate Right with CY/L
30	XPAL	ptr	Exchange Pointer Low
34	XPAH	ptr	Exchange Pointer High
3C	XPPC	ptr	Exchange Pointer with PC
40	LDE		Load from Extension
50	ANE		AND Extension
58	ORE		OR Extension
60	XRE		Exclusive-OR Extension
68	DAE		Decimal Add Extension
70	ADE		Add Extension
78	CAE		Complement and Add Extension
8F	DLY	disp	Delay
90	JMP	disp(ptr)	Jump
94	JP	disp(ptr)	Jump If Positive
98	JZ	disp(ptr)	Jump If Zero
9C	JNZ	disp(ptr)	Jump If Not Zero
A8	ILD	disp(ptr)	Increment and Load
B8	DLD	disp(ptr)	Decrement and Load
C0	LD	@disp(ptr)	Load
C4	LDI	data	Load Immediate
C8	ST	@disp(ptr)	Store
D0	AND	@disp(ptr)	AND
D4	ANI	data	AND Immediate
D8	OR	@disp(ptr)	OR
DC	ORI	data	OR Immediate
E0	XOR	@disp(ptr)	Exclusive OR
E4	XRI	data	Exclusive-OR Immediate
E8	DAD	@disp(ptr)	Decimal Add
EC	DAI	data	Decimal Add Immediate
F0	ADD	@disp(ptr)	Add
F4	ADI	data	Add Immediate
F8	CAD	@disp(ptr)	Complement and Add
FC	CAI	data	Complement and Add Immediate

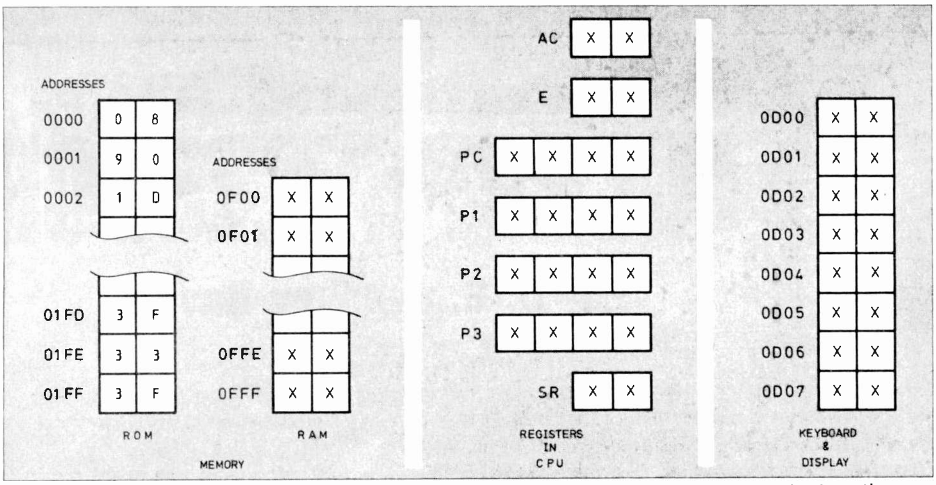


Fig. 1. Conceptual block-diagram of the main parts of the SC/MP Kit. Each memory location holds 2 hex digits and is specified by an address of 4 hex digits. The RAM can be loaded with any values, denoted by "X", but the ROM has fixed contents. The seven registers are for temporarily holding data and addresses in the CPU. The keyboard and display are interfaced as if they were 8 memory locations

means "load the accumulator", the accumulator being a register for temporarily storing one 8-bit number. The data to be loaded is taken as the next 8-bit number; thus the instruction C4, 8F will load the accumulator with 10001111_2.

In the SC/MP CPU all instructions are either one or two 8-bit numbers long. Encountered in a different context though, 8F might be interpreted differently; for example as the instruction, it represents "delay". *Instructions and data are indistinguishable so the only way the CPU knows what to do is by the context.*

The CPU is no use without a memory to contain the sequence of instructions to be obeyed—the program and the data.

The OPCODE INDEX OF INSTRUCTIONS (previous page) is reproduced from the SC/MP Instruction Guide.

MEMORY

The memory can be thought of as containing a number of *locations*, each capable of holding two hex digits (8 bits). The size of binary number around which the memory of a particular computer is organized is termed the *word*, and the SC/MP resembles most other microcomputers in having an 8-bit word (large computers commonly have 32-bit words). Each location of memory can be specified by a unique address, which is four hex digits; i.e. it can lie between 0000 and FFFF. The CPU can therefore address up to 65536_{10} words of memory. The word contained in a particular location is called the *contents* of that address.

Two types of memory are provided in the SC/MP kit: a ROM (Read Only Memory), and a Read/Write memory commonly called RAM (Random Access Memory) though strictly this is a misnomer. The ROM provided has 0200 locations ($=512_{10}$) with addresses 0000 to 01FF; see Fig. 1. This has fixed contents—the Keyboard Kit Program, which enables the user to modify the contents of any address in the RAM or to begin execution of a program there. The RAM provided occupies locations 0F00 to 0FFF, a total of 0100 ($=256_{10}$), and these can be both written to and read from by the CPU. The RAM is used for one's own programs and data.

WRITING A PROGRAM

Having constructed a microprocessor kit, the owner may feel rather helpless since it is difficult to see what is going on inside it. Most instructions give unremarkable results, and it is necessary to go back and examine the memory or a register to see the effect. One instruction in the SC/MP Instruction Set is, however, ideal for experimentation; the delay instruction 8F.

All the other instructions take from 5 to 22 *microcycles* to be executed, where a microcycle is 2 microseconds with the 1MHz crystal supplied in the kit. The delay instruction can be programmed to take from 13 to 131593 microcycles depending on the value in the second word and, to a lesser extent, the contents of the accumulator. The longest delay is obtained when the second word and the accumulator both contain FF. Here is a sample program:

Address:	Contents:	Comment:
0F20	C4	Load AC with:
0F21	FF	$+255_{10}$
0F22	8F	Delay with:
0F23	FF	$+255_{10}$
0F24	3F	Exchange P3 and PC

The last instruction, 3F, causes a jump back into the Keyboard Kit Program. The above program is executed by pressing *GO*, entering the start address 0F20, then pressing *TERM* to execute. The display will go blank for the duration of the delay; about one third of a second.

THE REGISTERS

The SC/MP CPU contains seven different registers which can be used by the programmer, four of these holding two words and the other three holding a single word; see Fig. 1. These registers can be loaded with numbers by the relevant instructions, and each has a different role to play in the operation of the CPU. Most other makes of microprocessor have at least these registers, or close equivalents.

The most important register is the *accumulator*, or AC, which holds one word. In all, 37 of the 46 instructions of the SC/MP use the AC. Instructions are available to perform the following operations where the data can either be *immediate* (i.e. given in the second word), or else contained in a location specified in some way by the second word (see below):

- Load AC with data
- AND AC with data
- OR AC with data
- Exclusive-OR with data
- Add AC to data
- Decimal add AC to data
- Add AC to complement of data

} Result in AC

Instructions are also provided to exchange the AC with other registers, shift the contents of AC, and so on.

The *extension* register also holds one word, but is less versatile than the AC. It can be specified as the data for the instructions listed above. The *status* register contains the carry bit, and five bits controlled by or controlling the logic levels or corresponding pins on the microprocessor package.

THE PROGRAM COUNTER

The *program counter* or PC contains the two-word address of the instruction currently being or about to be executed. This automatically gets incremented after each instruction so that the instructions are read and executed in serial order. Sometimes it may be necessary

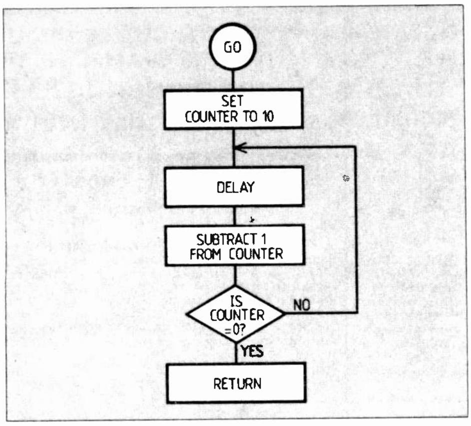


Fig. 2. Flowchart illustrating how a loop can extend the delay provided by the "delay" instruction. By convention, in flowcharts squares denote operations and diamonds decisions

to overrule this and jump to a different address. This is achieved by adding a number to the PC; for example:

Address:	Contents:	Comment:
0F24	90	Jump by:
0F25	FE	−2

The jump instruction 90 adds the number in the next word, the *displacement* or *disp*., to the PC. Since it is useful to be able to have negative jumps (as in this example) as well as positive ones, the disp. is interpreted by the CPU as what is called a *twos-complement* binary number. In this notation the leftmost bit is interpreted as a sign bit; if "1" the number is negative; if "0" it is positive. The 8 bits can then be used to represent the numbers from -128_{10} to $+127_{10}$ as follows:

Binary:	Hex:	Decimal:
10000000	80	−128
......	...	....
11111111	FF	−1
00000000	00	0
00000001	01	+1
......	...	....
01111111	7F	+127

One way of looking at it is that FE is −2 in this notation since FE+2=00 (ignoring the carry). Thus in the above program the instruction executed after 0F25 is not 0F26 but 0F26 −2 =0F24 again. The program thus loops interminably and as such is fairly useless. The most useful jump instructions are those which only cause a jump if a certain condition is satisfied, such as "jump if AC=0".

KEYBOARD KIT PROGRAM

The ROM supplied with the SC/MP kit interprets which key has been pressed, displays the address and contents entered, and loads new data into the RAM. It also enables one to jump to a location and begin execution there. Without this program there would be no way of writing programs into the memory; but it also serves other useful functions. When the Keyboard Kit Program is first entered, say by executing the "exchange P3 with PC" instruction at the end of a program, it conveniently saves the contents of the registers in the top 7 words of the RAM before using the registers itself. Similarly before executing one's own program following the *GO* command it loads the registers with the values from these locations. The locations are assigned as follows:

Address:		Contents:
0FF9	P1H	Higher word of P1
0FFA	P1L	Lower word of P1
0FFB	P2H	Higher word of P2
0FFC	P2L	Lower word of P2
0FFD	AC	Accumulator
0FFE	E	Extension register
0FFF	SR	Status register

Note that P3 is not included since this contains the return address to the Keyboard Kit Program, and so will not be used by one's own programs. The instruction "exchange P3 with PC" can be used to force a jump to the Keyboard Kit Program from the middle of one's own program by exchanging it temporarily for one of the instructions. The contents of the registers just before that point can then be discovered by examining the relevant memory locations.

ADDRESSING MEMORY

Suppose that a certain program needs to add 07 to a number at a certain address, say 0F60. There is no way of doing this in a single instruction; instead the AC must be loaded with the contents of 0F60, 07 added, and the AC stored back to 0F60—three instructions. How then can one specify the location required? The obvious way would be to give the full address in the two words after the instruction: YZ, 0F, 60, where YZ stands for the assumed "load" instruction.

Unfortunately *Direct Memory Addressing*, as this is called, is not available on the SC/MP (unlike the Intel 8080 or Motorola 6800). Instead *Indexed Addressing* is used; the address is specified relative to the PC or one of the three two-word pointer registers P1, P2, and P3 (see Fig. 1). The second word of the instruction is treated as a displacement to be interpreted as a twos-complement binary number and added to the pointer register specified in the instruction, giving the *effective address* of the data. Using the PC this program can be written:

Address:	Contents:	Comment:
0F20	C0	Load AC from PC+
0F21	3F	Disp.
0F22	F4	Add to AC:
0F23	07	Data
0F24	C8	Store from AC to PC+
0F25	3B	Disp.
0F26	3F	Exchange P3 with PC

Notice that 0F21+3F=0F60 and 0F25+3B=0F60 so the load and store instructions both address the required location.

By using instead one of the three pointer registers, addresses at greater displacements from the current instruction than -128_{10} to $+127_{10}$ can be specified. If all the data for a program were stored from 0F50 to 0F70, one of the pointer registers—say P2—could be loaded with 0F50 and these locations referred to as P2+0, P2+1, etc. P2 is said to point to the area of memory containing the data. Using P2 the program becomes:

Address:	Contents:	Comment:
0F20	C2	Load AC from P2+
0F21	10	Disp.
0F22	F4	Add to AC:
0F23	07	Data
0F24	CA	Store from AC to P2+
0F25	10	Disp.
0F26	3F	Exchange P3 with PC
....	..	
0FFB	0F	Sets P2H
0FFC	50	Sets P2L

The contents of 0FFB and 0FFC will, as explained earlier, be loaded into P2 by the Keyboard Kit Program. In this example the displacement is the same since the contents of P2 do not change.

LOOPS

The delay instruction has already been used to give a short delay, and several such instructions placed in series will of course give proportionately longer delays. A better way is to use a loop as shown in the flowchart of Fig. 2. This will multiply the delay by 10 ($=16_{10}$) giving just over 4 seconds. Location 0F29 is used to count the number of iterations, and a conditional jump causes a return to the Keyboard Kit Program when this reaches 00. This must be set to 10 before re-running the program:

Address:	Contents:	Comment:
0F20	C4	Load AC with:
0F21	FF	Data

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AC128	18*	BCY71	15	MJE341	68
AC176	19*	BCY72	15	MJE2955	140
AC187	19*	BD106	140	MJE3055	110
AC188	19*	BD131	40*	MPF102	30
AD149	50*	BD132	40*	OA47	30
AD161	45*	BD133	42*	OA90	9
AD162	45*	BD135	38	OA91	9
AF114	25*	BD136	50	OA200	10
AF115	25*	BD137	38	OA202	10
AF116	25*	BD138	40	OC28	75
AF117	25*	BD139	40*	OC35	50
AF118	45	BD140	42*	OC44	18
AF239	65	BD181	145	OC45	16
BA127	11	BD240	70	OC71	15
BA145	16	BD241	70	OC171	30
BA148	16	BD242	75	OCP71	75
BA200	10	BF167	24*	TIL77	78
BAY61	25	BF173	24*	TIL78	78
BB103	45*	BF178	30*	TIP31A	50*
BB104	60*	BF179	30*	TIP32A	55*
BB105	37*	BF180	35*	TIP41A	60
BB106	55*	BF181	35*	TIP42A	70
BB109	49*	BF182	35	TIP40	330
BB110	45*	BF183	30	TIP141	365
BB113	345*	BF185	45	TIP142	435
BC107	10	BF194	10*	TIP145	380
BC107b	13	BF195	10*	TIP146	415
BC108	10	BF196	10*	TIP147	495
BC108b	13	BF197	10*	TIS43	30
BC109	10	BF198	12	ZTX107	10
BC109c	15	BF199	13	ZTX108	10
BC139	27	BF200	30	ZTX109	10
BC140	42	BF225	32	ZTX300	10
BC141	25	BF244	30	ZTX500	15
BC142	25	BF245	30	1N914	5
BC143	25	BF254	30	1N4001	5
BC147	9*	BF255	30	1N4002	5
BC148	9*	BF262	40	1N4003	6
BC149	9*	BF458	57	1N4004	6
BC157	10*	BF494	35	1N4005	6
BC158	10*	BF495	40	1N4006	7
BC159	10*	BFX29	28	1N4007	7
BC160	33	BFX30	28	1N4148	5
BC161	33	BFX34	140	1N5401	13
BC177	15	BFX41	45	1N5404	16
BC178	15	BFX84	27	1N5408	23
BC179	15	BFX85	27	2N1613	20
BC182L	12*	BFX86	27	2N2218	48
BC183L	12*	BFX87	38	2N2219	30
BC184L	12*	BFX88	27	2N2646	55
BC186	25	BFX89	87	2N2904	24
BC187	25	BFY50	16	2N2905	24
BC212L	12*	BFY51	16	2N2926B	10*
BC213L	12*	BFY52	16	2N2926R	10*
BC214L	12*	BFY90	75	2N2926O	10*
BC237	17	BP101	85	2N2926Y	10*
BC238	17	BPW34	260	2N2926G	10*
BC239	17	BR100	20	2N2053	16
BC261	20	BR101	30	2N3054	45
BC262	20	BRY39	40	2N3055	50
BC307	16	BRY56	50	2N3391	16
BC317	15	BSX21	45	2N3702	14
BC337	15	BSY89	165	2N3704	30
BC338	15	BU108	250*	2N3705	15
BC461	40	BY103	36	2N3708	28
BC462	40	BY127	10	2N3819	25
BC516	60	BY164	70	2N3820	45
BC517	65	BY187	90	2N3823	40
BC546	45	BYX10	30	2N3905	15
BC547	9	BYX36	4	2N5397	58
BC547b	14	BYX94	6	2N5458	130
BC548	12*	E100	40	2N5461	50
BC549	12*	E300	45	2N6027	32
BC556	45	E310	60	40603	80
BB557	15	E420	140	40673	85

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CAPACITORS ELECTROLYTIC

µF	6 3V	10V	16V	25V	35V	63V
0 47						8*
1 0						8*
2 2					8*	8*
3 3					8*	9*
4 7				8*	9*	9*
10			8*	8*	9*	12*
22	8*	8*	8*	9*	11*	15*
33	8*	9*	9*	11*	12*	16*
47	9*	9*	10*	12*	15*	22*
100	10*	12*	12*	16*	20*	36*
150			15*			
220	12*	14*	16*	21*	27*	50*
330	15*	17*	18*	24*	33*	70*
470	16*	19*	21*	31*	39*	90*
1000	21*	24*	33*	46*	72*	110*
2200	33*	40*	52*	79*	122*	150*
4700	42*	54*	97*	120*	150*	185*

RESISTORS

potentiometers: single gang have nylon shaft.

	1K	5K	10K	25K	50K	100K	250K	500K	1M	1M	
Single gang	log and lin									log	30p*
Single gang and DPST	log		log and lin			log					50p*
Tandem	log and lin					log					90p*
Tandem and DPST		N/A					log			N/A	95p*

FIXED

Carbon Film	0·5W	5%	E12	2R2 to 10 M	2*
Wire Wound	2·5W	5%	E24	0·22 R to 270 R	20
Metal Film	0·4W	1%	E96	4R99 to 100 K	25
Metal Oxide	0 5W	2%	E24	10 R to 1 M	6
Wire Wound	17W	5%	EG	1 RO to 47 OR	30

Resistance wire 5 ohms/metre, rated at 2 A, for low inductance high wattage resistors 5/cm

Negative temperature coeficient. Resistance at 25° C.

150R	20	1K	33
4K7	33	10K	33
22K	33	47K	33

Sub miniature preset 0·1W E12 47 R to 2·2 M fits 0 1" pitchboard 10*

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7404	16	7453	16	74145	70
7405	16	7454	16	74147	130
7406	30	7460	16	74148	130
7407	39	7470	30	74150	150
7408	18	7472	28	74151	75
7409	22	7473	28	74153	80
7410	18	7474	28	74154	135
7411	24	7475	47	74155	80
7412	26	7476	30	74156	80
7413	30	7480	45	74157	80
7414	70	7481	100	74160	100
7415	34	7482	85	74161	100
7416	32	7483	100	74162	100
7417	30	7484	120	74163	100
7420	16	7485	120	74164	120
7421	40	7486	34	74165	120
7422	20	7489	290	74166	120
7423	36	7490	39	74174	120
7424	30	7491	70	74175	80
7425	30	7492	45	74177	90
7426	24	7493	45	74180	90
7427	28	7494	80	74181	300
7428	40	7495	70	74182	84
7430	16	7496	75	74185	140
7432	27	74100	100	74189	320
7437	27	74107	35	74190	150
7438	27	74109	65	74191	150
7439	27	74110	50	74192	110
7440	16	74118	85	74193	110
7441	68	74121	32	74195	100
7442	68	74122	50	74196	160
7443	100	74123	70	74197	160
7444	100	74125	40	74198	250
7445	100	74126	70	74199	210
7446	100	74128	45		

CMOS

4000	21	4013	60	4040	106
4001	21	4015	93	4049	55
4002	23	4016	63	4050	50
4007	21	4017	93	4061	21
4008	95	4020	120	4069	25
4009	70	4023	21	4081	21
4010	66	4024	85	4093	80
4011	21	4025	21	4528	117
4012	21	4026	200		

ICS

AY-1-0202	master generator	16 dil	830*
CA3080	OTA	TO5	90
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CA3090AQ	decoder	14 dil	520
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HA2405	Quad opamp	16 dil	1600
ICM7038A	clock time base	8 dil	470
L129	5V regulator	TO220	125
L130	12V regulator	TO220	125
L131	15V regulator	TO220	125
LM301AN	opamp	8 dil	65
LM308N	opamp	8 dil	130
LM309K	5V regulator	TO3	180
LM317K	adjust reg.	TO3	385
LM311H	voltage comparator	TO5	245
LM318N	opamp	14 dil	385
LM324N	quad opamp	14 dil	245
LM325H	15V regulator	TO5	340
LM326H	12V regulator	TO5	340
LM327H	+5 −12V regulator	TO5	340
LM380N	audio amp	14 dil	140*
LM318N	dual audio pre amp	14 dil	220*
LM555N	timer	8 dil	50
LM556N	dual timer	14 dil	140
LM566CN	vco	14 dil	170
LM703LH	rf amp TO5	8 dil	100
LM709CN	opamp	8 dil	50
LM723CH	voltage regulator	TO5	55
LM723CN	voltage reg.	14 dil	75
LM740	fet input opamp	TO5	620
LM741CN	opamp	8 dil	30
LM748CN	opamp	8 dil	90
LM1812N	ultrasonic transceiver		800
LM3900N	quad norton amp	14 dil	90
LM3909N	led flasher	8 dil	90
LX5700	temperature transducer	TO46	410
M252	rhythm generator	16 dil	950*
M253	rhythm generator	24 dil	1350*
MC1310P	decoder	14 dil	220*
MC1312P	matrix SQ	14 dil	250*
MC1314P	vca SQ	16 dil	400*
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MC1468L	dual regulator	14 dil	420
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MC14553P	3 digit counter		640
MC14566P	time base		230
MM5314N	clock	24 dil	450
MM5316N	clock	40 dil	550
MM5318	clock		660
MM5841N	TV display driver	28 dil	1200*
MM74C14	hex trigger	14 dil	200
RG194YC	dual regulator		870
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SN76013N	audio	16 dil	150*
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SO41P	mixer	14 dil	195
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TAA131	opamp		140
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TCA740	DC tone		490
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0... 50µA	0... 1mA
0...100µA	0... 5mA
0...500µA	0... 10mA
50 0 50µA	0... 50mA
100 0 100µA	0...100mA
500 0 500µA	0...500mA

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0... 30µA	0... 50µA
0... 100µA	0... 200µA
0...500µA	

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THYRISTORS AND TRIACS

THYRISTORS

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6A 400V TO220	125
16A 400V TO220	350

DIAC

ER 900 28 32V	36
BR 100	20

TRIACS 400V insulated tab TO220

4 amp	50p	8 amp	80p
6 amp	60p	10 amp	90p

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6VA 235 20VA 435

Secondary Volts	Secondary Current 6VA Style	20VA Style
2 × 4·5V	2 × 0·6A	2 × 2·2A
2 × 6V	2 × 0·5A	2 × 1·6A
2 × 12V	2 × 0·25A	2 × 0·8A
2 × 15V	2 × 0·2A	2 × 0·6A
2 × 20V	2 × 0·15A	2 × 0·5A

Subminiature transformers

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Back copies of Elektor and Elektor EPS circuit boards available at published prices. Prices valid to 31st March 1977.

BARCLAYCARD

0F22	8F	Delay with:
0F23	FF	Data
0F24	B8	Decrement & load AC
0F25	04	from PC + Disp.
0F26	9C	Jump if AC≠0 by:
0F27	F8	−8
0F28	3F	Exchange P3 with PC
0F29	10	Loop counter

The instruction at 0F24, B8, decrements the number at the specified location and loads the AC with the result. By changing the loop counter initial value delays of up to 67 seconds can be obtained.

SOUNDS

Unlikely as it may sound, an ordinary transistor radio is a useful tool for the microprocessor programmer. Consider what happens on running the following program:

Address:	Contents:	Comment:
0F30	8F	Delay with:
0F31	FF	Data
0F32	90	Jump by:
0F33	FC	−4

The program can never exit from the loop, each time jumping back to 0F30. On beginning execution at 0F30 the keyboard display will go blank and nothing ostensibly happens. Now place the transistor radio near to the circuit board and turn it on. A click of about 3Hz will be heard corresponding to each jump, due to radiation by the circuit's power supply lines. By decreasing the delay parameter at 0F31 a higher pitch may be obtained; for example, 06 gives a note near middle C. More complex programs have been devised to play tunes, and below is a program that generates a note which rises in pitch more and more rapidly; it is left to the reader to work out how!

Address:	Contents:	Comment:
0F20	C4	Load AC with:
0F21	00	0
0F22	8F	Delay with:
0F23	01	1
0F24	B8	Decrement & load AC from PC+
0F25	0B	+0B
0F26	9C	Jump if AC≠0 by:
0F27	F8	−8
0F28	B8	Decrement & load AC from PC +
0F29	F8	−8
0F2A	9C	Jump if AC≠0 by:
0F2B	F6	−0A
0F2C	B8	Decrement & load AC from PC +
0F2D	F6	−0A
0F2E	90	Jump by:
0F2F	F0	−10
0F30	00	Loop counter

Although crude, this method of listening to a computer is a useful one; in fact in the early days of computers the radio was a standard piece of fault-tracing gear. For more serious music synthesis the flag outputs on the microprocessor can be fed to the input of an audio amplifier; these outputs are controlled by loading the status register with suitable numbers.

DISPLAY INTERFACE

The keyboard and display look to the CPU just like a row of eight consecutive memory locations, 0D00 0D07; see Fig. 1. To illuminate a digit, a binary number is stored in the location corresponding to that digit (0D00 is the rightmost digit). Each of the lower seven bits of the number controls the illumination of one of the segments of the display digit; when set to "1" the segment is lit, "0" not lit. The lowest bit controls the "a" segment through to the highest but one which controls the "g" segment.

In this way any combination of the seven segments, not only the numerals, may be formed. Only one display is illuminated at a time. The following program illustrates how this works by generating a character moving along the displays and changing as it goes:

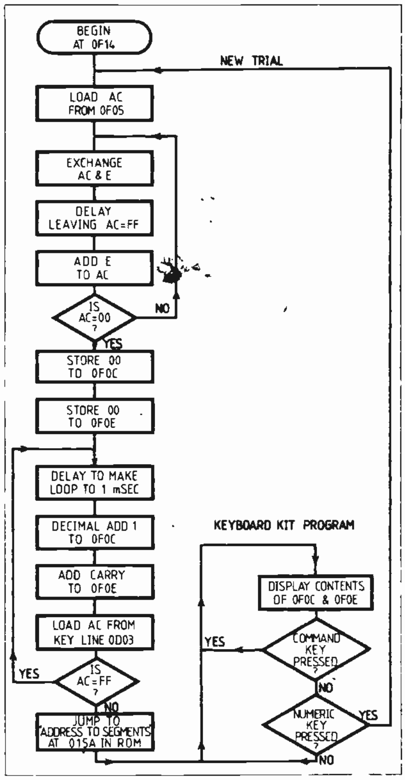

Fig. 3. Flowchart for the millisecond reaction timer program, which consists of three basic parts: the random delay, the millisecond counter, and the display section

Address:	Contents:	Comment:
0F20	8F	Delay with:
0F21	40	Data
0F22	A8	Increment & load AC from PC +
0F23	02	+2
0F24	C9	Store AC to P1 +
0F25	00	Counter
0F26	90	Jump by:
0F27	F8	−8
....	...	
0FF9	0D	Sets P1H
0FFA	00	Sets P1L

On entering the program the Keyboard Kit Program puts 0D00, the first display address, into P1. The displacement at 0F25 selects one of the eight displays, and the character is illuminated by the store instruction at 0F24.

THE DISPLAY ROUTINE

One part of the Keyboard Kit Program, the Display Routine, reads the data in locations 0F00 to 0F07 of the RAM and uses these to light up the eight display digits in the way just described. This routine cycles repeatedly through the eight displays, giving an apparently continuous display, until a key-press is detected. Then the routine jumps either to the address in P3 (if a command key was pressed) or to P3+2 (if a number key was pressed).

Since this part of the ROM is written as a subroutine, one's own programs can use it to display the results of calculations, interpret key-presses etc. It assumes that P2 points to the first digit code, normally 0F00, and it takes the eight words as the eight digit codes. By altering the value in the P2 register before entering the Display Routine, eight codes stored at a different starting address can be displayed.

The exercise in the SC/MP Keyboard Kit Users' Manual demonstrates this; on jumping to 0185 (the start of the

Display Routine) the codes previously entered in locations 0F20 to 0F27 cause "did good" to be displayed.

Another useful part of the Keyboard Kit Program, Address to Segments, takes the two words in P2+0C and P2+0E and generates the four segment codes for the four hex digits in them. The final program given below uses this, which starts at 015A, to display the reaction time.

REACTION TIMER

The following program measures reaction times to the nearest millisecond, using one of the keys on the keyboard as the response button. After an unpredictable delay of between 2 and 30 seconds a segment lights up on the display. At this instant the program starts counting in milliseconds until the subject presses the "MEM" key. Then the reaction time is displayed (in decimal) as four digits on the display. Pressing the "0" key resets the program for another attempt. The flowchart of Fig. 3 should make the operation clear. ★

Reaction Timer Program

Address:	Contents:	Comment:
0F14	C2	Load AC from P2 +
0F15	05	Disp.
0F16	01	Exchange AC and E
0F17	8F	Delay with:
0F18	A0	Data
0F19	02	Clear carry bit
0F1A	70	Add E to AC
0F1B	9E	Jump if AC≠0 to P2 +
0F1C	15	Disp.
0F1D	C4	Load AC with:
0F1E	00	Data
0F1F	CA	Store AC to P2 +
0F20	0C	Disp.
0F21	CA	Store AC to P2 +
0F22	0E	Data
0F23	C4	Load AC with:
0F24	A5	Data
0F25	8F	Delay with:
0F26	00	Data
0F27	02	Clear carry bit
0F28	C2	Load AC from P2 +
0F29	0C	Displ.
0F2A	EC	Decimal add to AC:
0F2B	01	Data
0F2C	CA	Store AC to P2 +
0F2D	0C	Disp.
0F2E	C2	Load AC from P2 +
0F2F	0E	Disp.
0F30	EC	Decimal add to AC:
0F31	00	0 (and carry bit)
0F32	CA	Store AC to P2 +
0F33	0E	Disp.
0F34	C1	Load AC from P1 +
0F35	03	Disp.
0F36	F4	Add to AC:
0F37	01	+1
0F38	9A	Jump if AC≠0 to P2 +
0F39	22	Disp.
0F3A	C4	Load AC with:
0F3B	01	Data
0F3C	37	Exchange AC and P3H
0F3D	C4	Load AC with:
0F3E	59	Data
0F3F	33	Exchange AC and P3L
0F40	3F	Exchange P3 and PC
0F41	92	Jump to P2 +
0F42	39	Disp.
0F43	92	Jump to P2 +
0F44	13	Disp.
....	..	
0FF9	0D	Sets P1H
		Display & keyboard
0FFA	00	Sets P1L
0FFB		Sets P2H
		RAM
0FFC	00	Sets P2L

NEWS BRIEFS

Microprocessors at Seminex '77

At this year's Seminex London symposium, from April 18 to 22, special attention is being given to the developments in microprocessors.

Held in the main theatre of the Imperial College, three of the five days symposium will be devoted to six sessions (two each day) on various aspects of microprocessors. These sessions have been composed in association with SERT and are designed to attract delegates on a one, two or three day basis.

The microprocessor programme runs from April 19 to 21 and its contents are as follows:

Day One—*Introduction, Some Microprocessor Systems*; Day Two—*System Development and Design Aids, Latest Developments in Design*; Day Three—*High Performance Applications, Using the Microprocessor*.

Other subjects being covered during the symposium are: Digital I.C.s (7 papers), Linear I.C.s (8 papers), Hybrids and Optoelectronics (6 papers) and Power Semiconductors (7 papers).

Further details and procedure for obtaining tickets to the Seminex '77 London Symposium can be obtained from Seminex Ltd., 2 Old Stone Link, Ship Street, East Grinstead, Sussex, RH19 4EF.

POINTS ARISING

CINE/TAPE SYNCHRONISER *(October 1976)*

It has been brought to our attention that the motors fitted to some types of cine projector are not capable of being started on load. Constructors should therefore check that their projectors are suitable before using the Auto Start circuit.

GAMES MACHINE *(December 1976)*

In Fig. 3, page 971, the pin connections for the plastics encapsulated uA7805 are shown incorrectly. Pins 2 and 3 should be transposed. Pin 1 is correct as shown.

CAR EXHAUST MONITOR *(January 1977)*

We understand that some readers have been experiencing difficulty in obtaining the gas detector type TGS 308. This device can be obtained from Trampus Electronics Ltd., 58-60 Grove Road, Windsor, Berks. SL4 1HS. *(See advertisement on page 70 of the same issue).*

SOLAR HEATING SYSTEM CONTROLLER *(February 1977)*

The system shown in Fig. 1 is intended only to show the general principles of solar water heating. A practical system requires a number of additional features, such as expansion and header tanks.

A list of solar heating manufacturers and installation consultants is published by the International Solar Energy Society (UK Division), Royal Institution, 21 Albemarle Street, London W1.

In Fig. 4, the track fourth from the top of the board should be deleted, and the three tracks above it (and their connections) moved down by one space.

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2N698	0·62	2N3705	0·15	40362	0·48	BC160	0·50	BD131	0·51	BFX88	0·40
2N699	0·55	2N3706	0·16	40363	1·20	BC161	0·50	BD132	0·54	BFX89	1·25
2N706	0·24	2N3707	0·18	40406	0·58	BC167	0·12	BD135	0·37	BFY50	0·34
2N706A	0·12	2N3708	0·16	40407	0·45	BC168	0·12	BD136	0·37	BFY51	0·38
2N708	0·21	2N3709	0·18	40408	0·65	BC169	0·12	BD137	0·35	BFY52	0·36
2N709	0·50	2N3710	0·16	40409	0·65	BC170	0·16	BD138	0·38	BFY53	0·34
2N718	0·27	2N3711	0·18	40410	0·65	BC171	0·16	BD139	0·40	BFY90	1·37
2N718A	0·30	2N3712	1·20	40411	2·85	BC172	0·12	BD140	0·40	BRY39	0·50
2N720A	0·80	2N3713	2·30	40594	0·75	BC177	0·20	BD239	0·40	BSX20	0·31
2N914	0·35	2N3714	2·45	40595	0·85	BC178	0·20	BD240	0·45	BSX21	0·32
2N916	0·30	2N3715	2·55	40673	0·73	BC179	0·23	BD241	0·45	BU105	1·50
2N918	0·38	2N3716	2·80	AC126	0·37	BC182	0·11	BD242	0·47	BU205	2·[illegible]
2N929	0·25	2N3771	1·85	AC127	0·44	BC182L	0·14	BD243	0·60	MEO402	0·20
2N930	0·26	2N3772	2·00	AC128	0·37	BC183	0·11	BD244	0·62	MEO404	0·15
2N1131	0·60	2N3773	2·90	AC151V	0·35	BC183L	0·14	BD245	0·65	MEO412	0·20
2N1132	0·60	2N3789	2·90	AC152V	0·50	BC184	0·12	BD246	0·66	ME4102	0·10
2N1613	0·35	2N3790	3·10	AC153	0·49	BC184L	0·14	BD529	0·42	ME4104	0·10
2N1711	0·37	2N3791	3·10	AC153K	0·35	BC207	0·12	BD530	0·47	MJ480	1·35
2N1893	0·38	2N3792	3·50	AC176	0·40	BC208	0·11	BDY20	1·13	MJ481	1·55
2N2102	0·60	2N3794	0·20	AC176K	0·60	BC212	0·14	BF115	0·38	MJ490	1·35
2N2218	0·33	2N3819	0·36	AC187K	0·55	BC212L	0·17	BF117	0·70	MJ491	1·85
2N2218A	0·37	2N3820	0·38	AC188K	0·55	BC213	0·14	BF121	0·55	MJ2955	1·25
2N2219	0·30	2N3823	0·75	AD161	0·85	BC213L	0·16	BF123	0·55	MJE340	0·58
2N2219A	0·32	2N3904	0·21	AD162	0·85	BC214	0·16	BF152	0·25	MJE370	0·58
2N2220	0·35	2N3906	0·22	AF106	0·55	BC214L	0·17	BF153	0·25	MJE371	0·60
2N2221	0·22	2N4036	0·67	AF109	0·75	BC237	0·17	BF154	0·25	MJE520	0·45
2N2221A	0·26	2N4037	0·55	AF124	0·65	BC238	0·17	BF159	0·35	MJE521	0·65
2N2222	0·25	2N4058	0·20	AF125	0·65	BC239	0·16	BF160	0·30	MJE2955	1·40
2N2222A	0·25	2N4059	0·20	AF126	0·65	BC251	0·15	BF161	0·60	MJE3055	0·85
2N2368	0·25	2N4060	0·20	AF127	0·65	BC253	0·22	BF166	0·40	MP8111	0·35
2N2369	0·25	2N4061	0·17	AF139	0·69	BC257A	0·17	BF167	0·38	MP8112	0·40
2N2369A	0·29	2N4062	0·18	AF186	0·50	BC258A	0·17	BF173	0·38	MP8113	0·45
2N2646	0·75	2N4126	0·17	AF200	0·70	BC259B	0·18	BF177	0·30	MPF102	0·30
2N2647	1·40	2N4289	0·20	AF239	0·74	BC261A	0·21	BF178	0·35	MPSA05	0·23
2N2904	0·36	2N4919	0·65	AF240	0·98	BC262B	0·19	BF179	0·35	MPSA06	0·24
2N2904A	0·37	2N4920	0·70	AF279	0·84	BC263C	0·30	BF180	0·40	MPSA12	0·35
2N2905	0·37	2N4921	0·50	AF280	0·85	BC300	0·45	BF181	0·40	MPSA55	0·24
2N2905A	0·38	2N4922	0·53	BC107	0·15	BC301	0·45	BF182	0·45	MPSA56	0·24
2N2906	0·28	2N4923	0·70	BC108	0·15	BC303	0·60	BF183	0·45	MPSU05	0·50
2N2906A	0·25	2N5190	0·60	BC109	0·15	BC307	0·20	BF184	0·38	MPSU06	0·56
2N2907	0·21	2N5191	0·70	BC113	0·17	BC308	0·18	BF185	0·30	MPSU55	0·55
2N2907A	0·22	2N5192	0·75	BC115	0·19	BC309C	0·25	BF194	0·14	MPSU56	0·60
2N2924	0·15	2N5195	0·90	BC116	0·19	BC317	0·14	BF195	0·13	TIP29A	0·45
2N2925	0·17	2N5245	0·35	BC116A	0·20	BC318	0·13	BF196	0·14	TIP29C	0·60
2N3019	0·55	2N5294	0·40	BC117	0·22	BC327	0·20	BF197	0·17	TIP30A	0·49
2N3053	0·30	2N5295	0·40	BC118	0·16	BC328	0·19	BF198	0·18	TIP30C	0·65
2N3054	0·60	2N5296	0·40	BC119	0·30	BC337	0·19	BF200	0·35	TIP31A	0·50
2N3055	0·70	2N5298	0·40	BC121	0·45	BC338	0·21	BF225J	0·25	TIP31C	0·66
2N3390	0·25	2N5447	0·15	BC132	0·30	BC547	0·12	BF244	0·35	TIP32A	0·50
2N3391	0·25	2N5448	0·15	BC134	0·15	BC548	0·13	BF245	0·34	TIP32C	0·75
2N3391A	0·25	2N5449	0·19	BC135	0·15	BC549	0·13	BF246	0·75	TIP33A	0·80
2N3392	0·16	2N5457	0·32	BC136	0·19	BCY30	1·03	BF254	0·24	TIP33C	1·10
2N3393	0·15	2N5458	0·33	BC137	0·14	BCY31	1·06	BF255	0·24	TIP34A	0·90
2N3394	0·15	2N5459	0·29	BC140	0·40	BCY32	1·70	BF257	0·37	TIP34C	1·20
2N3439	0·88	2N5484	0·34	BC141	0·45	BCY33	1·00	BF258	0·45	TIP35A	2·50
2N3440	0·64	2N5486	0·38	BC142	0·30	BCY34	1·20	BF259	0·49	TIP36A	3·35
2N3441	0·85	2N6027	0·53	BC143	0·30	BCY38	2·00	BF459	0·45	TIP41A	0·70
2N3442	1·35	2N6101	0·65	BC147	0·12	BCY42	0·60	BFR39	0·28	TIP41C	0·85
2N3638	0·16	2N6107	0·42	BC148	0·12	BCY58	0·25	BFS21A	2·60	TIP42A	0·80
2N3638A	0·16	2N6109	0·42	BC149	0·13	BCY59	0·25	BFS28	1·04	TIP42C	0·95
2N3639	0·30	2N6121	0·38	BC153	0·27	BCY70	0·25	BFS61	0·30	TIP2955	0·65
2N3641	0·20	2N6122	0·41	BC154	0·27	BCY71	0·26	BFS98	0·27	TIP3055	0·55
2N3702	0·17	2N6123	0·43	BC157	0·12	BCY72	0·24	BFX29	0·38	TIS43	0·30

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CA3030	1·24	LM3401	0·70	TAA621	2·15
CA3030A	1·89	LM3900	0·75	TAA661A	1·32
CA3045	1·40	LM3905	1·60	TAA661B	1·32
CA3046	0·89	LM3909	0·68	TAA700	3·91
CA3048	2·23	MC1035	1·75	TAA930A	1·00
CA3049	1·66	MC1303	1·47	TAA930B	1·05
CA3052	1·62	MC1304	1·85	TAD100	1·95
CA3053	0·60	MC1305	1·85	TBA120	0·65
CA3080	0·6[illegible]	MC1306	1·00	TBA400	1·50
CA3080A	1·88	MC1310	1·91	TBA500	2·21
CA3086	0·51	MC1312	1·98	TBA500Q	2·30
CA3088	1·59	MC1327	1·54	TBA510	2·21
CA3089	2·52	MC1330	0·92	TBA510Q	2·30
CA3090	3·80	MC1350	0·75	TBA520	2·21
CA3130	0·94	MC1351	1·20	TBA520Q	2·30
LM301A	0·65	MC1352	0·97	TBA530	1·98
LM301N	0·44	MC1357	1·45	TBA530Q	2·07
LM304	2·45	MC1458	0·91	TBA540	2·21
LM307N	0·65	NE555	0·53	TBA540Q	2·30
LM308C	1·82	NE556	1·05	TBA550	3·13
LM308N	1·17	NE565	1·30	TBA550Q	3·22
LM309K	2·10	NE566	1·65	TBA560Q	3·22
LM317K	3·00	NE567	1·80	TBA570	1·29
LM318N	2·25	SAS560		TBA570Q	1·38
LM323K	6·40	SAS570		TBA641B	2·50
LM339N	1·75	S042P		TBA651	1·80
LM348N	1·91	76001N	1·57	TBA700	1·52
LM360N	2·75	76003N	2·55	TBA700Q	1·61
LM370N	3·00	76008K	2·50	TBA720Q	2·30
LM371N	2·25	76013N	1·70	TBA750	1·98
LM372N	2·15	76013ND	1·57	TBA750Q	2·07
LM373N	2·25	76018K	2·50	TBA800	1·20
LM374N	2·25	76023N	1·70	TBA810	1·16
LM377N	1·75	76023ND	1·57	TBA820	1·05
LM378N	2·25	76033N	2·55	TBA920	1·79
LM379S	3·95	76110N	1·46	TBA920Q	2·99
LM380-8	0·90	76115N	1·87	TBA940	1·62
LM380N	0·98	76116N	2·06	TCA160C	1·85
LM381A	2·45	76131N	1·30	TCA160B	1·61
LM381N	1·60	76226N	1·94	TCA270	2·25
LM382N	1·25	76227N	1·51	TCA280A	1·30
LM384N	1·45	76228N	1·75	TCA290A	3·13
LM386N	0·80	76530N	0·91	TCA420A	1·84
LM387N	1·05	76532N	1·50	TCA730	3·22
LM388N	1·00	76533N	1·30	TCA740	2·76
LM389N	1·00	76544N	1·44	TCA750	2·30
LM702C	0·75	76545N	2·09	TCA760	1·38
LM709C	0·65	76546N	1·44	TCA800	3·13
LM709N	0·45	76550N	0·41	UAA170	2·00
LM710C	0·60	76552N	0·65	UAA180	2·00
LM710N	0·60	76570N	2·08		
LM723C	0·85	76620N	1·10	DIL	
LM723N	0·75	76650N	1·10	SOCKETS	
LM741C	0·65	76660N	0·50	8 PIN	0·15
LM741N	0·50	76666N	0·92	14 PIN	0·16
LM741-8	0·40	TAA310A	1·50	16 PIN	0·18
LM747N	0·90	TAA320A	1·15	22 PIN	0·30
LM748-8	0·50	TAA350A	2·48	24 PIN	0·35
LM748N	0·50	TAA521	1·00	28 PIN	0·45
LM1800	1·76	TAA522	1·90	40 PIN	0·55

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CD4009	0·57	CD4024	0·79	CD4049	0·56
CD4010	0·57	CD4025	0·20	CD4050	0·56
CD4011	0·20	CD4027	0·56	CD4510	1·54
CD4012	0·20	CD4028	0·91	CD4511	1·54
CD4013	0·57	CD4029	1·17	CD4516	1·40
CD4014	1·01	CD4030	0·57	CD4518	1·25
CD4015	1·01	CD4031	2·26	CD4520	1·25
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SN7404	0·26	SN7420	0·21	SN7446	0·96	SN7474	0·33	SN7491	0·77	SN74122	0·54	SN74164	0·98	SN74197	3·90
SN7405	0·26	SN7423	0·30	SN7447	0·89	SN7475	0·46	SN7492	0·49	SN74123	0·48	SN74165	0·98	SN74198	0·90
SN7406	0·59	SN7425	0·30	SN7448	0·89	SN7476	0·39	SN7493	0·49	SN74141	0·80	SN74167	4·20	SN74199	2·28
SN7407	0·59	SN7427	0·30	SN7450	0·21	SN7480	0·55	SN7494	0·85	SN74145	0·83	SN74174	0·98	SN76003N	2·28
SN7408	0·22	SN7430	0·21	SN7451	0·21	SN7481	1·25	SN7495	0·61	SN74150	1·66	SN74175	0·98	SN76013N	1·90
SN7409	0·22	SN7432	0·20	SN7453	0·21	SN7482	0·77	SN7496	0·88	SN74151	0·85	SN74176	0·98	SN76023N	1·91
SN7410	0·21	SN7437	0·43	SN7454	0·21	SN7483	1·04	SN74100	1·23	SN74153	0·85	SN74180	2·96	SN76033N	2·50

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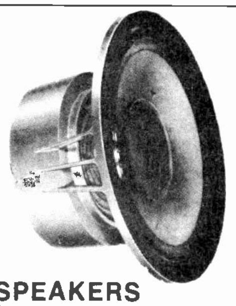

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4042	90p
4043	100p
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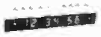
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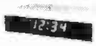
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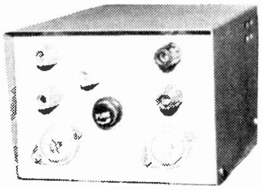

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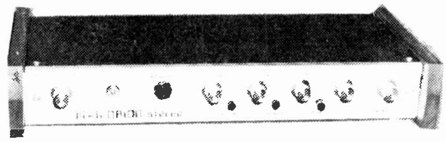

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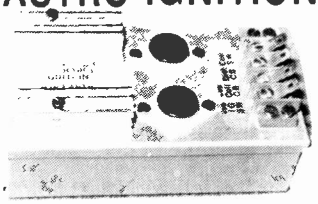

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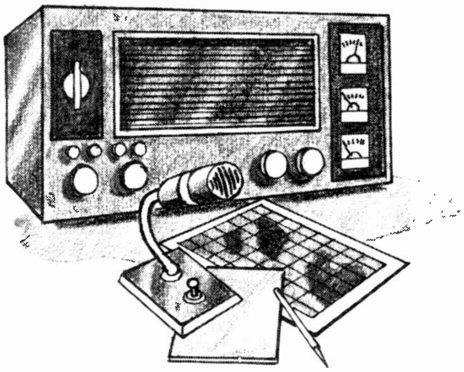

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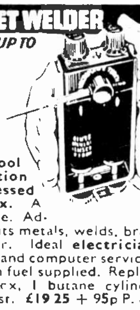

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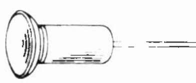

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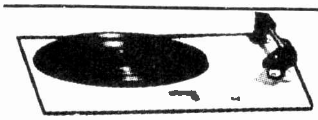

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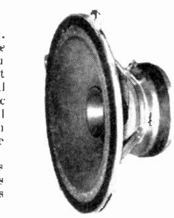

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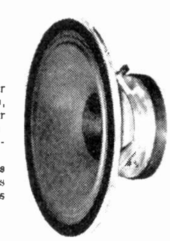

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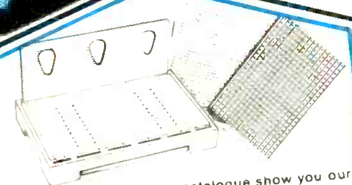

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