ISSN 0142-7229

electronics today

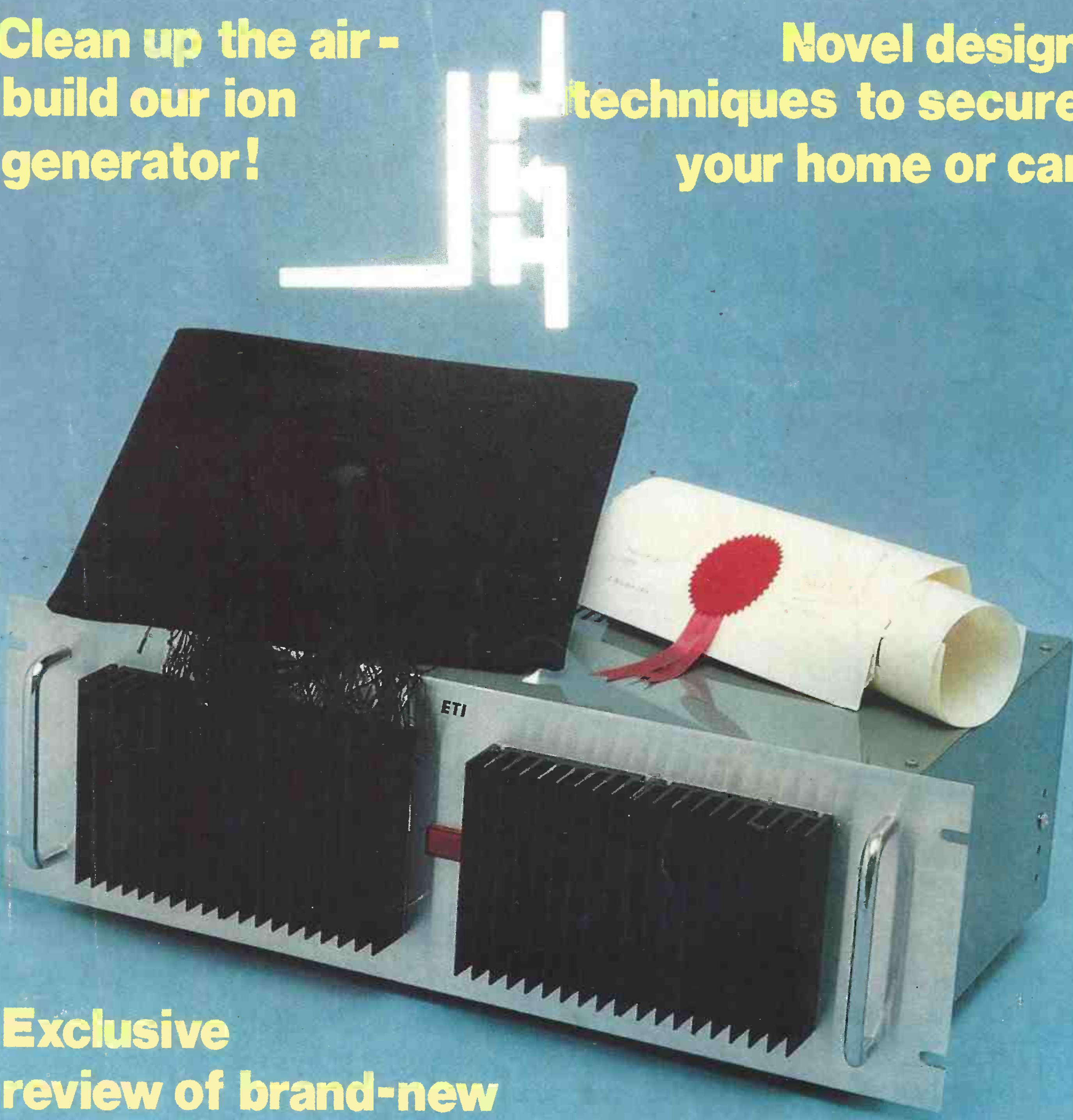
INTERNATIONAL JUNE 1982 75p

MOSFETS MAKE THE GRADE!

Brilliant new design for peak performance

Clean up the air - build our ion generator!

Novel design techniques to secure your home or car



Exclusive review of brand-new breadboarding system

...AUDIO....COMPUTING....MUSIC....RADIO....ROBOTICS.

POWER PACKED — by POWERTRAN

Powertran's black boxes are packed with punch. Not only are they superb kits to buy and build they really do the job! Imaginative and ingenious design goes hand in hand with top quality materials and outstanding performance capability. With their smart black styling the kits harmonise visually as well as musically.
Your can built each unit independantly for its set task and then gradually increase your array until you have a complete bank of formidable controllable power.

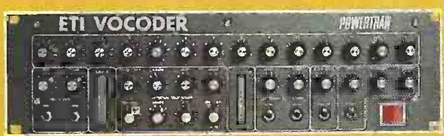
THE FIRST WORDS AND THE LAST WORD IN ELECTRONIC KITS — SEE INSIDE BACK COVER OF THIS ISSUE!

Complete Kit — **£49.90** + VAT

MPA 200 is a low price, high power 100W amplifier. Its smart styling, professional appearance and performance, make it one of our most popular designs. With adaptable inputs the mixer accepts a variety of sources yet straightforward construction makes it ideal for the first-time builder.

Complete Kit — **£49.50** + VAT

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



Complete Kit — **£175.00** + VAT

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

Complete Kit — **£64.90** + VAT

SP2 200 twice the power with two of the reliable, durable and economic amps from the MPA200; fed by separate power supplies from a common toroidal transformer. Superb finish and quality components throughout — up to (even over!) the standard of high priced factory-built units.

DJ90 Stereo Mixer — this is a really versatile new mixer that enables the constructor DJ to produce a professional performance every time. There are two stereo inputs for magnetic cartridges, a stereo auxiliary input and mike input. Other 'plus' features are auto-panning for fast or slow, slider controls, multi-mixing, ducking, interrupt, input modulation, in short everything. . . the whole works — AND — under £100 complete! (We have illustrated the DJ90 teamed in our own console with the Chromatheque and an SP2 200 and speakers.

Complete Kit — **£97.50** + VAT

Digital Delay Line — our latest kit! With its ability to give delay times from 1.6 mSecs to up to 1.6 secs. Many powerful effects including phasing, flanging, A.D.T., chorus, echo & vibrato are obtained. The basic kit is extended in 400 mS steps up to 1.6 secs. Simply by adding more parts to the PCB. Compare with units costing over £1,000! Complete kit (400 mS delay) **£130** + VAT. Parts for extra 400 mS delay £9.50p.

. . . . Quite simply the best way to make music

POWERTRAN

WORLD LEADERS IN ELECTRONIC KITS

- **Money Back Guarantee** — If you are not completely satisfied with your Powertran Kit return it in original condition within 10 days for full refund.
- **Free Soldering Practice Kit** — To assist the beginner we will supply, on request with your first kit order, a free soldering practice kit with useful tips and illustrations.
- **Component Packs** — Most kits are available as separate packs (e.g. PCB component sets, hardware sets etc). Prices in our FREE catalogue.
- **Ordering** — Full ordering details, delivery service, and sales counter opening — outside back of this issue.

PORTWAY INDUSTRIAL ESTATE, ANDOVER, HANTS SP10 3NM. (0264) 64455.

ORDER BY PHONE (0264) 64455
Simply telephone us with your order and quote your Access or Barclaycard number
82 CATALOGUE FREE—CONTAINS FULL DETAILS OF ALL OUR KITS

electronics today INTERNATIONAL

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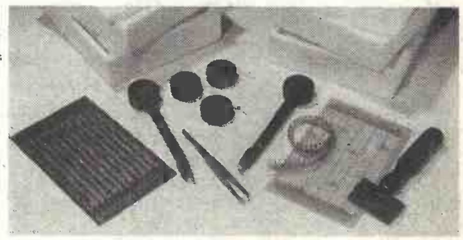
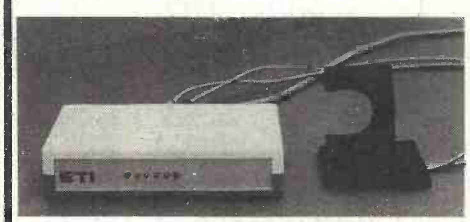
FEATURES



PROJECTS



INFORMATION

SWITCHES

TOGGLE: 2A, 250V.

SPST	33p
DPDT	44p

SUB-MIN TOGGLE

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

SLIDE 250V:

DPDT 1A	14p
DPDT 1A c/off	15p
DPDT 1/2A	13p

PUSHBUTTON 6A with 10mm Button

SPDT latching	99p
DPDT latching	145p
SPDT moment	99p
DPDT moment	145p

Mini Non Locking

Push to Make	15p
Push to Break	25p

DIL SWITCHES

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

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

ROTARY: Mains DP 250V 4 Amp on/off **56p**

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

WAFERS: (make before break) to fit the above switch mechanism. 1 pole/12 way; 2 pole/6 way; 3 pole/4 way; 4 pole/3 way; 6p/2 way **56p**
Mains DP 4A Switch to fit **45p**
Spacers 4p. Screen 6p

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

VEROBOARD 0.1in

	clad	plain
2½ × 3¼"	73p	52p
2½ × 5"	83p	–
3¾ × 3¾"	83p	–
3¾ × 5"	95p	79p
3¾ × 17"	326p	211p
4¾ × 17"	426p	
Pkt. of 100 pins	50p	
Spot face cutter	118p	
Pin insertion tool	162p	

VQ Board	175
DIP Board	386
Vero Strip	144

PROTO DECs

Veroblock	375p
S Dec	350p
Eurobreadboard	520p
Bimboard 1	575p
Superstrip SS2	1350p

VERO WIRING

PEN + Spool	310p
Spare Spool	75p
Combs	6p

DALO ETCH RESIST PEN + Spare tip **90p**

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

ULTRASONIC TRANSDUCER 40KHz **395p pr**

COPPER CLAD BOARDS

	Fibre glass	Single sided	Double-sided	S.R.B.P.
6" × 6"		90p	110p	9.5" × 8.5" 95p
6" × 12"		150p	195p	

PLUGS & SOCKETS

IDC HEADERS (Speed-block type)

	IDC-Header with Latch	Free Sokt.	PCB-Plugs Strt. pins	Angl pins
2 × 5 way	90p	85p	60p	65p
2 × 8 way	130p	110p	70p	78p
2 × 10 way	145p	125p	80p	90p
2 × 13 way	175p	150p	95p	110p
2 × 17 way	205p	180p	110p	135p
2 × 20 way	220p	190p	125p	150p
2 × 25 way	235p	200p	150p	175p
2 × 60 way	–	230p	200p	220p

EURO CONNECTORS

DIN	Socket	Plug Strt	Plug Angle
4618-31 way	180p	–	195p
41612 A + B 2 × 32 way	290p	220p	235p
41612 A + C 2 × 32 way	310p	225p	240p
41612 A + B + C 3 × 32 way	380p	245p	280p

PANEL METERS

FSD 60x45x35mm

0-50µA, 0-100µA, 0-500µA, 0-1mA, 0-5mA, 0-10mA, 0-50mA, 0-100mA, 0-500mA, 0-1A, 0-2A, 0-25V, 0-50V AC, 0-300V AC, "S", "VU"
496p each

RELAYS

REED, Encapsulated, Single Pole, 5W Normally Open, 200mA, 50V DC.

RL12	700Ω 6V to 9V	120p
RL13	1KΩ 9V to 12V	120p
RL14	1K7Ω 12V to 18V	120p
RL15	3KΩ 18V to 30V	135p

Single Pole, Change Over

RL16	1KΩ 4V to 10V	295p
RL17	1KΩ 9V to 12V	295p

Double Pole, Normally Open

RL18	350Ω 9V to 12V	200p

Miniature, enclosed, PCB mount. Our RL6 series.
S.P.C.O.
RL6-91 170Ω coil, 7V5 to 12V DC; 380V/6A AC; 1300VA/50W **210p**
D.P.C.O.
43Ω coil, 4V2-7V DC; 250V AC; 5A; 1100VA/150W **218p**
RL6-111 170Ω coil, 8V-14V; 250V AC 5A. **220p**
RL6-114 740Ω coil, 17V5-29V 250V 5A AC. **222p**

CONTINENTAL Cradle Type Relays. Miniature Plug-in relays. 110V DC; 12V AC. 2A/DC; 2.5A AC 30W/100VA.
2 pole c/over 185Ω; 6V-18V. RL201 **180p**
2 pole c/over 13V to 35V; 700Ω; RL202 **180p**
4 pole c/over 9V to 18V; 185Ω. RL211 **220p**
High Power "Heavy Duty" PCB Mounting, Cradle type. S.P.C.O. Power Gain 1:8000 380V AC/16A; 3.5K VA. 8 to 19V; 190M **295p**

PIEZO TRANSDUCERS
Type PB-2720 **75p**

BUZZERS, miniature, solid-state 6V; 9V & 12V **70p**

LOUDSPEAKERS Miniature, 0.3W; 8Ω.
2in, 2¾in, 2½in, 3in **80p**
2½in 40Ω, 64Ω or 80Ω **80p**

GAS & SMOKE DETECTORS
For the detection of combustible and Toxic Gases like: Propane, Butane, Methane, Ammonia, Carbon Monoxide, Sulphur and Organic solvents vapours like Alcohol, Benzene, etc. Ideal for use in Boats, Caravans etc.
Type: TGS812 & 813 **525p**
Socket for above **40p**

ASTEC UHF MODULATORS
Standard 6MHz **280p**
Wideband 8MHz **425p**

ETI Autoranging Digital Capacitance Meter. All parts available.

CRYSTALS

32.768KHz	150
100KHz	270
200KHz	295
455KHz	370
1MHz	295
1.008M	290
1.28MHz	392
1.6MHz	395
1.8MHz	395
1.8432M	220
2.0MHz	240
2.4576M	220
3.278M	150
3.5794M	98
3.6864M	300
4.0MHz	150
4.032MHz	290
4.80MHz	200
4.194304M	200
4.433619M	120
5.0MHz	180
5.185MHz	300
5.24288M	390
6.144MHz	140
6.5536MHz	225
7.168MHz	200
7.68MHz	150
8.0MHz	250
8.86723M	200
9.00MHz	150
10.0MHz	175
10.24MHz	200
10.7	175
12.0MHz	200
14.31818M	150
16.0MHz	290
18.0MHz	170
18.432M	250
19.968MHz	180
24.0MHz	150
26.69M	150
27.648M	170
27.145M	150
38.66667M	330
48.0MHz	190
100.0MHz	295
116.0MHz	175

ETI PROJECTS We stock most of the parts

JUMPER LEADS (Ribbon Cable Assembly)

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

AMPHENOL PLUGS: IEEE (24 way) **575p**; Centronic parallel (36 way) **560p**

DIL SOCKETS (TEXAS)

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

EDGE CONNECTORS: (Double type)

	.1	.156
2 × 15 way	–	140p
2 × 18 way	180p	145p
2 × 22 way	199p	200p
2 × 23 way	210p	–
2 × 25 way	225p	220p
2 × 30 way	245p	–
2 × 36 way	295p	–
2 × 40 way	315p	–
2 × 43 way	395p	–
2 × 75 way	560p	–

RIBBON CABLE Grey Color

price/ft		
10 way	12p	22p
16 way	18p	32p
20 way	25p	40p
24 way	35p	50p
34 way	48p	60p
40 way	55p	75p
50 way	65p	90p

DIL PLUG Headers)

	Solder	IDC
14 pin	44p	99p
16 pin	49p	105p
24 pin	88p	178p
40 pin	250p	255p

D CONNECTORS (Cannon type)

Pins	Plugs	Sockets	Covers
9 way	90p	110p	100p
15 way	130p	160p	98p
25 way	160p	210p	95p
37 way	250p	350p	135p

Soldercon Pins 100 pins **70p**; 500 pins **325p**

ZERO INSERTION FORCE DIL SOCKETS
28 way 820p; 24 way 575p; 40 way 975p

25 way 'D' CONNECTORS

	Plug	Socket
PCB Pins	200p	245p
RT. angle	210p	275p

We stock many more Plugs, Sockets and Jumper Leads.

25way 'D' CONNECTOR Jumper Lead Cable Assembly

18" long, Single End, Male	660p
18" long, Single End, Female	670p
36" long, Double Ended, M/M	1175p
36" long, Double Ended, F/F	1150p
36" long, Double Ended, M/F	1100p

ANTEX SOLDERING IRON
C-15W 420p; CX17W 430p.
CCN-15W 440p; CX25W 445p.
Spare tips, assorted sizes **60p**
Spare Elements **210p**
Iron stand with sponge **160p**

TRANSFORMERS: Prim. 240V

6-0-6V; 9-0-9V; 12-0-12V 100mA **98p**
pcb mounting, Miniature, Split Bobbin
3VA: 2x6V-0.25A; 2x9V-0.15A; 2x12V-0.12A; 2x15V-0.1A **200p**
6VA: 2x6V-0.5A; 2x9V-0.3A; 2x12V-0.25A; 2x15V-0.2A **270p**
Standard Split Bobbin type:
6VA: 2x6V-0.5A; 2x9V-0.4A; 2x12V-0.3A; 2x15V-0.25A **220p**
12VA: 2x4.5V-1.3A; 2x6V-1A; 2x9V-0.6A; 2x12V-0.5A; 2x15V-0.4A; 2x20V-0.3A **295p** (35p p&p)
24VA: 2x6V-1.5A; 2x9V-1.2A; 2x12V-1A; 2x15V-0.8A; 2x20V-0.6A **330p** (60p p&p)
50VA: 2x6V-4A; 2x9V-2.5A; 2x12V-2A; 2x15V-1.5A; 2x20V-1.2A; 2x25V-1A; 2x30V-0.8A **440p** (60p p&p)
100VA: 2x12V-4A; 2x15V-3A; 2x20V-2.5A; 2x25V-2A; 2x30V-1.5A; 2x50V-1A **920p** (75p p&p charge to be added over and above our normal postal charge).

VOLTAGE REGULATORS

1A TO3 metal case

	+ve		–ve	
5V	7805	145p	7905	220p
12V	7812	145p	7912	220p
15V	7815	145p	7915	220p
18V	7818	145p		–

1A TO220 Plastic Casing

5V	7805	45p	7905	55p
12V	7812	50p	7908	70p
15V	7815	50p	7912	55p
18V	7818	50p	7915	55p
24V	7824	50p	7918	65p
			7924	70p

100mA TO92 Plastic Casing

5V	78L05	30p	79L05	60p
6V	78L62	30p		–
8V	78L82	30p		–
12V	78L12	30p	79L12	60p
15V	78L15	30p	79L15	60p

CA3085	95p
LM300H	170p
LM304H	170p
LM305H	140p
LM309K	135p
LM317K	350p
LM317KP	99p
LM317H	280p
LM317T	125p
LM323K	500p
LM325N	240p
LM326N	240p
LM723	35p
TAA550	50p
TBA625B	75p
TDA1412	150p
78HO5 + 5V/5A	550p
78HG +5V to +25V 5A	599p
79HG-2.25V to 24V 5A	785p

CMOS

4000	10	4073	16	4536	295
4001	10	4075	16	4538	110
4002	12	4076	50	4539	110
4006	50	4077	18	4541	140
4007	16	4078	18	4543	100
4008	48	4081	16	4544	150
4009	24	4082	16	4549	375
4010	24	4085	50	4553	275
4011	11	4086	50	4554	190
4012	16	40890	125	4555	35
4013	25	4093	30	4556	35
4014	50	4094	120	4557	320
4015	50	4095	75	4558	120
4016	20	4096	75	4560	175
4017	42	4097	290	4566	175
4018	45	4098	75		
4019	25	4099	110		
4020	50	4160	95		
4021	50	4161	99		
4022	50	4162	99		
4023	16	4163	99		
4024	33	4174	99		
4025	16	4175	105		
4026	80	4194	105		
4027	24	4408	790		
4028	50	4409	790		
4029	60	4410	725		
4030	30	4411	675		
4031	125	4412	775		
4032	85	4415	480		
4033	125	4419	280		
4034	140	4422	770		
4035	65	4433	770		
40367	275	4435	850		
4037	115	4440	999		
4038	110	4450	350		
4039	290	4451	350		
4040	50	4490	350		
4041	60	4500	675		
4042	45	4501	28		
4043	50	4502	60		
4044	50	4503	40		
4045	105	4504	75		
4046	80	4506	35		
4047	60	4507	36		
4048	40	4508	150		
4049	25	451060			
4040	25	4511	50		
4051	45	4512	50		
4052	60	4513	199		
4053	50	4514	125		
4054	95	4515	125		
4055	95	4516	66		
4056	95	4517	275		
4057	1915	4518	40		
4059	480	4519	30		
4060	65	4520	70		
4061	2295	4521	130		
4062	995	4522	125		
4063	85	4526	70		
4066	30	4527	85		
4067	295	4528	70		
4068	16	4529	160		
4069	16	4530	90		
4070	15	4531	130		
4071	15	4532	80		
4072	15	4534	485		

OPTO ELECTRONICS

LEDs with Clips

TIL209 Red	13
TIL211 Grn.	17
TIL212 Yel.	18
TIL220 .2" Red	14
.2" Green, Yellow or Amber	18
0.2" Bi colour Red/Green	65p
Green/Yellow	78p
0.2" Tri colour Red/Green/Yellow	85p
Square LEDs. Red, Green, Yellow	30
Triangular LEDs Red	18
Green or yellow	22
LD271 Infra Red	46
SFH205 Detector	91
TIL32 Infra Red	58
TIL78 Detector	60
TIL38	45
TIL100	80
BARGRAPH. Red 10 segments	225

ISOLATORS

IL74	55
ILD74	99
ILQ74	185
TIL111/2/4	90
TIL117	125
4N33 Photo Darlington	135

7 Segment Displays

TIL307	675
TIL312 .3" CA	105
TIL313 .3" CC	105
TIL321 .5" CA	115
TIL322 .5" CC	115
DL704 .3" CC	99
DL707 .3" CA	99
DL747 .6" CA	180
.8" Orange CA	250
FND357 Red	120
FND500	115
.3" Green CA	150
.6" Green CA	215
.3" ±1 Red CA	150
.3" ±1 Green CA	150
DVM176	1885
LCD 3½ Digits	595
LCD 4 Digits	650
LCD 6 Digits	750

NEON with resistor, push fit. 250V mains. Round. Red or Amber **30p**
Rectangular, nut gixing Red, Amber, Green **30p**
TIL139 Reflective Optical Switch **296p**

OPTO

LS400C	256
OCP71	120
ORP12	86
ORP61	85
2N5777	45

BARGRAPH 3914 **500**

COMPUTER CORNER

- VIC 20 Micro Computer. Connects directly to a colour TV. Still only £165
- VIC Cassette Deck including a free 6 programme Cassette £38
- EPSON MX80T 10" Tractor Feed, 9 × 9 matrix, 80 column, Speed 80 CPS, Bi-directional, Centronics interface, Baud rate 110-9600 (RS232) £315
- EPSON MX80FT Has Friction feed & Tractor feed plus all the MX89's facilities £345
- VIDEO MONITOR 9", B&W, Attractively cased, Fully guaranteed. Value for money at £75
- SOFTY-2 As reviewed in PE Sept. '81 by Dr A.A. Berk. The complete microprocessor development system for Engineers and beginners alike. New powerful instructions. Accepts any 24 pin 5V single rail EPROM. Supplied fully built, tested. Enclosed in a black ABS case. Plug-in power supply included £169
- TEX EPROM ERASER Erases up to 32 ICs in 15-30 minutes... £33
- SPARE 'UV' Lamp bulb £9
- 5V/5A Power Supply Ready-built & tested £25
- ABS CASE Attractive, Beige/Brown for Superboard, UK101 NASCOM, or HOme brew £26
- Stack-Pak Drawers including 10 × C12 Cassettes 550p
- C12 CASSETTES in library cases 40p
- WEMON Watford's own 4K Ultimate Monitor IC specially designed to produce the best from your Superboard, UK101 & Enhanced UK 101 Superboard. As reviewed by Dr A.A. Berk in Practical Electronics June 1981 .... £15

(p&p on most of the above items is extra)

WATFORD'S UNIVERSAL MICRO EXPANSION SYSTEM

Designed by Watford Electronics, this extremely versatile and economical Expansion System as published in E.T.I., starting from December 1981 issue, offers a low cost flexible expansion system for: ZX81, UK101, SUPERBOARD, Acorn ATOM, PET, TANGERINE, TRS80, VIC 20, etc.
The Motherboard (interfaces with the Computer) has capability to accept up to five daughter Cards and can be paralleled for even more daughter cards.
All PC Boards are of Computer grade and are supplied in Kit form.
Just look at the Expansion possibilities:
MOTHERBOARD: Accepts up to five Daughter Cards. Full Kit: £36.50
SOUND CARD — Utilising up to three AY-3-8910 sound chips. (One supplied with Kit). Full Kit: £24.95
PIO Card — Using two 6520 PIA chips, this Board offers centronics parallel printer driver, digital to analogue converter & a host of other output facilities. Full Kit: £18.95
PROM Programmer — This simple but extremely useful card can blow 2716 or 2732 single rail EPROMS. Full Kit: £26.95
PROM Card — P.C.B. cards for housing four 2716 or two 2732 EPROMS.
For 4 × 2716 Full Kit: £11.95
For 2 × 2732 Full Kit: £11.75
RAM Card — 8K RAM card. Accepts 16 × 2114 chips. Supplied fully populated. Full Kit: £28.50
Coming soon: Speech Card, Disc Interface Card; 32K Dynamic RAM Card; High Resolution colour graphics Card.
(N.B. PCBs may be bought separately)

WATFORD'S BOOKSHOP CORNER

Texas TTL Data Book (Revised Edition)	850p
TTL Cook-Book	930p
European CMOS DataBook (Comprehensive)	795p
CMOS Cook-Book	895p
Illustrating BASIC	440p
A Bit of BASIC	540p
Advanced BASIC	840p
BASIC Computer Games	590p
More BASIC Computer Games	590p
Some Common BASIC Programs	1150p
Practical BASICAL Programs	1250p
6502 Software Design	910p
6502 Application Book	1020p
Programming the 6502 (C202)	1100p
Programming & Interfacing the 6502	1120p
6502 Assembly Language Programming	1300p
6809 Assembly Language Programming	1350p
zPractical Intro to PASCAL	550p
Using CP/M: A self teaching guide	950p
Z80 Microcomputer Handbook	840p
8080/Z80 Assembly Lang. Techniques	925p
Programming the Z80 (C280)	1250p
Z80 Assembly Language Programming	1300p
Intro to TRS-80 Graphics	840p
TRS80 BASIC — A self teaching guide	840p
PET & the IEEE 488 Bus (GP1B)	1350p
PET Graphics	1200p
PET/CBM Personal Computer Guide	1200p
PET Revealed	1000p
Library of PET Subroutines	1000p
Apple II Users' Guide	1250p
Programming in PASCAL (revised)	900p
CRT Controller Handbook	650p
CP/M Handbook with MP/M	1200p
Microprocessor Interfacing Technique	1350p
S100 & Other Micro Buses 3E	750p
Writing Interactive Compiler	750p
Getting Acquainted with your ZX81	500p
Mastering Machine Code on your ZX81	600p
ZX81 Companion	800p
ZX81 Pocket Book	650p
32 BASIC Programs for the PET Computer	1350p
VIC Revealed	1000p

Please add 55p P&P charge on books

No VAT on books

CUSTOMER: How can WATFORD sell full spec devices so cheaply?
WATFORD: It's simple. By bulk buying (direct from manufacturers where possible), low overheads and smaller margins which give us an edge over our competitors.

Sinclair ZX81 Personal Comp
the heart of a system that grows with you.

1980 saw a genuine breakthrough – the Sinclair ZX80, world's first complete personal computer for under £100. Not surprisingly, over 50,000 were sold.

In March 1981, the Sinclair lead increased dramatically. For just £69.95 the Sinclair ZX81 offers even more advanced facilities at an even lower price. Initially, even we were surprised by the demand – over 50,000 in the first 3 months!

Today, the Sinclair ZX81 is the heart of a computer system. You can add 16-times more memory with the ZX RAM pack. The ZX Printer offers an unbeatable combination of performance and price. And the ZX Software library is growing every day.

Lower price: higher capability
With the ZX81, it's still very simple to teach yourself computing, but the ZX81 packs even greater working capability than the ZX80.

It uses the same micro-processor, but incorporates a new, more powerful 8K BASIC ROM – the 'trained intelligence' of the computer. This chip works in decimals, handles logs and trig, allows you to plot graphs, and builds up animated displays.

And the ZX81 incorporates other operation refinements – the facility to load and save named programs on cassette, for example, *and* to drive the new ZX Printer.

New BASIC manual

Every ZX81 comes with a comprehensive, specially-written manual – a complete course in BASIC programming, from first principles to complex programs.

Kit: £49.95

Higher specification, lower price – how's it done?
Quite simply, by design. The ZX80 reduced the chips in a working computer from 40 or so, to 21. The ZX81 reduces the 21 to 4!

The secret lies in a totally new master chip. Designed by Sinclair and custom-built in Britain, this unique chip replaces 18 chips from the ZX80!

New, improved specification
- Z80A micro-processor – new faster version of the famous Z80 chip, widely recognised as the best ever made.
- Unique 'one-touch' key word entry: the ZX81 eliminates a great deal of tiresome typing. Key words (RUN, LIST, PRINT, etc.) have their own single-key entry.
- Unique syntax-check and report codes identify programming errors immediately.
- Full range of mathematical and scientific functions accurate to eight decimal places.
- Graph-drawing and animated-display facilities.
- Multi-dimensional string and numerical arrays.
- Up to 26 FOR/NEXT loops.
- Randomise function – useful for games as well as serious applications.
- Cassette LOAD and SAVE with named programs.
- 1K-byte RAM expandable to 16K bytes with Sinclair RAM pack.
- Able to drive the new Sinclair printer.
- Advanced 4-chip design: micro-processor, ROM, RAM, plus master chip – unique, custom-built chip replacing 18 ZX80 chips.

Built: £69.95

Kit or built – it's up to you!
You'll be surprised how easy the ZX81 kit is to build: just four chips to assemble (plus, of course the other discrete components) – a few hours' work with a fine-tipped soldering iron. And you may already have a suitable mains adaptor – 700 mA at 9 V DC nominal unregulated (supplied with built version).

Kit and built versions come complete with all leads to connect to your TV (colour or black and white) and cassette recorder.

uter-

Available now-the ZX Printer for only £59.95

Designed exclusively for use with the ZX81 (and ZX80 with 8K BASIC ROM), the printer offers full alphanumerics *and* highly sophisticated graphics.

A special feature is COPY, which prints out exactly what is on the whole TV screen without the need for further intructions.

At last you can have a hard copy of your program listings – particularly useful when writing or editing programs.

And of course you can print out your results for permanent records or sending to a friend.

Printing speed is 50 characters per second, with 32 characters per line and 9 lines per vertical inch.

The ZX Printer connects to the rear of your computer – using a stackable connector so you *can* plug in a RAM pack as well. A roll of paper (65 ft long x 4 in wide) is supplied, along with full instructions.

16K-byte RAM pack for massive add-on memory.

Designed as a complete module to fit your Sinclair ZX80 or ZX81, the RAM pack simply plugs into the existing expansion port at the rear of the computer to multiply your data/program storage by 16!

Use it for long and complex programs or as a personal database. Yet it costs as little as half the price of competitive additional memory.

With the RAM pack, you can also run some of the more sophisticated ZX Software – the Business & Household management systems for example.

How to order your ZX81

BY PHONE – Access, Barclaycard or Trustcard holders can call 01-200 0200 for personal attention 24 hours a day, every day.

BY FREEPOST – use the no-stamp-needed coupon below. You can pay by cheque, postal order, Access, Barclaycard or Trustcard.

EITHER WAY – please allow up to 28 days for delivery. And there's a 14-day money-back option. We want you to be satisfied beyond doubt – and we have no doubt that you will be.

To: Sinclair Research Ltd, FREEPOST , Camberley, Surrey, GU15 3BR. **Order**

Qty	Item	Code	Item price £	Total £
	Sinclair ZX81 Personal Computer kit(s). Price includes ZX81 BASIC manual, excludes mains adaptor.	12	49.95	
	Ready-assembled Sinclair ZX81 Personal Computer(s). Price includes ZX81 BASIC manual and mains adaptor.	11	69.95	
	Mains Adaptor(s) (700 mA at 9 V DC nominal unregulated).	10	8.95	
	16K-BYTE RAM pack.	18	29.95	
	Sinclair ZX Printer.	27	59.95	
	8K BASIC ROM to fit ZX80.	17	19.95	
	Post and Packing.			2.95

☐ Please tick if you require a VAT receipt TOTAL £______

*I enclose a cheque/postal order payable to Sinclair Research Ltd, for £______

*Please charge to my Access/Barclaycard/Trustcard account no.

*Please delete/complete as applicable.

Please print.

Name: Mr/Mrs/Miss

Address:

FREEPOST – no stamp needed. Offer applies to UK only. ET106

sinclair ZX81

6 Kings Parade, Cambridge, Cambs., CB2 1SN. Tel: (0276) 66104 & 21282.

Memotech's New Memory System for the ZX81

It grows as you progress

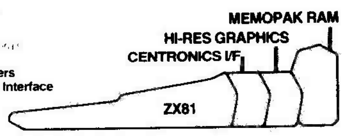
Memopak 16K Memory Extension - £39.95 incl.VAT

It is a fact that the ZX81 has revolutionised home computing, and coupled with the new Memopak 16K it gives you a massive 16K of Directly Addressable RAM, which is neither switched nor paged. With the addition of the Memopak 16K your ZX81's enlarged memory capacity will enable it to execute longer and more sophisticated programs, and to hold an extended database.

The 16K and 64K Memopaks come in attractive, custom-designed and engineered cases which fit snugly on to the back of the ZX81, giving firm, wobble-free connections. See below for ordering information.

Coming Soon...

Memotech Hi-Res Graphics
Centronics Interface and Software Drivers
Memotech Digitising Tablet **RS232 Interface**



All these products are designed to fit 'piggy-back' fashion on to each other, and use the Sinclair power supply. WATCH THIS SPACE for further details. We regret we are as yet unable to accept orders or enquiries concerning these products – but we'll let you know as soon as they become available.

How to order your Memopak.

By Post: Fill in the coupon below and enclose your cheque/P.O./Access or Barclaycard number.

By Phone: Access/Barclaycard holders please ring Oxford (0865) 722102 (24-hour answering service).

Memopak 64K Memory Extension -£79.00 incl.VAT

The 64K Memopak is a pack which extends the memory of the ZX81 by a further 56K, and together with the ZX81 gives a full 64K, which is neither switched nor paged, and is directly addressable. The unit is user transparent and accepts basic commands such as 10 DIM A(9000).

BREAKDOWN OF MEMORY AREAS

0–8K . . . Sinclair ROM
8–16K . . . This section of memory switches in or out in 4K blocks to leave space for memory mapping, holds its contents during cassette loads, allows communication between programmes, and can be used to run assembly language routines.
16–32K . . . This area can be used for basic programmes and assembly language routines.
32–64K . . . 32K of RAM memory for basic variables and large arrays.

With the Memopak 64K extension the ZX81 is transformed into a powerful computer, suitable for business, leisure and educational use, at a fraction of the cost of comparable systems.

Unique 3 month trade-in offer!

When your programming needs have outgrown the capacity provided by 16K RAM, and you find it necessary to further extend your ZX81's capacity, we will take back your 16K Memopak and allow a discount of £15.00 against your purchase of our 64K model.*

**We reserve the right to reject, for discounting purposes, units which have been either opened or damaged in any way.*

Please make cheques payable to Memotech Limited
Please debit my Access/Barclaycard* account number

**Please delete whichever does not apply*

SIGNATURE ______________ DATE ______________

Please send me:

	Quantity	Price	Total
16K RAM, Assembled		£39.95	
64K RAM, Assembled		£79.00	
		Postage	£2.00
		Total Enclosed	

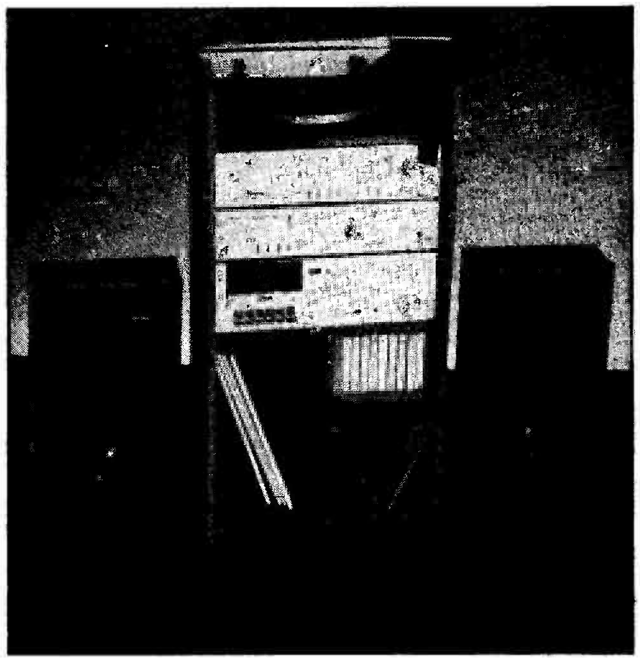
NAME ______________ ADDRESS ______________

ETI3

We want to be sure you are satisfied with your Memopak – so we offer a 14-day money back Guarantee on all our products.

Memotech Limited, 3 Collins Street, Oxford OX4 1XL, England Telephone: Oxford (0865) 722102/3/4/5

DIGEST

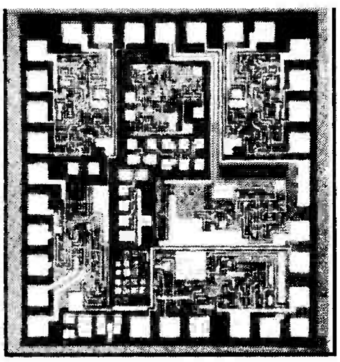


Ace Catalogue

Whoops — we forgot to mention Ace Mailtronix in the 'Buying Mail Order' article. This is a shame because they've got a good little catalogue with a wide range of components at reasonble prices — what's more the prices are VAT-inclusive (I hate pricing an order and then finding I've got to add on 15%). Ace offer all the services in the survey except surplus components and books, and can be found at 3A Commercial Street, Batley, West Yorks, WF17 5HJ.

Power Tower

That's what Binatone are calling this hi-fi stack system, and what you have to do is guess the price of it. Nope, you're wrong — the whole lot costs £150. Honest. From the top down we've got a belt-drive record deck, three-waveband stereo tuner, stereo cassette deck with soft eject, LED meter and metal tape facility, 40 W total peak music power (hmmm...) stereo amp and matching two-way stereo speakers. The cabinet also has storage space for singles, albums and cassettes and at the price, Binatone are feeling quite pleased with themselves.



Eye Of The Needle

It's definitely electronics-as-art month; here's a sample of the work of Manchester photographer Ad Sternberg. Mr Sternberg has developed a unique method of photographing microchips, many of which are only slightly larger than a typewriter dot. Most of his work is done in full colour and is on display in companies such as Plessey, National Semiconductor and Ferranti. It took a great deal of time to develop the custom-built equipment for such an exacting branch of photomicrography, but the results are certainly worth it.

Robot Revival

We're not ones to boast, but since we published our report on Industrial Robots in September '81 things appear to be picking up a bit. The British robot population is now growing at more than 35% a year and has moved up to fifth in the world league table. Last year's total was approximately 700. Even more encouraging is the attitude of the unions, which is surprisingly lacking in hostility. In fact Terry Duffy, AUEW president, has this to say of robots on the factory floor: "Failure to accept the challenge of new technology would, in my opinion, be to sabotage our national future. Robots are here to stay." How very refreshing to hear such sensible sentiments.

Another promising trend is the entry into the market of the major computer manufacturers who, until now, hadn't bothered to compete with the specialist firms. GEC, for example, is expected to augment its own in-house robotics facility through co-operation deals with Japanese companies (Japan still dominates the world robotics scene). With this sort of investment by big companies there seems to be no reason why Britain should'nt become a major supplier of industrial robots within the next two or three years.

Master Minds

What have the following five in common: Jack Kilby, Henry Ford, Ottmar Mergenthaler, Ernest O. Lawrence and Max Tishler? Well, no, none of them *have* appeared on the Muppet Show, but we had something else in mind. They've all just been appointed to the US National Inventors' Hall of Fame, and the one we're really interested in is Jack Kilby. He's the Texas Instruments engineer who, back in 1958, invented the integrated circuit and hence fathered all the goodies we've got today. Kilby holds more than 50 patents and is still going strong as a consultant to TI. Wonder what it feels like to be responsible for the state of the world's technology....

Dial-A-Muzak

It's bad enough being assaulted by non-stop muzak in shops and hotels but now you won't be able to escape even when making phone calls. The Hong Kong Trade Development Council have sent us details of the Music Phone; as well as the usual modern features like auto-redial and jack plug connection, this gadget has a 'music switch'. If someone wants to place you on hold without you hearing their discussion with a third party, this control plays soft music to you while you're waiting. The manufacturers, Yee King Enterprises Company, are producing 12,000 phones a month and exporting most of them to the USA and Europe; further evidence that it's all a fiendish oriental plot to subvert the West. Arrggh!

Stamp On It

No real reason for using this photograph in Digest except that it intrigued us. Apparently it's some kind of tiny inductor thingy and since none of you have got soldering irons that small you won't want to know anything else about it, will you?

Rapid Electronics

Tel: 0206 36412
Hill Farm Industrial Estate
Boxted, Colchester
Essex CO4 5RD

BARCLAYCARD VISA — ACCESS

LINEAR

★555 CMOS	80	ICL7106	790	LM382	120	MC3302	150	SL480	170	★XR2206	300
556CMOS	150	ICL7611	95	LM384	130	MC3340	135	SL490	250	ZN414	100
709	25	ICL7621	180	LM386	65	★ML922	400	SN76477	250	ZN423	125
★741	14	ICL7622	180	LM387	120	ML924	195	TBA120S	70	ZN424	135
748	35	ICL8038	320	LM393	100	ML925	210	TBA800	80	ZN425E	390
9400CJ	350	ICM7555	80	LM709	25	ML926	140	TBA810	96	ZN426E	330
AY-3-1270	840	ICM7556	150	LM710	50	ML927	140	TBA820	80	ZN427E	650
AY-3-8910	600	LF351	45	LM711	60	ML928	140	TBA950	290	ZN428E	480
★AY-3-8912	625	LF353	85	LM725	350	ML929	140	TCA940	170	ZN1034E	200
CA3046	60	LF356	90	LM733	75	NE515	270	TDA1004	300		
CA3080	65	LM10	395	★LM741	14	NE529	225	TDA1008	320		
CA3089	215	LM301A	25	LM747	75	NE531	150	TDA1022	560		
CA3090AQ	375	LM311	70	LM748	35	NE544	300	TDA1024	125		
CA3130E	90	LM318	120	LM1458	40	★NE555	16	TL071	45		
CA3140E	45	★LM324	40	LM2917	200	★NE556	45	TL072	65		
CA3160E	100	LM339	50	LM3900	50	NE565	120	TL074	100		
CA3160	140	LM348	65	LM3911	120	NE566	150	★TL081	30		
CA3189	290	LM358	50	LM3914	200	NE567	100	TL082	50		
CA3240	110	LM377	150	LM3915	220	NE571	425	TL084	95		
		★LM380	65	LM13600	120	RC4136	68	TL170	50		
		LM381	120	MC1310	150	SN76018	150				

OPTO

★3mm red	8	★5mm red	8
★3mm green	12	★5mm green	12
★3mm yellow	12	★5mm yellow	12

Clips to suit **3p each**

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

Seven Segment Displays

Com. cathode		Com. anode	
DL704 0.3"	95	DL707 0.3"	95
★FND500 0.5"	80	FND507 0.5"	90
TIL313 0.3"	105	TIL312 0.3"	105
TIL322 0.5"	115	TIL321 0.5"	115

All disp-lays are supplied with pinouts

CONNECTORS

DIN	Plug	Skt	Jack	Plug	Skt
2 pin	9p	9p	2.5mm	10p	10p
3 pin	12p	10p	3.5mm	9p	8p
5 pin	13p	11p	Standard	16p	20p
Phono	10p	12p	Stereo	24p	25p
1mm	12p	13p	4mm	18p	17p

UHF (CB) Connectors
PL259 Plug **40p** Reducer **14p**
SO239 Square chassis socket **38p**
SO239S Round chassis socket **40p**

IEC 3 pin 250V/6A
Plug chassis mounting **38p**
Socket free hanging **60p**
Socket with 2m lead **120p**

TRANSISTORS

AC125	35	BC157	10	BC558	10	BFX84	25	TIP30	45	★ZTX107	8	2N3054	55
AC126	25	BC158	10	BCY70	18	BFX85	25	TIP30A	45	★ZTX108	8	2N3055	50
AC127	25	★BC159	8	BCY71	18	BFX86	28	TIP30B	50	ZTX109	12	2N3442	120
★AC128	20	BC160	45	BCY72	18	BFX87	25	TIP30C	60	ZTX300	14	★2N3702	6
AC176	25	BC168C	10	BD115	80	BFX88	25	TIP31A	45	ZTX301	16	2N3703	9
AC187	22	BC169C	10	BD131	35	BFY50	23	TIP31B	45	ZTX302	15	★2N3704	6
AC188	22	BC170	8	BD132	35	BFY51	23	TIP31C	55	ZTX304	17	2N3705	9
AD142	120	BC171	10	BD133	50	BFY52	23	TIP32A	45	ZTX341	30	2N3706	9
AD149	80	BC172	8	BD135	30	BFY53	32	TIP32B	55	ZTX500	15	2N3707	10
AD161	40	BC177	18	BD136	30	BFY55	32	TIP32C	60	ZTX501	15	2N3708	10
AD162	40	BC178	18	BD137	30	BFY56	32	TIP33A	50	ZTX502	15	2N3709	10
AF124	60	BC179	18	BD138	30	BRY39	40	TIP33C	75	ZTX503	18	2N3772	190
AF126	50	BC182	10	BD139	35	BSX20	20	TIP34A	60	ZTX504	25	2N3773	210
AF139	40	★BC182L	8	BD140	35	BSX29	35	TIP34C	85	2N697	20	★2N3819	18
AF186	70	BC183	10	BD204	110	BSY95A	25	TIP35A	160	2N698	40	2N3820	40
AF239	75	BC183L	10	BD206	110	BU205	160	TIP35C	180	2N706A	20	2N3823	65
BC107	10	BC184	10	BD222	85	BU206	200	TIP36A	170	2N708	20	2N3866	90
BC107B	10	★BC184L	7	BF180	35	BU208	170	TIP36C	195	2N918	35	2N3903	10
★BC108	9	BC212	10	BF182	35	MJ2955	99	TIP41A	60	2N1132	22	2N3904	10
BC108B	12	BC212L	10	BF184	25	MJE340	50	TIP42A	60	2N1613	30	2N3905	6
BC108C	12	BC213	10	BF185	25	MJE520	65	TIP120	90	2N2218A	45	2N3906	10
★BC109	9	BC213L	10	BF194	12	MJE521	95	TIP121	90	2N2219A	25	2N4037	45
BC109C	12	BC214	10	BF195	12	MJE3055	70	TIP122	90	2N2221A	25	2N4058	10
BC114	22	★BC214L	8	BF196	12	MPF102	40	TIP141	120	2N2222A	20	2N4060	10
BC115	22	BC237	8	BF197	12	MPF104	40	TIP142	120	2N2368	25	2N4061	10
BC117	22	BC238	14	BF198	18	MPSA05	22	TIP147	120	2N2369	16	2N4062	10
BC119	35	BC308	14	BF199	18	MPSA06	25	TIP2955	60	2N2484	25	2N5457	36
BC137	40	BC327	14	BF200	30	MPSA12	30	TIP3055	55	2N2646	45	2N5458	36
BC139	40	BC328	14	★BF244B	22	MPSA55	30	TIS43	40	2N2904	20	2N5459	30
BC140	30	BC337	14	BF245	30	MPSA56	30	TIS44	45	2N2904A	20	2N5485	36
BC141	30	BC338	14	BF256B	45	MPSU05	55	TIS45	45	2N2905	22	2N5777	45
BC142	25	BC477	30	BF257	32	MPSU06	55	TIS90	30	2N2905A	22	2N6027	30
BC143	25	BC478	30	BF258	25	MPSU55	60	TIS91	30	2N2906	25	40360	40
BC147	8	BC479	30	BF259	35	MPSU56	60	★VN10KM	45	2N2906A	25	40361	50
BC148	8	BC517	40	BF337	40	TIP29	35	VN46AF	75	2N2907	25	40362	50
BC149	9	★BC547	7	BFR40	23	TIP29A	40	VN66AF	85	2N2907A	25	40408	70
		BC548	10	BFR80	25	TIP29B	55	VN88AF	95	2N2926	9	40594	100
		BC549	10	BFX29	25	TIP29C	60			2N3053	23		

CMOS

4000	14	★4017	43	4036	285	4055	115	4082	20	4502	70	4529	150
★4001	12	4018	60	4039	295	4059	480	4085	65	4503	50	4532	95
4002	14	4019	35	4040	55	4060	85	4086	65	4507	38	4534	495
4006	65	4020	55	4041	75	4063	90	4089	140	4508	200	4538	110
4007	17	4021	65	4042	55	★4066	35	★4093	33	4510	65	4543	110
4008	58	4022	70	4043	60	4067	395	4094	140	★4511	50	4549	380
4009	30	4023	18	4044	65	4068	15	4095	90	4512	70	4553	295
4010	35	4024	40	4046	70	4069	18	4097	340	4514	180	4555	45
★4011	13	4025	18	4047	70	4070	18	4098	85	4515	180	4556	48
4012	17	★4026	96	4048	55	4071	18	4099	95	4516	75	4559	390
★4013	26	4027	30	★4049	28	4072	18	40106	50	★4518	45	4560	180
4014	60	4028	55	4050	28	4073	20	40109	100	4520	70	4584	45
4015	60	4029	75	4051	60	4075	20	40163	100	4521	200	4585	99
★4016	26	4030	35	4052	70	4076	60	40173	100	4526	80	4724	140
		4031	170	4053	60	4077	25	40175	100	4527	90		
		4034	170	4054	110	4081	18	40193	120	★4528	75		

TTL

7400	11	7413	24	7442	40	7480	45	74107	30	74155	60	74177	75
7401	11	7414	35	7444	85	7482	70	74109	32	74156	60	74179	65
7402	12	7416	25	7446	60	7483	50	74121	28	74157	43	74180	65
7403	14	7417	25	7447	48	7485	75	74122	45	74160	60	74181	135
7404	14	7420	15	7448	50	7486	25	74123	48	74161	60	74182	75
7405	17	7421	20	7450	16	7489	180	74125	40	74162	60	74190	70
7406	26	7422	20	7451	16	7490	28	74126	40	74163	60	74191	70
7407	26	7427	28	7453	16	7492	45	74132	40	74164	60	74192	70
7408	15	7428	28	7454	16	7492	40	74141	65	74165	60	74193	65
7409	16	7430	15	7460	16	7493	30	74165	65	74167	180	74194	70
7410	14	7432	25	7472	25	7494	35	74147	100	74170	165	74195	63
7411	20	7433	27	7473	28	7495	50	74148	75	74173	60	74196	63
7412	20	7438	27	7474	25	7496	45	74150	75	74174	65	74197	63
		7437	27	7475	38	7497	120	74153	45	74175	70	74198	95
		7440	17	7476	30	74100	80	74154	75	74176	55	74199	95

LS TTL

LS00	13	LS21	15	LS76	20	LS125	30	LS161	42	LS221	60	LS365	38
LS01	14	LS22	16	LS78	24	LS126	30	LS162	42	LS240	90	LS366	38
LS02	14	LS26	18	LS83	50	LS132	45	LS163	42	LS241	80	LS367	38
LS03	14	LS27	15	LS85	70	LS136	30	LS164	50	LS242	80	LS368	50
LS04	15	LS30	16	LS86	25	LS138	35	LS165	120	LS243	85	LS373	80
LS05	15	LS32	16	LS90	35	LS139	35	LS166	85	LS244	80	LS374	80
LS08	16	LS37	16	LS92	38	LS145	75	LS170	170	LS245	120	LS375	50
LS09	16	LS38	16	LS93	35	LS147	160	LS173	70	LS247	75	LS377	90
LS10	16	LS40	16	LS95	45	LS148	95	LS174	60	LS251	40	LS378	70
LS11	16	LS42	38	LS96	110	LS151	40	LS175	60	LS257	48	LS390	75
LS12	15	LS47	40	LS107	45	LS153	40	LS190	55	LS258	45	LS393	75
LS13	25	LS48	80	LS109	30	LS154	120	LS191	55	LS259	95	LS399	220
LS14	48	LS51	16	LS112	30	LS155	45	LS192	55	LS266	25	LS541	135
LS15	15	LS55	30	LS113	30	LS156	45	LS193	60	LS273	90	LS670	175
LS20	15	LS73	25	LS114	30	LS157	35	LS195	50	LS279	50		
		LS74	25	LS122	42	LS158	36	LS196	60	LS283	45		
		LS75	27	LS123	55	LS160	42	LS197	68	LS353	100		

COMPONENT KITS

An ideal opportunity for the beginner or the experienced constructor to obtain a wide range of components at reduced prices

¼W 5% Resistor Kit. Contains 10 of each value from 4.7Ω to 1M (650 resistors) **480p.**

Ceramic Capacitor Kit. Contains 5 of each value from 22p to 0.01 (135 caps.) **370p.**

Polyester Capacitor Kit. Contains 5 of each value from 0.01 to 1uF (65 caps.) **575p each.**

Preset Kit. Contains 5 of each hor. Value from 100Ω to 1M (total 65 presets). **425p each.**

Nut and Bolt Kit. Total 300 items. **140p.**

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

TRANSFORMERS

Please add carriage charges to our normal post charges

Miniature mains.
606V, 909V, 12012V all @ 100mA **100p each**

High quality. **Split** bobbin construction
6VA 0-6, 0-6 @ 0.5A, 0-9, 0-9V @ 0.4A
0-12, 0-12V @ 0.3A **220p each.**
12VA 0-6, 0-6 @ 1A; 0-9, 0-9V @ 1.2A;
0-12, 0-12 @ 0.5A, 0-15, 0-15V @ 0.4A
295p each (plus 40p carriage)
25VA 0-6, 0-6 @ 1.5A, 0-9, 0-9 @ 1.2A,
0-12, 0-12V @ 1A, 0-15, 0-15V @ 0.8A,
330p each (plus 60p carriage)
50VA 0-12, 0-12V @ 2A, 0-15, 0-15V @ 1.5A;
400p each (plus 75p carriage)

PANEL METERS

Sixe 60 × 46 × 35mm.

0-50μA	0-500mA
0-100μA	0-1A
0-500μA	0-50V AC
0-1mA	VU
0-10mA	0-300V AC
0-50mA	0-25V
0-100mA	0-30V DC

495p each

POTENTIOMETERS

Rotary. Carbon track Log or Lin 1K-2M2.
Single **32p.** Stereo **85p**
Single switched **80p**
Slide 60mm travel single Log or Lin 5K-500K. **63p.**
Preset. Submin horiz. 100M-1M. **7p each.**
Cermet precision multiturn 0.75W ¾in 100 ohms to 100K. **88p each**

ORDERING INFO

All prices exclude VAT. Please add to total order. Please add 50p carriage on all orders under £10 in value. Send cheque/PO or Access/Visa number with your order. Please note our new address. Callers most welcome — we are just 10 minutes from the centre of Colchester. Telephone orders welcome with Access and Visa. Official orders welcome from colleges and schools etc. Export orders no VAT but please add carriage.

REGULATOR MADNESS!

Special prices on popular regulators.

Prices valid to 30th June 82.

		Volts	Amps	1+	10+
78L05	T092	5	100mA	25p	23p
78L12	T092	12	100mA	25p	23p
7805	Plastic	5	1	38p	34p
7812	Plastic	12	1	38p	34p
7905	Plastic	5	1	45p	42p

BRIDGE RECTIFIERS

1A 50V	22
1A 400V	35
2A 200V	40
2A 400V	45
6A 100V	80
6A 400V	95
VM18 DIL 0.9A 200V	50

CABLES

20 metre pack single core connecting cable, ten different colours	65p
Speaker cable	10p/m
Standard screened	16p/m
Twin screened	24p/m
2.5A 3 core mains	23p/m
10 way ribbon	65p/m
20 way ribbon	120p/m

SOCKETS

★8 pin	7p	22 pin	20p
★14 pin	9p	24 pin	22p
★16 pin	10p	28 pin	26p
18 pin	15p	40 pin	32p
20 pin	18p		

Soldercon pins **60p** 100

TRIACS + SCRS

SCRs		TRIACs	
TIC45	28	400V 4A	50
C106D	30	400V 8A	65
400V 8A	70	400V 16A	95
400V 12A	99	BR100	25

RESISTORS

¼W 5% Carbon film E12 series. 4.7Ω-10M. **1p each**
½W 5% Carbon film E12 series 4.7Ω-4M7. **2p each**
¼W 1% Metal film. E24 series 10Ω-1M. **6p each.**

CRYSTALS

100KHz	290	6.0M	200
200KHz	370	6.144M	180
1MHz	300	7.00M	250
1.008M	370	8.0M	170
1.8432M	300	10.0M	180
2.0M	270	12.0M	290
2.4576M	220	16.0M	240
3.276M	240	18.0M	240
3.579M	120	18.432M	220
4.0M	150	19.968M	300
4.194M	150	38.6667M	320
4.43M	125	48.0M	220
5.0M	240	116M	300

SWITCHES

Submin. Toggle
SPST **55p** SPDT **60p** ★DPDT **50p**
Miniature toggle
SPDT 80p SPDT centre off **90p**
DPDT **90p** DPDT centre off **100p**
Standard toggle
SPST **35p** DPDT **48p**
★Miniature DPDT slide **12p**
★Push to make **12p** Push to break **22p**
Rotary type adjustable stop
1P12W 2P6W, 3P4W, 4P3W **all 55p each**
DIL switches
4 SPST **80p** 6 SPST **80p** 8 SPST **100p**
Heavy Duty Foots

VERO

★Verobloc **350p.**
Size 0.1 matrix

2.5 × 1"	22p
2.5 × 3.75"	75p
2.5 × 5"	85p
3.75 × 5"	95p
VQ Board	160p
Veropins per 100	
Single sided	50p
Double sided	60p
Spot face cutter	105p

CAPACITORS

Polyester. Radial Leads. 250V. 280 type
0.01, 0.015, 0.022, 0.033, **6p**; 0.047, 0.068, 0.1, **7p**;
0.15, 0.22, **9p**; 0.33, 0.47, **13p**; 0.68, **20p**; 1u **23p.**

Electrolytic Radial or Axial leads.
0.47/63V, 1/63V, 2.2/63V, 4.7/63V, 10/25V, **7p**;
22/25V, 47/25V, **8p**; 100/25V, **9p**; 220/25V, **14p**;
470/25V, **22p**; 1000/25V, **30p**; 2200/25V, **50p**
Polyester. Miniature Siemens PCB
1n, 2n2, 3n3, 4n7, 6n8, 10n, 15n, **7p**; 22n, 33n, 47n, 68n, **8p**;
100n, **9p**; 150n, **11p**; 220n, **13p**; 330n, **20p**; 470n, **26p**;
680n, **29p**; 1u, **33p**; 2u2, **50p.**

Tantalum bead.
0.1, 0.22, 0.33, 0.47, 1.0 @ 35V **12p**; 2.2, 4.7, 10 @ 25V, **20p**; 15/16V **30p**; 22/16V, **27p**; 33/16V, **45p**; 47/6V, **27p**; 47/16V, **70p**; 68/6V, **40p**; 100/10V, **90p.**

Ceramic. 22p-0.01u. 50V. **3p each.**
★Mullard Miniature ceramic plate.
★1.8pF to 100pF. **6p each.**
Polystyrene. 5% tolerance.
10p-1000p **6p.** 1500-4700p **8p.** 6800-0.012 **10p.**
Trimmers. Mullard 808 Series.
2-10pF **22p.** 2-22pF **30p.** 5.5-65pF **35p.**

BOXES

Dimensions in inches. Aluminium

3 × 2 × 1	70p	6 × 4 × 2	120p
4 × 3 × 1½	85p	6 × 4 × 3	150p
4 × 3 × 2	100p	8 × 6 × 2	180p

Plastic with lid and screws.
3 × 2 × 1in. **55p**
4½ × 3 × 1½in. **88p**
7 × 4 × 2in. **160p**

PCB MATERIALS

Alfac PCB transfer sheets — please state type (e.g. DIL pads etc.)	45p
Dalo etch resist pen	100p
Fibre glass board 3.75" × 8"	75p
Ferric Chloride 250ml bottle	100p

SOLDERING IRONS

Antex CX 17W Soldering Iron	420p
2.3mm and 4.7mm bits to suit	55p
CX 17W element	190p
Antex X25 25W Soldering Iron	440p
3.3mm and 4.7mm bits to suit	55p
X25 25W element	190p
Solder pump desoldering tool	480p
Spare nozzle for above	70p
10 metres 22 swg solder	100p

REGULATORS

Positive		Negative	
78L05	30	79L05	65
78L12	30	79L12	65
78L15	30	79L15	65
7805	45	7905	45
7812	45	7912	45
7815	50	7915	55
LM309K	130	LM723	40
LM317K	320	LM338K	475
LM317T	120	78H05	
LM323K	350	5A 5V	550

DIODES

BY127	12	★1N4001	3
OA47	10	1N4002	5
OA90	8	1N4006	7
OA91	7	1N4007	7
OA200	8	1N5401	15
OA202	8	1N5404	16
1N914	4	1N5406	17
★1N4148	2	400mW zen.	6p

★BZX61 Series zeners.
★1.3W. 4V7-39V **15p each.**

HARDWARE

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

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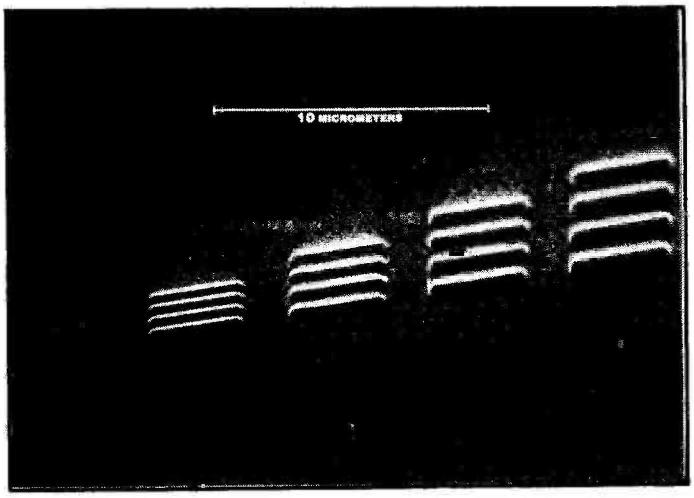
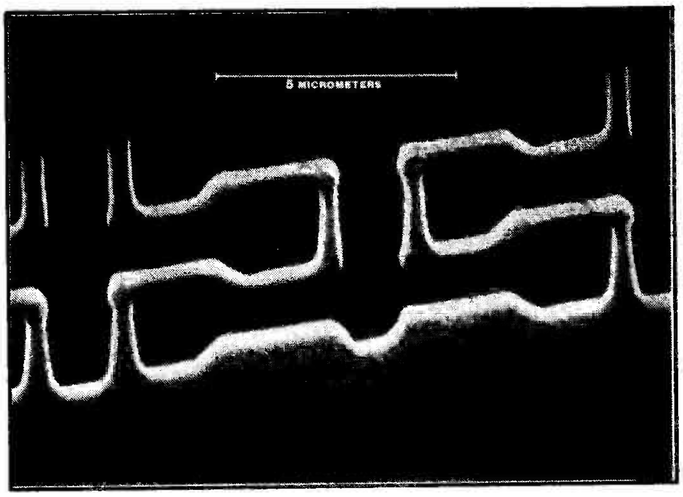


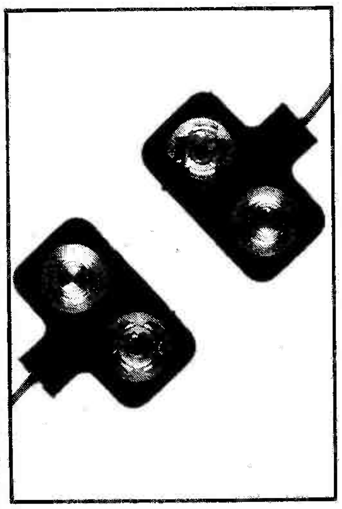


Submicron Sculpture

These remarkably neat and tiny patterns were produced using the new Direct-Write Lithography System (VLS-1000) developed by Varian Associates of California. The system will produce high-density, submicron circuits at a throughput of 10-15 four inch wafer levels per hour. The first picture is a resolution test pattern while the second is a gate array pattern — somewhat beautiful, is it not?

New UD

Maxell have brought out a new UD cassette with a considerably better performance than the previous one. High frequency saturation level, bias noise level and housing stability are said to be particularly good. Apparently it's due to the wonder ingredient, New PX Gamma Ferric Oxide, which has fewer voids and more uniform particle size. The magnetic particle layer is also extremely uniform, causing modulation noise and DC noise to be minimised. The New UD cassettes will be on sale from early April. By the way, lads, just *love* the new TV ad.



Making Connections

A new range of low cost moulded battery clips have been announced by Dau. The moulded connector (a PP3 type is shown) offers long term reliability by overcoming corrosion problems. For further information contact Dau (UK) Ltd, 70-74 Barnham Road, Barnham, Bognor Regis, West Sussex PO22 0ES.

Shorts

● Good news for kit builders — the new Spring/Summer 82 catalogue from Heathkit is out, with several additions to their already extensive range and a Spring Sale on many items.

● A word processing package is now available for the TRS-80 Model I and II that offers a professional range of facilities for a reasonable price. You'll need 48K, one disc drive, and £79.00 plus VAT and postage. "Newscript" is available from E.A. International, 8 High St., Meldreth, Royston, Herts SG8 6JV.

● Hewlett-Pckard are getting a bit carried away with VLSI technology — they've just developed a chip set for mainframe-like performance which includes a 32-bit processor running off an 18 MHz clock, a 16K x 8 RAM and a 16K x 40 ROM chip. Jeez....

● Made in Wales.... the TC-2011 20" colour TV from Panasonic. The set features auto-search tuning, channel memory, a teak cabinet and 3 W audio output, and is available now from authorised dealers.

● Celdis of Reading can now supply the new Mostek MK4802 16K static RAM direct from stock. Organised as 2K x 8 for ease of use, the chip is compatible with all the other members of Mostek's Bytewyde memory family.

● The latest BAEC newsletter has reached us; amongst other things it contains a catalogue survey, projects, book reviews and a nice write-up on the Breadboard exhibition. Thank you, gentlemen — we're glad you enjoyed it too.

● Rapid Electronics are on the move — by the time you read this they'll be at Hill Farm Industrial Estate, Boxted, Colchester, Essex. This is just off the A12 and Rapid say callers will be most welcome.

● Winner of the recent "Office of 2000 AD" design competition was an attache case containing a data processor/transmitter/receiver; if you press a button the case describes itself and how it works through a built-in loudspeaker. The day my briefcase starts talking to me is the day I give up the Beaujolais....

● Still and moving pictures from one shop; the Fotòvalue photographic franchise are to introduce Telefunken VHS video into their camera shops. Products for sale are a video recorder, four televisions, accessories (including a Teletext adaptor) and a colour camera.

● Good old Goonhilly (you remember, Telstar and all that) is to get a facelift. British Telecom are replacing the antenna ready for use with the Intelsat system from the end of 1984. Cost is estimated at £3 million.

● Semiconductor Specialists are now stocking two of Raytheon's high-performance dual low-noise op-amps, the RC5532 and the RC5532A. Suitable for applications in high quality audio equipment and instrumentation circuits, these chips are an all-round improvement over standard items such as the 1458.

● Why send us a press release about Britain exporting Tigers to Africa, we wondered? Because Tigers are telephone management and accounting systems manufactured by Minster Automation, that's why. Nice to see some foreign cash flowing this way for a change.

● IMF Electronics have launched a couple of professional monitor loudspeakers and a studio monitor. They feature such esoteric delights as a "ferro-fluid damped tweeter" and are apparently rather good.

● KGB Micros Ltd are now selling an IEEE 488 interface bus for Superbrain for £200. With a name like that, how can you dare refuse to buy one?

● Build a better photodiode and the world will beat a path to your door. The BPW41D from Ferranti has a very high rejection of wavelengths below 700 nm and is ideal for infra-red remote control and data transmission systems.

● Mitsubishi — bless you — have recently succeeded in manufacturing an amorphous solar cell, with the world's highest energy conversion efficiency (8.5%). My dictionary says amorphous means 'shapeless'; must be great fun trying to build them into equipment.

GLOBAL SPECIALTIES CORPORATION

GSC

At last the message has come through, all you old solderers can throw away the soldering irons and the perforated circuit boards. NOW you can use PROTO-BOARDS from GSC. Despite daily break-throughs in components and packaging, designing and testing new circuit con-cepts is often a lot more manual work than creative work. No wonder if you are using old fashioned perforated boards and time-consuming soldering. With PROTO-BOARDS any component can be plugged in, tested, removed, and used again. Circuits can often be designed from component pinouts and the circuit diagram does not need to be drawn until after the circuit is working properly. PROTO-BOARD designing is very much like careful single-sided printed circuit design in terms of the effects of parasitics and in terms of operation at high frequency or low levels. Well planned grounds and judicious use of shielded cable can permit operation through VHF frequencies. So, you old solderers, stop soldering on! Send off for our FREE 40 page catalogue; we have a PROTO-BOARD to fit any size budget.

PROTO BOARDS

Models PB-203, PB-203A and PB 203AK offer a large breadboarding area and a built in regulated power supply housed in a rugged metal cabinet Models PB6 to PB105 offer various breadboarding areas screw mounted onto sturdy back plates with non slip, non scratch vinyl feet Red and black binding posts are included, the red being electrically insulated from the back plate, the black being electrically connected for ground

PB 203

Includes 5VDC, 1 amp power supply, available at binding posts, two binding posts (V1, V2) remain uncommitted The perfect board for TTL and other 5 volt logic designs

PB 203A

Every development engineer should have one of these, includes 5VDC 1 amp power supply. Also includes separate + 5.5 to 18 VDC and 5 5 to 18 VDC power supplies, each capable of supplying 500 mA at 15 VDC. Power supplies are factory preset to + 15 VDC but can be independently adjusted

PB 203AK

Identical to PB 203A but in kit form

PB 6

A kit form breadboard with 4 binding posts 630 contact points and includes non slip rubber feet

PB 100

Another kit form breadboard with 760 contact points

PB 101

A robust laboratory breadboard accepts up to 10 IC'S, 940 contact points.

PB 102

A fully assembled breadboard with 1240 contact points

PB 103

With 2250 contact points this board is perfect for prototyping and custom circuit applications

PB 104

A total IC capacity of 32 with 3060 contact points makes this the ultimate electronics development engineers breadboard

PB 105

The newest Protoboard, 4560 contact points, 48 IC capacity!

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MODEL NO	NO OF SOLDERLESS TIE POINTS	IC CAPACITY (14 pin DIP's)	UNIT PRICE	PRICE INC P&P 15% VAT	QTY REQUIRED
PB6	630	6	9.75	12 36	
PB100	760	10	12.50	15.52	
PB101	940	10	17 90	22 31	
PB102	1240	12	24.95	30.41	
PB103	2250	24	39.00	46 57	
PB104	3060	32	49.00	58.07	
PB105	4560	48	71 00	83.95	
PB203	2250	24	61.00	72.96	
PB203K	2250	24	89.00	104.65	
PB203AK	2250	24	71 00	83.95	

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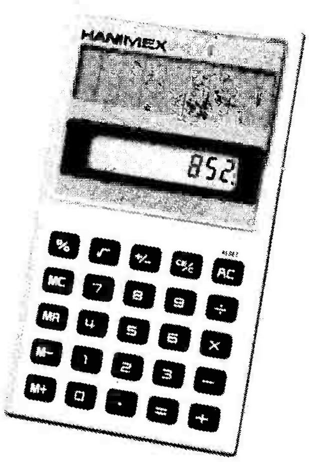
CB11 3AQ

West Hyde Wonders

We've just received the latest West Hyde catalogue; curiously they're always out of step with the seasons (this one's dated Winter 81-82) but who cares, there are lots of goodies inside. With boxes and racks to suit any application you can think of, and then some, this is definitely the first place to look if you're after an enclosure.

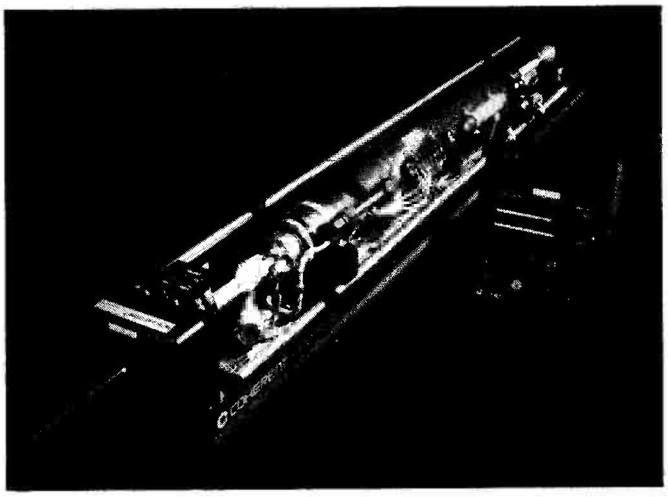


Solar Sums

Provided you don't want to do any calculations in the dark, Hanimex's new light-activated calculators dispense with the need for batteries. Even dim light is sufficient now that a new generation of very efficient light-sensitive cells have been developed, and Hanimex expect these calculators will become the leading solar calculators of the year. The SC852 has a list price of £13.95 while the 853 is £10.95.

Who's Kidding Who?

Now this is very silly. In fact we thought it was a joke, except that the press release is dated March 1st, not April 1st. Anyway, BL Systems and ITR have announced the TARDIS — Time and Attendance Direct Input System — which is claimed to be much more efficient than traditional shop floor clocking-on methods. It says here that the key feature of TARDIS is the use of TIMELORD clocks — honest! — and that the computer-controlled system cuts the work involved in payroll/attendance calculations by up to 75%. Watch out, Doctor; the Time-and-motion Men are out to get you!



Process Your Post

Hands up all those with ordinary weighing machines in their postrooms? Bit of a drag, isn't it, peeling the sticky labels off the scale and fixing new ones every time the PO puts its rates up? This microprocessor-controlled scale can be easily updated by the customer to keep track of inflation, and it offers a lot more besides. The scale is "user-friendly", letting you know what you've done wrong, and can be helpful in other ways (weighs?) too. For example, it can tell you the cheapest way to send a packet overseas. For more details on the Intermail XK 10/25 contact Paul Numan of C. Stevens and Son (Weighing Machines) Ltd, 287/289 Goswell Road, London EC1V 7LD.

In Coherent

Innova 90 lasers, developed by Coherent (UK) Ltd and to be exhibited at Electro-optics/Laser International 82, are an entirely new concept in ion laser design. The "Cool Disc" bore technology gives higher guaranteed power capability with longer life expectancy, while other design features mean a hands-off, trouble-free laser for both research and industry. Maybe we can get our hands on one and have a *real* game of Space Invaders. . .

A Fine Pear

Apparently the microcomputer industry has some sort of preoccupation with fruit. We already have the Apple and Tangerine systems and shortly we'll have the PEAR II. This PAL-colour microcomputer is based on the ubiquitous 6502 microprocessor and is intended for the more advanced user who wants to choose from various programming languages. Typical options are BASIC, Pascal, FORTRAN or COBOL. The standard system has 32K of RAM, on-board expandable to 96K using bank-select. Further expansion to suit your requirements is accomplished using plug-in cards. The PEAR II will be available around September/October of this year for £975 plus VAT, and further information can be obtained from Pearcom Ltd, 17 Nobel Square, Basildon, Essex SS13 1LP. Anyone for pomegranite?

Dai-Electric

Hospitals at Wrexham and Swansea are to have reliable fire and alarm monitoring systems fitted by the Welsh Health Technical Services Organisation. The Statiscan System is based on a single three-core cable and uses time-division multiplexing to transmit hundreds of signals from the monitoring points to the central consoles. (Of course, you all know about TDM because we featured it in Notebook in April.) The system is produced by Static Systems Group of Wolverhampton and will no doubt be of great use when the home rule nuts run out of English holiday cottages to burn. •

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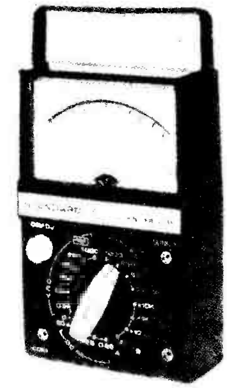

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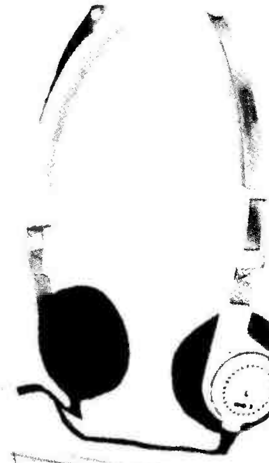

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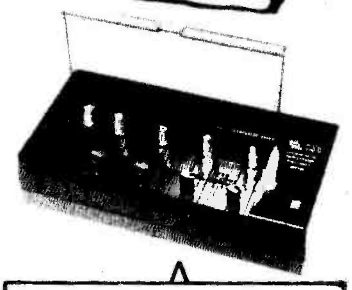

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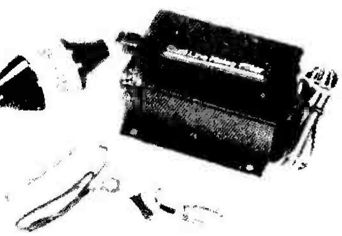

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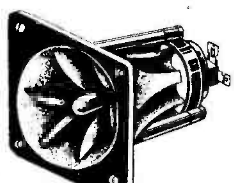

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NEXT MONTH

electronics today INTERNATIONAL

TV BARGRAPH

Surely your television can be put to better use than as an aid for insomnia? The video game manufacturers pointed the way and we've published a couple of designs ourselves — but how about using the television as a research tool? Next month we do just that with our TV Bargraph project; a device that displays analogue voltages as a histogram (columns) on any domestic 625-line set. The horizontal axis may be at the bottom of the screen (for positive-only inputs) or half-way up for AC signal displays, and the number of channels is user-selectable. The basic unit has eight, while additional channel cards will give 16, 32 (how about 1/3 octave spectrum analysis over the audio band?), 64 and even 128 channels on a good TV. We could have used a video controller chip for this project, but you wouldn't have learnt much from it; the circuit uses standard logic ICs so you can see how the TV sync signals are generated. Don't wait for ITV2; get a new channel on your telly with the July ETI.

MOSFET BRIDGING MODULE

Now you'd think most ordinary people would be more than happy with the power output of the MOSFET amplifier published this month. But we know better. Time and again it's been proved that ETI readers like to provoke their neighbours, weaken their foundations and generally make their presence felt with LOUD music; and who are we to argue? To forestall the inevitable requests for more power, next month we show you how a cheap, simple add-on circuit will enable you to bridge two ETI-5000 modules, giving a 300 W output and shattered windows in the living room.

VIDEO SYSTEMS

Next month we fearlessly take the lid off video recording — literally. Taking time off from hi-fi, Stan Curtis has been unbolting all kinds of video recorders and finding out exactly what's inside and what it does. You never knew there was so much in it. Don't miss the July issue for the story even the video magazines couldn't bring you.

AUDIOPHILE

We've been waiting to get our hands on one of these for a long time. Look at the sleek lines, the compact build, the elegant black enclosure, the hint of mysteries within to enthrall you long into the night. (And if you haven't figured out that next month's article features the power amp rather than the admittedly lovely lady, then one of us has the wrong magazine). The long months of flattery, threats, bribery and begging have finally resulted in a Magnetic Field Power Amplifier — the Carver Cube — being delivered into the hot, eager hands of your editor (now stop that!). As Stan Curtis pointed out a year ago, this extraordinary amp is only 7" on a side and can punch out an incredible 200 W per channel. In that article the technical merits of the design were examined; now Ron Harris can reveal all concerning the sound quality. It's in Audiophile next month — be there!

LOOK OUT FOR THE JULY ISSUE ON SALE JUNE 5th

Articles described here are in an advanced state of preparation. However, circumstances may dictate changes to the final contents.

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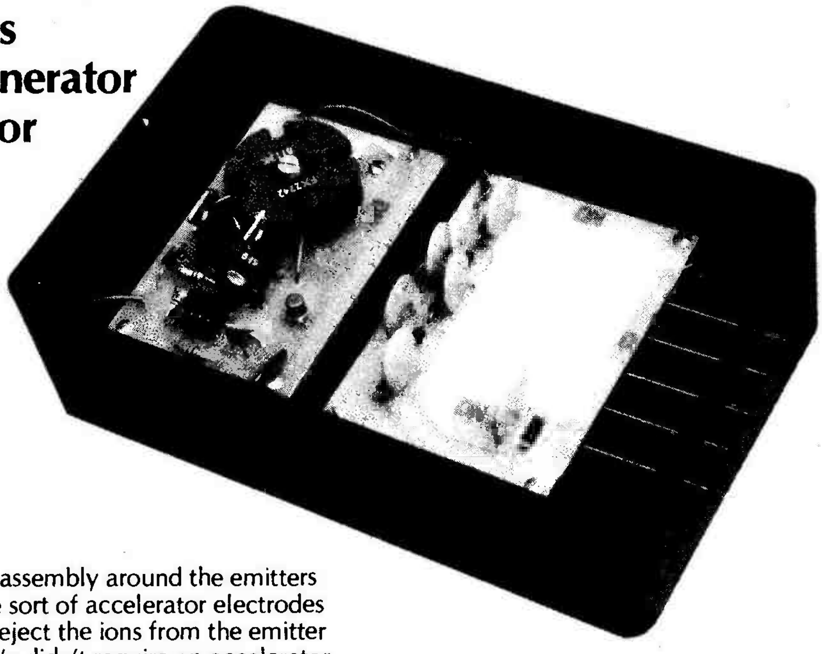
NEGATIVE ION GENERATOR

For readers who just have to find out for themselves what this subject is all about, this negative ion generator should provide a good basis for experiment. Design by Jonathan Scott. Development by Graeme Teesdale.



The rise in popularity of negative ion generators, the claims made for them, and the attention they have received in newspapers and magazines recently has undoubtedly intrigued many readers with a technical background or interest. As the electronics associated with a negative ion generator is relatively simple, generally employing readily available components, this article describes how to build a unit that can be used as the basis for experiment.

Design Of The Emitter Head

The object of the emitter head is to take in the HT, in our case about 3 kV, and produce a stream of negative ions flowing forwards into the room in which the generator is placed. The ions are produced by a very intense field gradient, which is induced by the high voltage and the geometry of the head assembly. This ion flow is a corona wind.

It is a basic principle of electrostatic physics that the field gradient is stronger in the immediate vicinity of a point projection, the gradient being greater when the point is sharper so most ion generators employ some combination of sharp projections and high voltage.

Pointing The Way

If the points are spaced well away from other parts of the unit the ions will naturally repel themselves away from the region of emission. However, if the point or points are partially enclosed in the case of the device there may need to be either a chimney-shaped assembly around the emitters or some sort of accelerator electrodes to help eject the ions from the emitter head. We didn't require an accelerator as the points protrude beyond the slot in the case.

Wherever there is ion production there will be ozone production. Ozone is corrosive as well as a strong antibacterial agent, and is poisonous in sufficient concentration. In order to keep it to a minimum, as low a voltage as possible should be used. Our project has been designed to give the lowest voltage compatible with adequate ion production. The design should be such as not to allow any arcing or serious breakdown; this is really only likely if you try using an "accelerator", as there will be no metal in close proximity to the emitter otherwise.

The best metal for the points which is easily obtainable is steel, preferably stainless. This is hard enough to hold an edge and will resist the effects of cathode stripping. The latter is undesirable both because the fine point will be eroded away, and also because the heavy metal ions which are ejected are undesirable agents in the air we breathe (stick to getting your minerals from cornflakes).

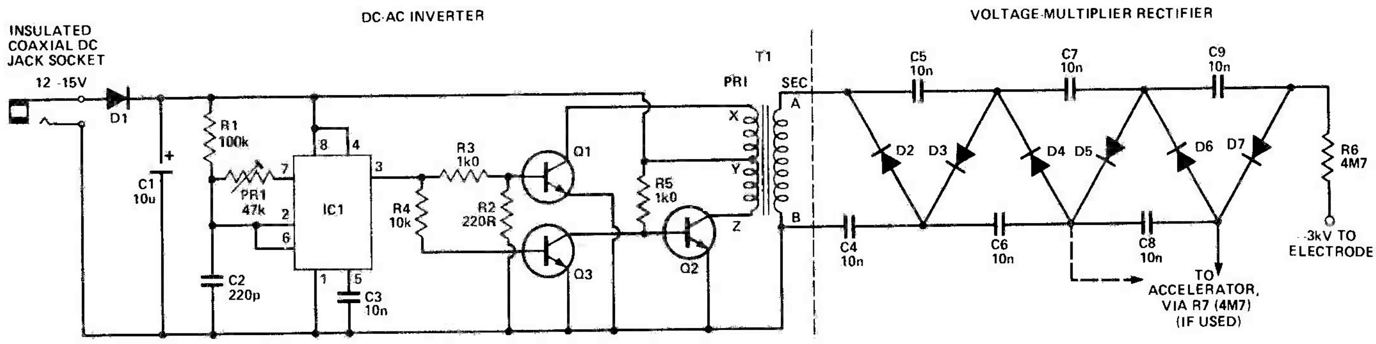
There is no shock hazard as the unit is not mains powered and there is a very large series resistance between the points and the multiplier output. At most, there results something between a nip and a tickle if you touch the emitter points.

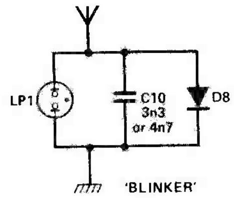
Construction

First stage of construction is to assemble the components on the PCBs; commence with the inverter board. Insert the resistors, capacitors, IC and transistors before asembling the transformer to it. As usual, take care with the orientation of the diode, IC1 and the transistors. Next, wind the transformer — details are given in the box. The transformer employs a potcore and this can be held on to the PCB with a nylon bolt — do not use a metal bolt. Cut the transformer coil wires to length, scrape off the insulation and solder them in place. The TIP31C transistors, Q1 and Q2, do not actually require any heatsink, though they do get warm in operation.

The high voltage board may be assembled next. Take care with the orientation of the diodes. Stand the capacitors erect on the board so that they do not touch each other or you may have arc-over problems between these components.

Mount the appropriate components on the 'blinker' board





NOTE
IC1 IS 555
Q1,2 ARE TIP 31C
Q3 IS BC107
D1,8 ARE 1N4001
D2-7 ARE 1N4007

Fig. 1 Circuit diagram for all three sections of the negative ion generator. Current consumption of the unit is a little too high for use with ordinary batteries; we recommend you run it from a battery eliminator pack or a 12 V car battery.

PARTS LIST

Resistors (all ¼ W, 5%)

R1	100k
R2	220R
R3,5	1k0
R4	10k
R6,7	4M7

Potentiometer

PR1	47k miniature vertical preset

Capacitors

C1	10u 16 V tantalum
C2	220p ceramic
C3	10n polycarbonate
C4-9	10n 1 kV ceramic
C10	3n3 or 4n7 polystyrene or ceramic

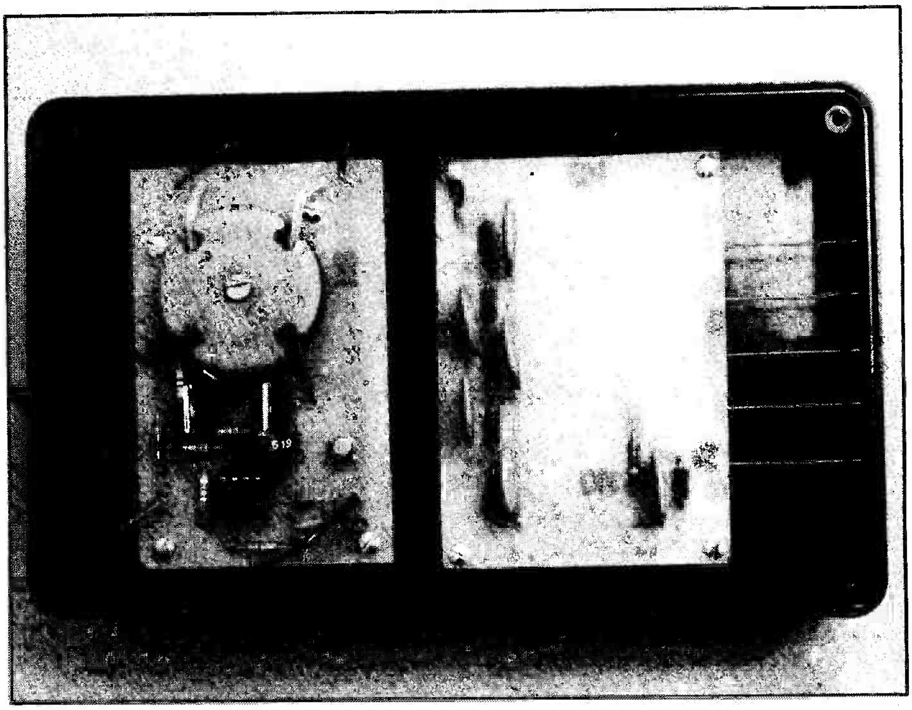
Semiconductors

IC1	555
Q1,2	TIP31C
Q3	BC107 or BC547
D1,8	1N4001
D2-7	1N4007 or similar (1 kV PIV)

Miscellaneous

LP1	wire-ended neon bulb (no series resistor)

PCBs (see Buylines); potcore and former (FX2242 — see Buylines); coaxial DC jack socket; case (180 x 110 x 55 mm, Vero ref. 75-2861D); five needles.



The inverter and high voltage boards mounted side by side in the case, with the emitter needles protruding through the slot in the side of the case.

next, as you'll need this for a testing aid. It is important to watch the diode polarity here. The cathode of the diode goes to the pad marked with the 'ground' symbol. Note that the components are mounted on the *copper* side.

The emitter points are steel needles soldered directly to the PCB. The easiest method is to tape the needles, parallel and the correct distance apart, so they overhang the end of a wooden block etc. Support the board underneath, and touching, the overhanging needles and solder them in place before removing the tape. Since ions will be ejected from any sharp point we recommend you cut all the component leads on the high voltage board and then resolder them, using enough extra solder to give rounded solder blobs. (Make sure the same is true of the needle connections). This will prevent unwanted ion leakage.

The DC input socket we mounted on one side of the box. Exactly how the DC coaxial jack socket is wired will depend on how your plug pack output plug is wired. Some have the outer connector connected to positive, while others have it connected to the negative.

Getting It Going

You will need a multimeter and a supply of between 9 V DC and 14 V DC. Switch the meter to the current range to read 300 mA full scale or more, and connect it in series with the DC supply input. Switch the supply on and, assuming all is well, adjust PR1 on the inverter board for *minimum* current. This could be between about 220-280 mA.

Run the unit for a few minutes, then switch off, discharge the rectifier capacitors and feel Q1 and Q2. One should not be markedly hotter than the other, otherwise you have adjusted PR1 incorrectly or you have a fault — most likely a transistor inserted incorrectly or a dry joint between the output of IC1 (pin 3) and the bases of Q1, Q2, or Q3.

Having confirmed everything

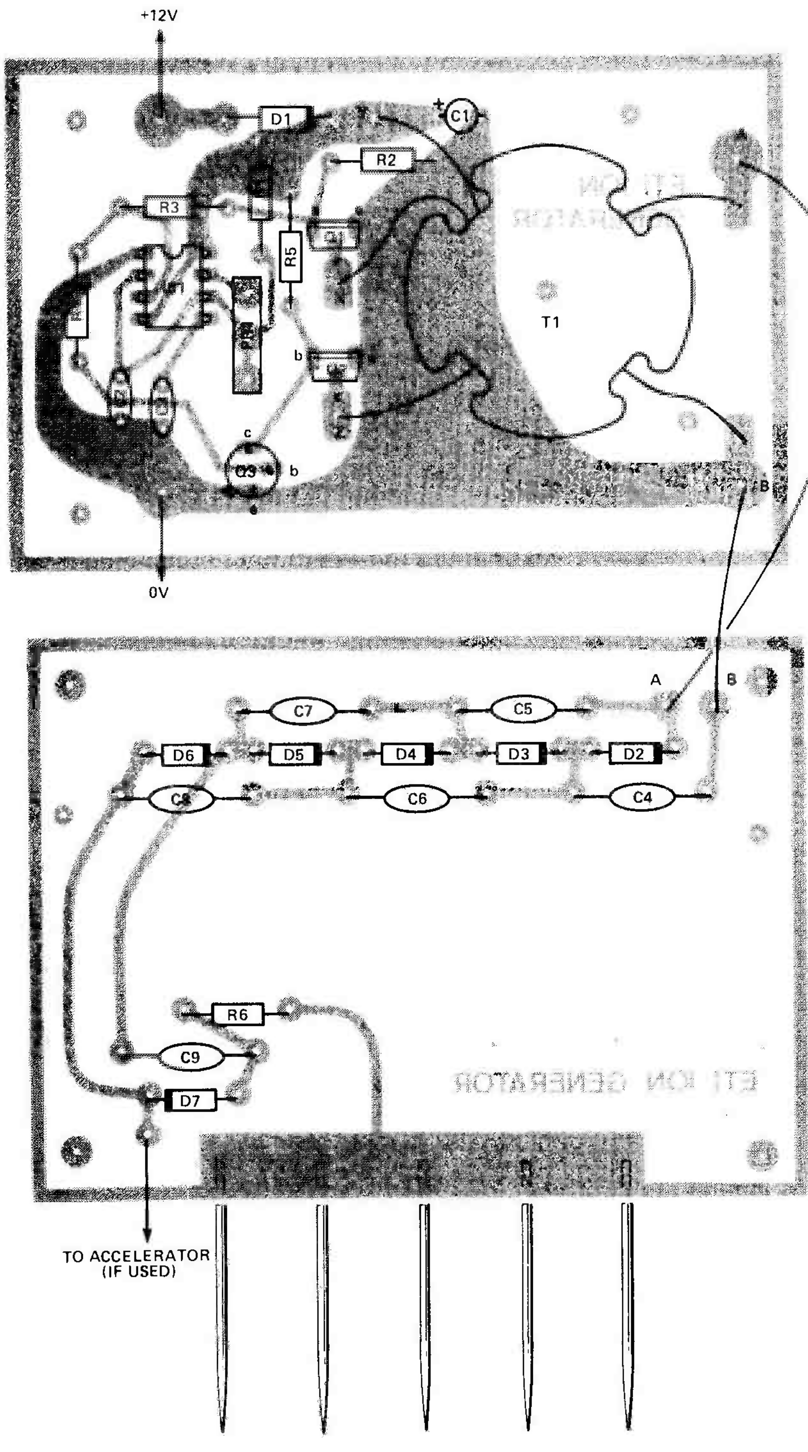


Fig. 2 Component overlay and wiring for the ion generator. The two-board design will allow for different physical layouts and connection pads are provided for experimentation with accelerators and off-board emitters.

HOW IT WORKS

The DC-to-AC inverter consists of a 555 astable multivibrator, the output of which is used to drive two transistors operated in push-pull. The collectors of Q1 and Q2 switch current through each side of the transformer (T1) primary in turn. Diode D1 prevents any damage from a supply connected with reverse polarity. Capacitor C1 is a bypass. IC1 oscillates at around 25 kHz, determined by R1 and C2. The exact frequency is unimportant. The mark-to-space ratio of the output of IC1 (at pin 3) may be adjusted by PR1, which is connected in series with pin 7 of IC1.

The output of IC1 drives the base of Q1 directly, via R3 and R2. Q1 turns on when the output of IC1 goes high. Resistor R3 is there principally to limit the base current supplied to Q1, while R2 serves to discharge the base emitter junction capacitance so that Q1 turns off quickly when the output of IC3 goes low.

When pin 3 of IC1 goes high, Q3 also turns on, preventing Q2 from turning on. When pin 3 of IC1 goes low, Q1 and Q3 turn off and Q2 will turn on as base bias will be supplied via R5. Thus current is alternatively switched through each side of the primary T1. The secondary provides a voltage step-up of 25:1. If the supply voltage is 12 V DC, then the peak-to-peak output from the secondary of T1 will be 600 V.

The voltage-multiplier rectifier employs the well-known Cockcroft-Walton circuit, where the output of successive half-wave rectifiers is connected in series with the previous one. This circuit provides a multiplication of six times. Thus, with a 12 V DC supply, the output will be about − 3.6 kV. With a 10 V DC supply (as can be obtained from a 9 V DC battery eliminator), about − 3 kV is obtained. An output for an 'accelerator' is provided.

The high voltage output to the emitter head is taken via a 4M7 resistor to ensure that only low short-circuit current occurs if the emitter head is accidentally contacted or excessively humid air causes 'flashover' from the emitter.

The blinker is simply a crude relaxation oscillator. When a charge builds up on the 'antenna' pad, it will charge C10. When the voltage on C10 reaches the breakdown voltage of LP1 (about 70 V), the neon will conduct. This will discharge the capacitor, the voltage across it falling until it reaches the extinguishing voltage of the neon (about 30-40 V), which will then cease conduction. While the neon conducts, it will emit light, but as it discharges C10 fairly rapidly, all you will see is a brief flash from the neon. Diode D8 ensures only negative charges operate the blinker.

When the neon ceases conduction, the charge on C10 will build up again and the whole process will be repeated.

works as it should, and having adjusted PR1, assemble it all into the case and you can check its operation with the blinker.

Turn the ioniser on and grasp the blinker so that your thumb is in good contact with the pad marked by the 'ground' symbol. Hold the blinker such that the 'antenna' pad is about 10 mm in front of the emitter. You should be able to count around one blink per second if all is well and this is a good 'benchmark' for successful operation when you experiment with different head designs and geometries.

Notes On Experimentation

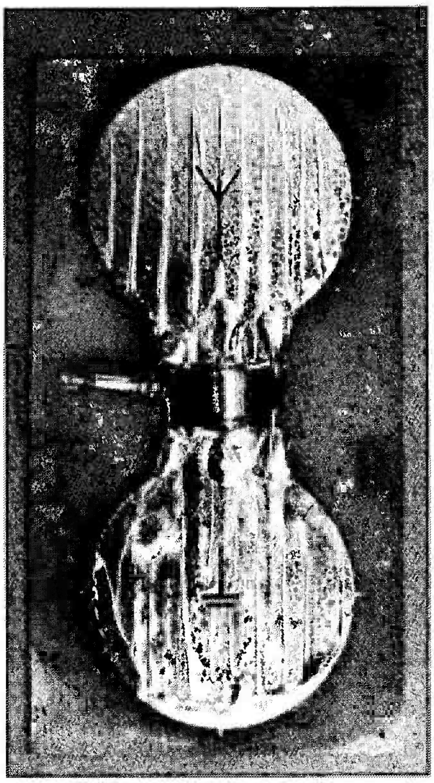
This project shows but one way to construct a negative ion generator and the electronics can readily serve as the basis for experimenting with different designs. Higher voltages are unnecessary — and are not usual in commercial designs — and can lead to problems with ozone generation, breakdown, etc. A connection is available on the high voltage board for supplying an 'accelerator' on an emitter head. It should be connected via a 4M7, ¼ W resistor. The accelerator voltage could be tapped off lower down the rectifier chain if desired — we suggest at the junction of C6 and C8.

The exact value of capacitors C4 to C9 on the high voltage board is not important and may be any value between about 1nF and 22nF or so, but should not be lower than 1nF. The voltage rating of these capacitors should not be less than 1000 V.

The DC supply should not be greater than 15 V or more turns be wound on the secondary of T1, else you may experience insulation breakdown within the transformer.

BUYLINES

None of the electronic components for this project should cause any supply problems. The FX2242 is stocked by C.T. Electronics (Acton) Ltd. of 267/270 Acton Lane, London W4 5DG. Suitable steel needles can be obtained from your family sewing drawer! Failing that, any sewing accessories supplier can help you. The boards can be obtained from our PCB Service at the prices given on page 82.



The assembled blinker, which we tinned with solder to avoid sweaty finger marks and oxidation. The cathode of D8 is at the bottom.

TRANSFORMER WINDING DETAILS

Potcore: FX2242
Secondary: 125 turns of 0.2 mm diameter enamelled copper wire.
Primary: 10 turns, centre-tapped, of 1.0 mm diameter enamelled copper wire.

The secondary is wound on the potcore bobbin first. Wind it in five or six neat layers. Slip thin plastic sleeving over the start and finish leads so that the sleeving is held well inside the bobbin. As you finish winding each layer, insulate it with 1 mm mylar sticky tape (if you can obtain it) or electrical insulation tape (a bit heavy, but it will do the job). Wind the next layer on the insulation of the previous layer, and so on until you finish winding. Wind several layers of insulation over the completed secondary. Leave the start and finish wires protruding from the different sides of the bobbin so that they exit via different slots of the assembled potcore.

Wind the primary over the secondary; it can be wound bifilar (two wires together, five turns, connect finish of one to start of other to provide centre tap) or in one winding — but don't forget the centre tap. Wind the primary so that its wires exit the potcore opposite the secondary wires.

In operation, if you have breakdown problems (arcing sounds inside the potcore) it means you have not wound or insulated your secondary carefully enough and you'll have to rewind the transformer.

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LM555CN	0.16
LM556CN	0.45
LM725CN	3.20
LM741CN	0.14
LM747CN	0.64
LM748CN	0.34
REGULATORS	
7805	0.39
7812	0.39
7815	0.39
78L05	0.29
78L12	0.29
78L15	0.29
7905	0.55
7912	0.55

Device	Price
7915	0.55
79L05	0.59
79L12	0.59
79L15	0.59
LM309K	0.99
LM317K	3.20
LM323K	4.95
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Z80 FAMILY	
Z80 CPU	3.49
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6800	2.99
6802	3.99
6803C	11.60
6809	9.99
6810	1.12
6821	1.25
6840	4.20
6850	1.50

Device	Price
4010	0.35
4011	0.12
4012	0.15
4013	0.29
4014	0.58
4015	0.58
4016	0.25
4017	0.45
4018	0.58
4019	0.29
4020	0.58
4021	0.60
4022	0.62
4023	0.17
4024	0.35
4025	0.16
4026	0.99
4027	0.30
4028	0.55
4031	1.65
4033	1.60
4034	1.55
4035	0.72
4040	0.54
4041	0.69
4042	0.54
4043	0.59
4044	0.64
4045	1.65
4046	0.68
4047	0.68
4048	0.54
4049	0.26
4050	0.26
4051	0.59
4052	0.68
4053	0.59
4054	1.20

Device	Price
4555	0.39
4556	0.44
4585	0.62
74LS SERIES	
74LS00	0.10
74LS01	0.11
74LS02	0.12
74LS03	0.12
74LS04	0.12
74LS05	0.13
74LS08	0.12
74LS09	0.12
74LS10	0.12
74LS11	0.12
74LS12	0.12
74LS13	0.22
74LS14	0.37
74LS15	0.12
74LS20	0.12
74LS21	0.12
74LS22	0.12
74LS26	0.15
74LS27	0.12
74LS28	0.15
74LS30	0.12
74LS32	0.12
74LS33	0.18
74LS37	0.15
74LS38	0.15
74LS40	0.12
74LS42	0.33
74LS47	0.39
74LS48	0.59
74LS49	0.59
74LS51	0.14
74LS54	0.15
74LS55	0.15

Device	Price
74LS166	0.84
74LS173	0.69
74LS174	0.45
74LS175	0.45
74LS181	1.28
74LS190	0.49
74LS191	0.49
74LS192	0.49
74LS193	0.45
74LS194	0.39
74LS195	0.39
74LS196	0.57
74LS197	0.59
74LS221	0.54
74LS240	0.69
74LS241	0.69
74LS242	0.78
74LS243	0.79
74LS244	0.60
74LS245	0.88
74LS247	0.80
74LS248	0.60
74LS249	0.63
74LS251	0.40
74LS253	0.39
74LS257	0.43
74LS258	0.39
74LS259	0.78
74LS261	1.95
74LS266	0.22
74LS273	0.70
74LS279	0.39
74LS283	0.44
74LS290	0.54
74LS293	0.45
74LS365	0.34
74LS366	0.36
74LS367	0.34
74LS368	0.35
74LS373	0.70
74LS374	0.70
74LS375	0.47
74LS377	0.70
74LS378	0.60
74LS379	0.64
74LS386	0.28
74LS390	0.54
74LS393	0.59
DIL SOCKETS LOW PROFILE - TIN	
8 pin	0.07
14 pin	0.09
16 pin	0.09
18 pin	0.13
20 pin	0.14
22 pin	0.17
24 pin	0.19
28 pin	0.25
40 pin	0.29
LOW PROFILE - GOLD	
8 pin	0.22
14 pin	0.29
16 pin	0.31
18 pin	0.33
20 pin	0.35
22 pin	0.40
24 pin	0.42
28 pin	0.54
40 pin	0.81
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4008	0.55
4009	0.28

Device	Price
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4060	0.79
4063	0.95
4066	0.34
4068	0.17
4069	0.17
4070	0.17
4071	0.17
4072	0.17
4073	0.19
4075	0.17
4076	0.62
4077	0.22
4078	0.24
4081	0.14
4082	0.19
4085	0.63
4086	0.69
4093	0.39
4502	0.69
4507	0.39
4508	1.90
4510	0.60
4511	0.49
4512	0.60
4514	1.49
4515	1.49
4516	0.69
4518	0.40
4519	0.28
4520	0.69
4521	1.49
4522	1.20
4526	0.70
4527	0.89
4528	0.70
4532	0.85
4541	0.99
4543	0.99
4553	2.90

Device	Price
74LS73	0.19
74LS74	0.16
74LS75	0.24
74LS76	0.20
74LS78	0.19
74LS83	0.44
74LS85	0.60
74LS86	0.15
74LS90	0.28
74LS91	0.74
74LS92	0.33
74LS93	0.33
74LS95	0.42
74LS109	0.21
74LS112	0.21
74LS113	0.23
74LS114	0.30
74LS122	0.39
74LS123	0.39
74LS124	1.20
74LS125	0.24
74LS126	0.25
74LS132	0.44
74LS136	0.28
74LS138	0.33
74LS139	0.35
74LS145	0.74
74LS148	0.90
74LS151	0.39
74LS153	0.28
74LS155	0.38
74LS156	0.36
74LS157	0.29
74LS158	0.31
74LS160	0.39
74LS161	0.37
74LS162	0.39
74LS163	0.38
74LS164	0.45
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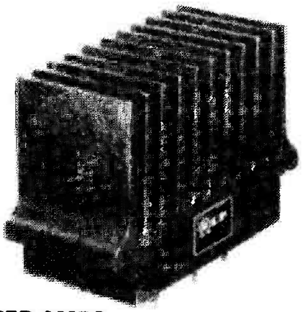

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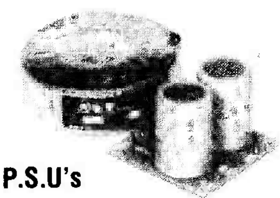
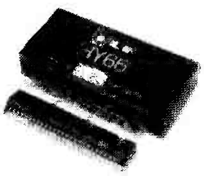


P.S.U's



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TECH TIPS

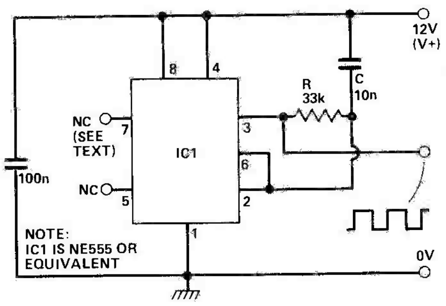
Surgeless 555 Clock

H.B. Broughton, Bishop's Stortford

The CMOS version of the 555 has two major advantages over the bipolar type: a) it is a micropower device; b) it is largely free of the supply current surges generated by an ordinary 555 every time its output changes state. This is important because the surge can upset other circuits powered from the same supply, but the problem can be avoided by using the rather unusual configuration shown, saving 60p an oscillator over the CMOS answer to this difficulty!

Experiment has shown that the supply surge (typically 300 mA by 100 ns) is roughly halved by using pin 3 (OUTPUT) of the 555 to charge/discharge the capacitor rther than pin 7 (DISCHARGE) and a resistor to V+. It is reduced to less than 25% of its typical size by using pin 3 *and* wiring the capacitor to V+, and is then small enough to be removed by a 100nF capacitor between the supply rails.

This gives the circuit shown, a 'surgeless' clock with frequency f = 6RC



(R in ohms, C in microfarads), mark/space ratio of typically 3:2, and voltage swing of 1 to 11 V. These figures were found using a load impedance of 330k; the frequency is affected if load impedance is less than about 10 x R, but if low impedances are to be driven, pin 7 can be used and the load wired from pin 7 to power: alternatively, a 1k5 reistor can be taken from pin 7 to power and the load put between pin 7 and ground, though this reduces the available voltage swing at pin 7.

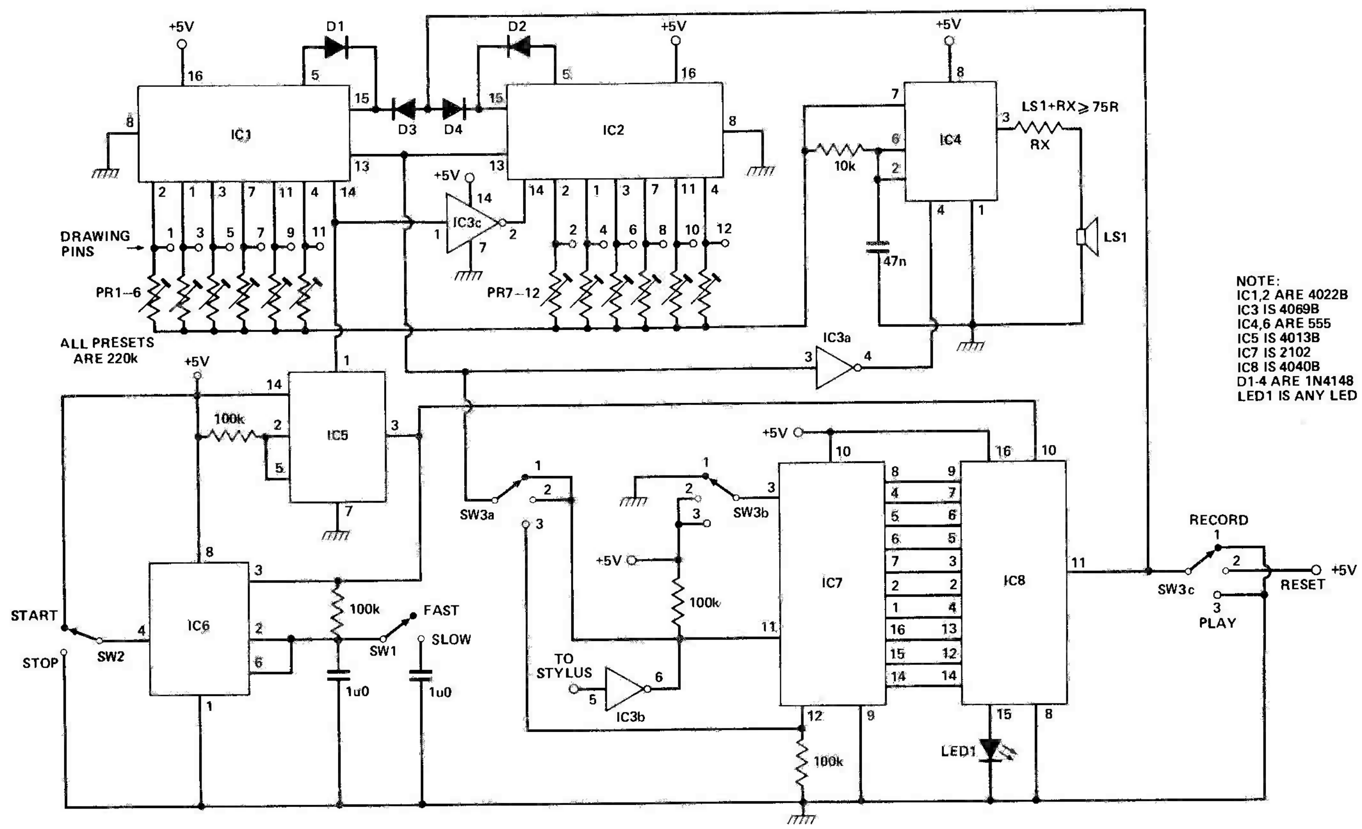
With the component values shown, this clock runs at 2 kHz and produces a nice clean square wave with low rise times.

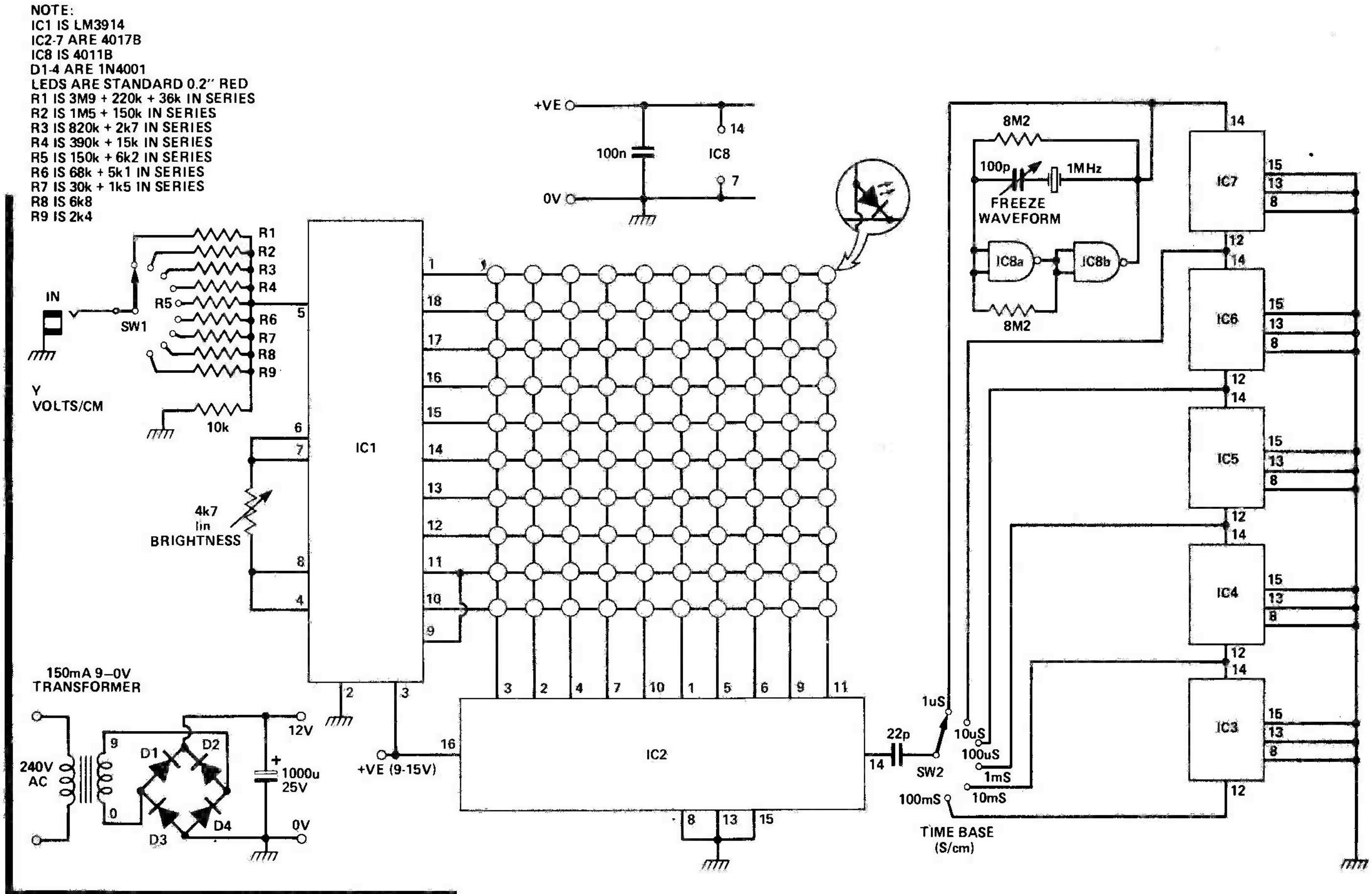
Stylophone With Memory

J.R. Walker, Norwich

This single-octave 'stylophone' can store and play back over a minute of music (two in 'slow' mode). The keyboard was constructed by pushing drawing pins into a plastic box on to which a C to C keyboard was drawn. The drawing pins are numbered one to twelve; this is just the order in which they are scanned and it doesn't matter what notes they actually are, since they are manually tuned by the presets PR1-12. LED1 indicates that no more memory is left, while SW2 allows you to stop in the middle of playback/record without affecting the tune. The unit is automatically reset when switching from play to record, and by leaving it on reset you can play tunes without affecting the one in memory. Like magnetic tape, recording completely wipes out what was previously recorded. To obtain the best results, record in 'slow' and play back in 'fast', since one finger playing is not a speedy operation!

In 'fast' mode IC6 oscillates at about





10 Hz, causing IC1 and IC2 to scan the keyboard (each one clocks on by one alternately). IC4 is held off by IC3a. If the stylus is placed on one of the drawing pins, nothing will happen until the counters get to that pin. At this point they stop and IC4 turns on, producing a note. The pitch of the note depends on which preset is driving pin 7 of IC4. The note stays on until the probe is removed from the pin, whereupon everything carries on as before.

With each pulse of IC6, IC7 clocks on once, counting from 1 to 1024 in the memory. IC8 remembers if a note was played at that point. On playback all counters are reset and IC8 plays back the tune, taking 1024/10 or over 100 seconds to do so. Slow mode takes roughly twice as long.

The power rail (5 V at 200 mA) should be well smoothed (say 1000uF-3300uF) to preserve the memory if the supply flickers (memory is lost on power-down). Although the circuit doesn't draw anything like 200 mA the capacity to deliver this current is important as IC4 and IC6 can draw heavily on the power rails.

Solid State Scope Using LEDs

G. Durant, Selby

This 'scope' is completely solid state, with the absence of the cathode ray tube. The tube is replaced by a 10 by 10 matrix of LEDs which provide a smaller, more robust substitute. The Y input is connected via a series resistor to IC1, an LM3914 which is an LED bargraph driver. The IC is used in the dot mode and therefore, if a waveform is applied to the Y input, a single 'dot' will appear to move up and down with the voltage from the wave. Input sensitivity is adjusted via SW1, which brings different series resistors into circuit. The resistors are odd values and are made up by placing two or three in series. If 1% resistors are used, an accuracy of about 0.25% can be achieved.

The LEDs must be spaced 1 cm apart, both on the X and Y axis. The use of an LED matrix screen means that the scope can be very thin — in fact pocket-size. Also, an LED screen does not need very high voltages to work it, so batteries could be used. The only problem is that at high frequencies the resolution is not as good as it could be, although the scope can be used nevertheless at frequencies up to 1 MHz.

The time base uses a crystal-controlled CMOS clock running at 1 MHz. This is broken down into lower frequencies by a string of divide-by-10 chips, in this case 4017s. These frequencies go to a six-way selector switch which selects the timebase frequency. The time base is variable from 100 mS right down to 1 uS in steps of 10. A 100pF variable capacitor, marked 'freeze waveform' is used to fine-tune the main oscillator, so the waveform can be frozen.

A suitable power supply is also shown, but any supply may be used with an output voltage of about 12 V (not more than 15 V). Even a 9 V battery could be used (eg PP9) as, in theory, only one LED is on at a time.

The scope can be expanded to use more LEDs, or to have a trigger device. For the beginner, however, the scope shown would be sophisticated enough to be of great service.

Tech-Tips is an ideas forum and is not aimed at the beginner. We regret we cannot [illegible] ETI is prepared to consider circuits or ideas submitted by readers for this page. All items [illegible] Drawings should be as clear as possible and the text should be typed. Text and drawings [illegible] Circuits must not be subject to copyright. Items for consideration should be sent to ETI [illegible] 145 Charing Cross Road, London WC2H 0EE.

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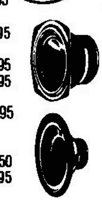

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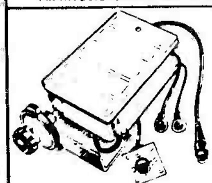

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MN35. 10 asstd switches, toggle, slide, micro etc.
MN37. 10 asstd audio connectors Din phono etc
MN38. 1 PCB with triac control IC data inc
MN39. 1 oscillator PCB loads of components (no data)
MN40. 50 Polystyrene capacitors.
MN41 12 BC549C (Plastic BC109C) Transistors
MN42. 10 BC107 Transistors.
MN43. 10 BC108 Transistors.
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MN51. 10 x 0.2" Red LEDs.
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MN69 4 min push to break switch

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2114L-200	225p	210p
2716 (+5V)	459p	
2532	450p	400p
2732	450p	400p
4116-200	90p	85p
6116-150	550p	500p

CONNECTOR SYSTEMS

I.D. CONNECTORS
(Speedblock Type)

No. of ways	Header Plug	Receptacle	Edge Conn.
10	90p	90p	200p
20	165p	165p	240p
26	200p	200p	300p
34	240p	240p	380p
40	270p	270p	550p
50	310p	310p	600p

D-CONNECTORS

	9 way	15 way	25 way	37 way
MALE				
Solder	95p	136p	200p	280p
Angled	160p	230p	265p	425p
FEMALE				
Solder	125p	190p	245p	375p
Angled	175p	240p	310p	500p
Hood	100p	100p	100p	150p

37 way Centromix Type Plug £6.50

DIL HEADER PLUGS

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

RIBBON CABLE (Grey)

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

JUMPER LEADS

24" Ribbon Cable with headers

1 end	145p	165p	240p	380p
2 ends	210p	230p	345p	540p

24" Robbon Cable with sockets

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1 end	160p	210p	270p	300p
2 ends	290p	385p	490p	540p

24" Robbon Cable with D Conn.
25 way Male 500p Female 550p

EDGE CONNECTORS

	0.1"	0.156"
2 × 18 way	–	150p
2 × 22 way	310p	170p
2 × 23 way	335p	–
2 × 25 way	350p	200p
1 × 43 way	260p	–
2 × 43 way	450p	–
2 × 50 way	–	400p
1 × 77 way	700p	–
S100 Conn.	–	600p

EURO CONNECTORS
(Indirect Edge Conn.)

DIN STD	Plug	Skt
41617 21 way	160p	160p
41617 31 way	200p	200p
41612 2 × 32 way	300p	350p
Angled 2 × 32 way	360p	400p
41612 3 × 32 way	370p	420p
Angled 3 × 32 way	–	450p
2 × 32 way IDC A + C		475p

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12V	7812	50p	7912	50p
15V	7815	50p	7915	50p
18V	7818	50p	7918	60p
24V	7824	50p	7924	60p
5V 100mA	78L05	30p	79L05	60p
6V 100mA	78L06	30p		
8V 100mA	78L08	30p		
12V 100mA	78L12	30p	79L12	60p
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KEYBOARD ENCODER

AY-6-2376 700p, 74C922 500p

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BAUD RATE GENERATORS

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MM58174 850p

LOW PROFILE SOCKETS BY TEXAS

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

WIRE WRAP SOCKETS BY TEXAS

8 pin 25p, 14 pin 35p, 16 pin 40p, 18 pin 50p, 20 pin 60p, 22 pin 65p, 24 pin 70p, 28 pin 80p, 40 pin 100p

TRANSISTORS

AD161/2 45p, BC107/8 13p, BC109C 14p, BC117 20p, BC147/8 9p, BC149 10p, BC157/8 10p, BC159 11p, BC169C 12p, BC172 12p, BC177/8 17p, BC179 18p, BC182/3 10p, BC184 11p, BC187 30p, BC212/3 11p, BC214 12p, BC237 15p, BC327 16p, BC337 16p, BC338 16p, BC461 25p, BC477/8 30p, BC516/7 40p, BC547B 14p, BC548C 12p, BC549C 16p, BC557KB 14p, BC559C 16p, BCY70 18p, BCY71 22p, BD131 75p, BD135/6 40p, BD139 40p, BD140 40p, BD189 60p, BD232 60p, BD233 75p, BD235 85p, BD241 60p, BD242 60p, BD379 60p, BD380 60p, BD677 40p, BF244B 35p, BF256B 50p, BF257/8 32p, BF337 30p, BFR39 25p, BFR40/1 25p, BFR79 25p, BFR80/1 25p, BFR96 180p, BFX29 40p, BFX30 27p, BFX84/5 40p, BFX86/7 27p, BFX88 27p, BFX89 180p, BFY50 24p, BFY51/2 24p, BFY56 33p, BFY90 80p, BRY39 45p, BSX19/20 24p, BU104 225p, BU105 190p, BU108 250p, BU109 225p, BU126 150p, BU180A 120p, BU205 200p, BU208 200p, BU406 145p, BUX80 £6, BUY69C 350p, E310 50p, MJ802 £4, MJ2501 225p, MJ2955 90p, MJ3001 225p, MJ4502 £4, MJE340 60p, MJE2955 100p, MJE3055 70p, MPF102 40p, MPF103/4 30p, MPF105 30p, MPSA06 30p, MPSA12 50p, MPSA13 30p, MPSA20 50p, MPSA42 50p, MPSA43 50p, MPSA56 32p, MPSA70 50p, MPSA93 40p, MPSU06 63p, MPSU07 60p, MPSU45 90p, MPSU65 78p, TIP29A 35p, TIP29C 40p, TIP30A 35p, TIP30C 40p, TIP31A 40p, TIP31C 40p, TIP32A 45p, TIP32C 40p, TIP33A 70p, TIP33C 80p, TIP34A 90p, TIP34C 120p, TIP35A 120p, TIP35C 140p, TIP36A 140p, TIP36C 150p, TIP41A 50p, TIP41C 55p, TIP42A 60p, TIP42C 65p, TIP54 160p, TIP120 75p, TIP121 75p, TIP122 80p, TIP142 120p, TIP147 120p, TIP2955 78p, TIP4055 70p, TIS93 30p, ZTX108 12p, ZTX300 13p, ZTX452 45p, ZTX500 15p, ZTX502 16p, ZTX504 18p, ZTX552 55p, ZTX652 60p, ZTX752 70p, VN66AF 72p, VN10KM 60p, VN66 80p, 2N697 25p, 2N698 45p, 2N706A 30p, 2N708 30p, 2N918 45p, 2N930 18p, 2N1131/2 36p, 2N1613 25p, 2N1711 25p, 2N2102 70p, 2N2160 350p, 2N2219A 25p, 2N2222A 25p, 2N2369A 25p, 2N2484 30p, 2N2646 45p, 2N2904/5 25p, 2N2906A 25p, 2N2907A 25p, 2N2926 9p, 2N3053 30p, 2N3054 65p, 2N3055 48p, 2N3442 140p, 2N3553 240p, 2N3584 250p, 2N3643/4 48p, 2N3702/3 12p, 2N3794/5 12p, 2N3796/7 14p, 2N3708/9 12p, 2N3773 300p, 2N3819 25p, 2N3820 40p, 2N3823 50p, 2N3866 90p, 2N3902 700p, 2N3903/4 18p, 2N3905/6 16p, 2N4037 65p, 2N4123/4 27p, 2N4125/6 27p, 2N4401/3 27p, 2N4427 90p, 2N4871 60p, 2N5087 27p, 2N5089 27p, 2N5172 27p, 2N5191 90p, 2N5194 90p, 2N5245 40p, 2N5298 60p, 2N5401 60p, 2N5457/8 40p, 2N5459 40p, 2N5460 60p, 2N5485 44p, 2N5875 250p, 2N6027 48p, 2N6052 300p, 2N6059 325p, 2N6107 65p, 2N6247 190p, 2N6254 130p, 2N6290 65p, 2SC1172 150p, 2SC1306 100p, 2SC1307 150p, 2SC1957 90p, 2SC1969 150p, 2SC2028 95p, 2SC2029 200p, 2SC2078 200p, 2SC2335 250p, 2SC2612 250p, 3N128 120p, 3N140 120p, 3N141 110p, 3N201 110p, 3N204 120p, 40290 260p, 40361/2 75p, 40408 90p, 40409 100p, 40410 100p, 40411 300p, 40594 120p, 40595 120p, 40673 75p, 40871/2 100p

DIODES

BY127 12p, BYX36 300 20p, OA47 8p, OA90/91 9p, OA95 9p, OA200 9p, OA202 10p, 1N914 4p, 1N916 7p, 1N4148 4p, 1N4001/2 5p, 1N4003/4 6p, 1N4005 6p, 1N4006/7 7p, 1N5401/3 14p, 1N5404/7 19p, 1S920 9p

BRIDGE RECTIFIERS

1A 50V 19p, 1A 100V 20p, 1A 400V 25p, 1A 600V 30p, 2A 50V 30p, 2A 100V 35p, 2A 400V 45p, 3A 200V 60p, 3A 600V 72p, 4A 100V 95p, 4A 400V 100p, 6A 50V 80p, 6A 100V 100p, 6A 400V 120p, 10A 400V 200p, 25A 400V 400p

ZENERS

2.7V-33V 400mW 9p, 1W 15p

TRIACS PLASTIC

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

THYRISTOR

3A 400V 100p, 8A 600V 140p, 12A 400V 180p, 16A 100V 180p, 16A 400V 180p, C106D 45p, MCR101 36p, TIC44 27p, 2N3525 130p, 2N4444 180p, 2N5060 30p, 2N5064 35p

PCB MOUNTING RELAYS

6 or 12V DC Coil SPDT 2A 24V DC 160p

6 or 12V DC Coil DPDT 5A 24V DC 240V AC 200p

6 or 12V DC Coil SPDT 10A 24V DC 240V AC 225p

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The mechanical construction of voltage divider and preamp is shown in Fig. 1. The major component (and main constructional member) is the switch SW1 (a Makaswitch type). Between wafers 1 and 2 is fitted screening plate 2 (measurements as in Fig. 3) and between wafers 2 and 3, screening plate 3 (dimensions in Fig. 4). The screening plates support the voltage divider board and are soldered to it (on the copper track). The preamplifier board forms the end of the switch assembly. The entire section is surrounded by screening plate 1 (dimensions in Fig. 1) which is screwed to the bottom of the case and to the front structure.

In order to achieve a good earth connection for the switch rotor a safety pin, mounted on screening plate 3 before assembly (Fig. 5) is used as an earth contact.

The component layouts for the voltage divider and preamplifier boards are shown in Figs. 6 and 7. Resistors R1, R2, R15, R17, R19 and R21 are soldered directly to the switch contacts. Resistor R15 passes through screening plate 2 (drill diameter 4 mm). The two 3 mm holes are used for the (insulated!) passage of the connecting wires for switch contact 1 as well as for the connection to R15/R16. The same is true for R19 and screening plate 3.

The equipment is housed in an aluminium case; Fig. 6 shows the necessary drillings and cut-outs in the front panel. The screen cut-out (64 x 55 mm) must be fitted with a 'light tube', to prevent the entry of unwanted light. In the prototype instrument a plastic box was used from a pack of screws, having the appropriate outside dimensions. Behind this cut-out, a green film is fitted (from stationers) on which the measurement scale (6 x 8 squares of 7 mm side) has been drawn with Indian ink. The screen is fixed to the inside of the front panel using strips of foam draught excluder.

Figure 6 illustrates how the main board and screening plate 1 are fixed to the front section, using a bracket for each (M3 countersunk screw through the front section and the fixing bracket).

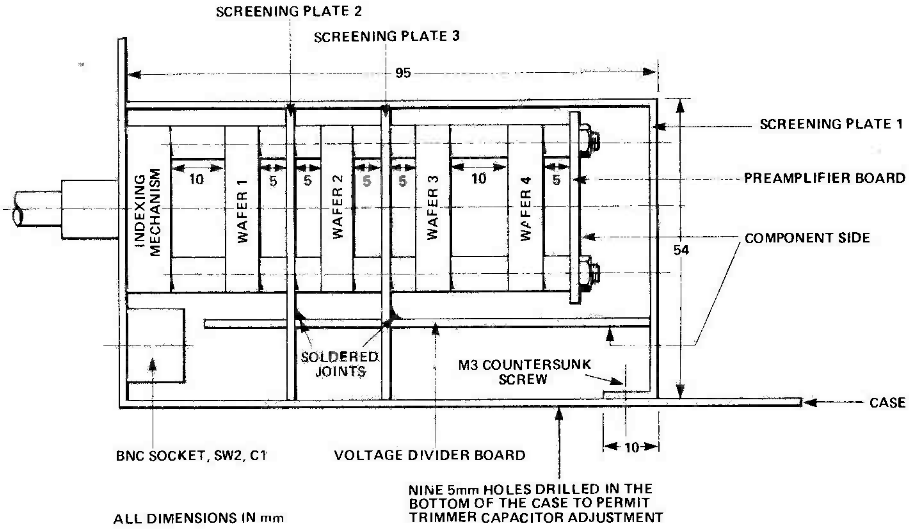


Fig. 1 Assembly of the voltage divider and preamp unit.

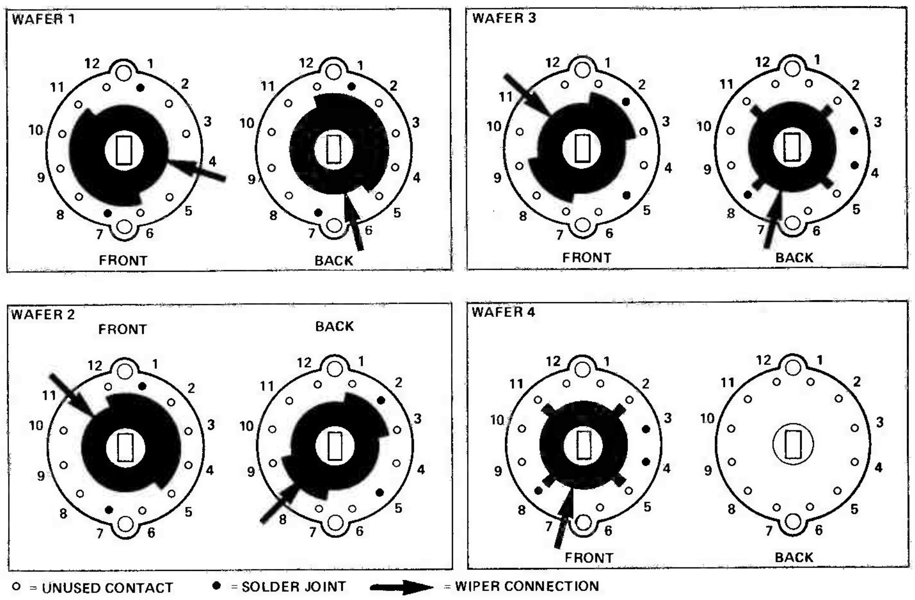


Fig. 2 SW1 contact wafer arrangement. Use in conjunction with the circuit diagram published last month.

The main board provides lengthwise stiffening of the case, since it is screwed at one end to the front section and at the other to the back panel (aluminium angle 10 x 10 x 1 x 70 mm long). The front half of the main board also provides lateral screening of the input voltage divider.

There are nine 5 mm diameter holes in the bottom of the case (mark and drill from the circuit board, after the components have been fitted) for the adjustment of trimmer capacitors CV1-9. There is also a countersunk hole to take the M3 screw used for fixing screening plate 1 (as in Fig. 1) and three other M4 countersunk holes for securing the power supply board

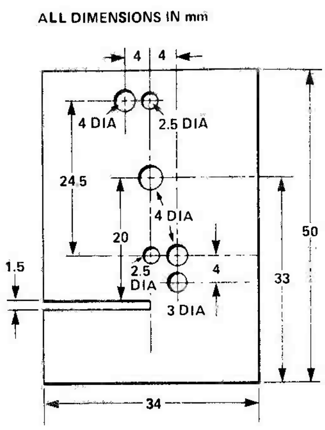


Fig. 3 Screening plate 2.

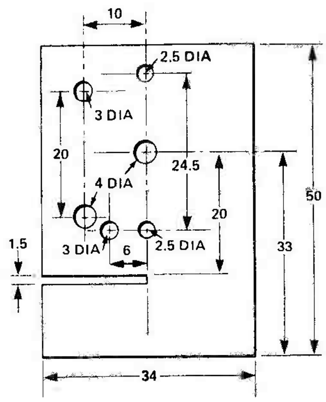


Fig. 4. Screening plate 3.

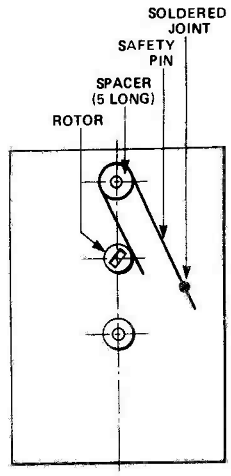


Fig. 5 Another view of screening plate 3.

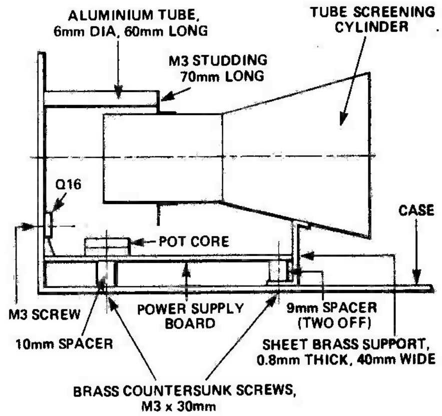


Fig. 7 The internal construction of the oscilloscope

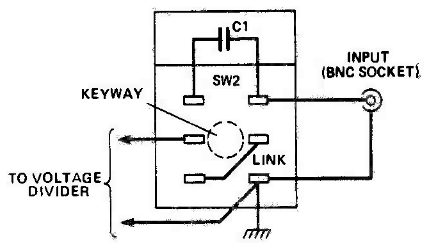
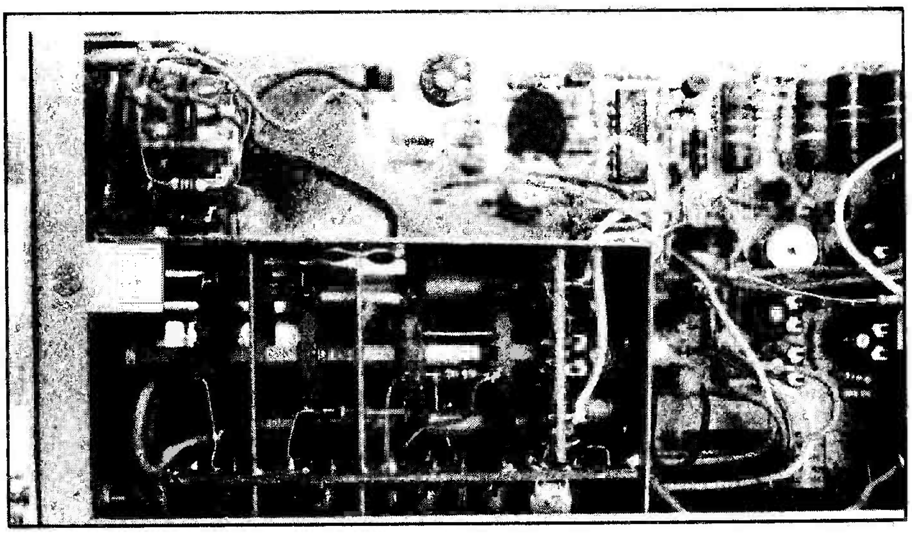


Fig. 8 The wiring details for SW2.



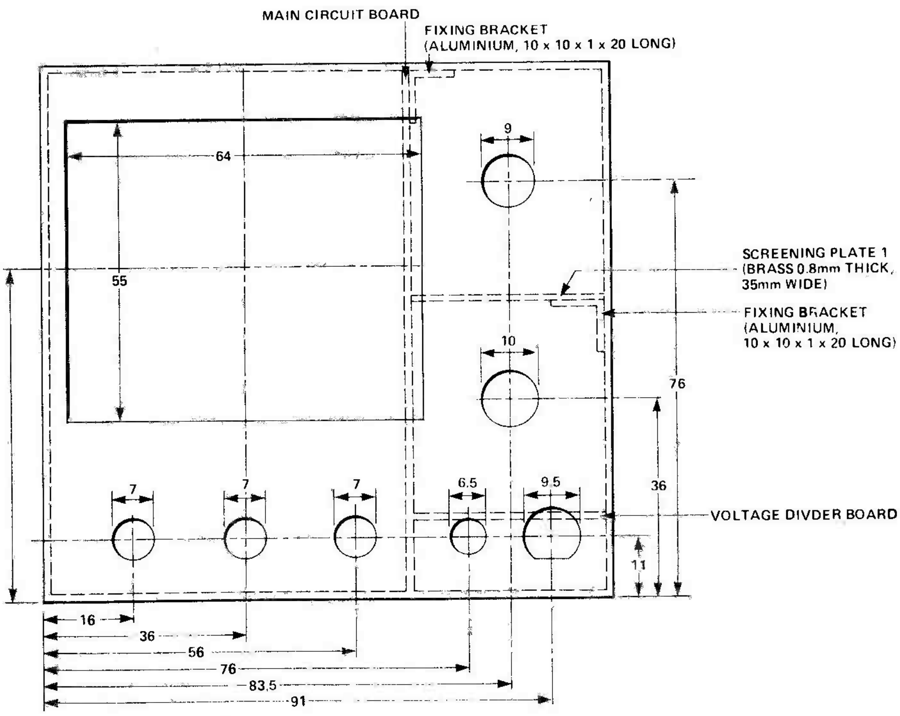


Fig. 6 The front panel drilling details.

(marked out from the board). Note that the screw which passes through the transformer core should be made of brass or plastic.

The cathode ray tube is passed through — and only held by — the draught-excluder-coated screening cylinder. The fixing of this cylinder is as shown in the photograph. The sheet brass supports are formed to the shape of the screening cylinder and soft-soldered or glued with Araldite. Q16 is screwed to, and insulated from, the back panel of the case (use a mica washer, and test the insulation after fixing!).

The back panel has six holes as follows; two x 8 mm for the insulated phono sockets (for the source voltage), four x 3.2 mm for the main circuit board fixing bracket, the M3 studding (tube fixture) and transistor Q16.

Switching On And Setting Up

An ammeter must be connected in the supply line for the initial operation. At switch-on, a current of about 850 mA (DC) should flow for a short time; this should fall within a few seconds to about 700 mA as the tube heater warms up and increases in resistance. The following checks and adjustments should be made in the order in which they are given.

Set the stabilised supply voltage (on C26) to 10 V, using PR7.

Check the V_{CE} voltage on Q18 or

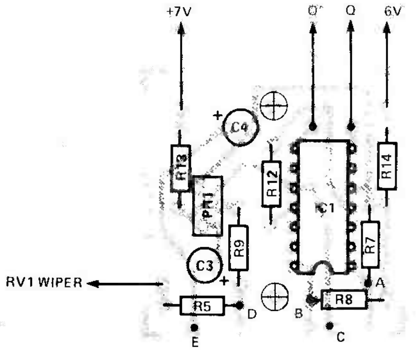


Fig. 9 Overlay for the preamp.

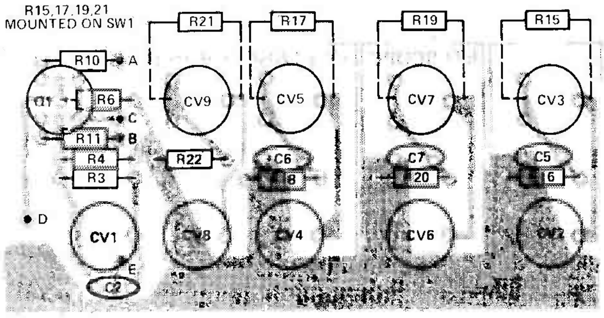


Fig. 10 Component overlay for the voltage divider board.

PARTS LIST

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

R1,2,10, 11,36,40,74	4 7 R
R3	90k9 1% metal film
R4,19	909k 1% metal film
R5,9,53,57	1 0 k
R6	100R 1% metal film
R7,8,49	2k05 1% metal film
R12	5 1 R
R13,14,77	1 0 R
R15,22	1M0 1% metal film
R16,47	10k 1% metal film
R17	750k 1% metal film
R18	332k 1% metal film
R20	110k 1% metal film
R21	500k 1% metal film
R23,26	22k ½W
R24,25	10k 1W
R27,28,29,64	150R
R30	47k
R31,82	22k
R32	100k
R33,34, 52,54,59,75	1k0
R35,37, 39,65,70	2k2
R38	220R
R41	56R
R42	10M
R43,50	4k7
R44	100k 1% metal film
R45	40k2 1% metal film
R46	20k5 1% metal film
R48	4k02 1% metal film
R51,58, 66,69,71,72	3k3
R55	330R
R56,62,63	470R
R60,61	22k 1W
R67	6k8
R68	56R ½W
R73	100R
R76	22R
R78,79	5k6 ½W
R80	1M0 ½W
R81	330k

Potentiometers

RV1,2	22k linear
RV3	22k linear with integral switch
PR1	22k miniature vertical preset
PR2,5	2k2 miniature horizontal preset
PR3,7	470R miniature horizontal preset
PR4,6	4k7 miniature horizontal preset
PR8	220k miniature horizontal preset
PR9	470k miniature horizontal preset
PR10	100k miniature horizontal preset

Capacitors

C1	68n 400 V polyester
C2	33p ceramic
C3,4	22u 16 V tantalum
C5	1n0 ceramic
C6,17	10p ceramic
C7	56p ceramic
C8	470n polycarbonate
C9	4u7 10 V tantalum
C10	150p ceramic
C11,14	47u 6V3 tantalum
C12,15, 16,18,27,28	4n7 ceramic
C13	4n7 160 V ceramic
C19	220n polycarbonate
C20	2n2 ceramic
C21,26,34,35	100u 16 V PCB electrolytic
C22	560p ceramic
C23	100n polycarbonate
C24	4n7 630 V ceramic
C25	2200u 25 V axial electrolytic
C29-32	22n 400 V polyester
C33	4u7 150 V PCB electrolytic
C36	100n 100 V polyester
C37	2u2 63 V axial electrolytic

Trimmer capacitors

CV1-9	5-20p 400 V trimmer (Valvo)
CV10	65p trimmer (Valvo)

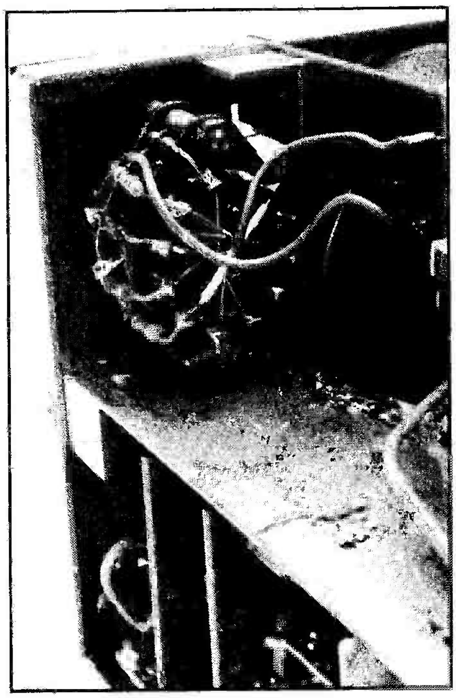
Semiconductors

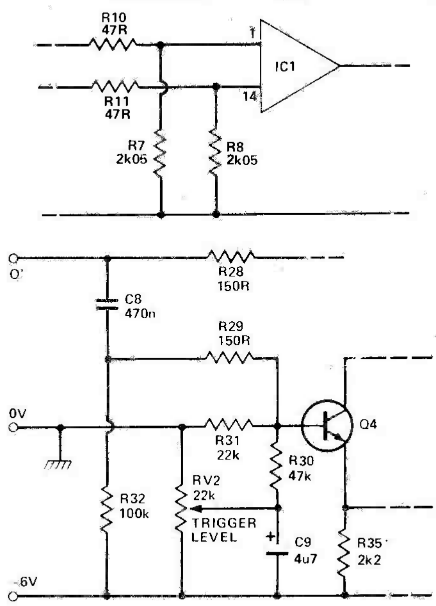
IC1	uA733
IC2	SN74132N
Q1	E430
Q2,3,11, 12,13	2N5551
Q4,8,15	BC252C
Q5	BF199
Q6,9	BF245A
Q7,10,14,17	BC172C
Q16,18,19	BD135
D1-3,8,17-21	1N4148
D4-7	1N4002
D9-12	BA158
D13-16	BAV20
ZD1	5V6 400 mW zener
ZD2	47V 400 mW zener

Miscellaneous

SW1	SEL type SM25-4-2E-25A-00U-No-Ag-1
SW2	three-way toggle switch
SW3	12 position wafer switch (with two wafers)
FS1	1 A fuse with PCB-mounting clips

PCBs (see Buylines); oscilloscope tube DG7-32; mumetal screen for tube; T1, potcore P18/11-3H1 without air gap (Valvo ref. 4322-022-04200), bobbin (4322-021-30280); enamelled copper wire; BNC socket; phono sockets; 1 mm brass sheet; various other hardware (see text); case.

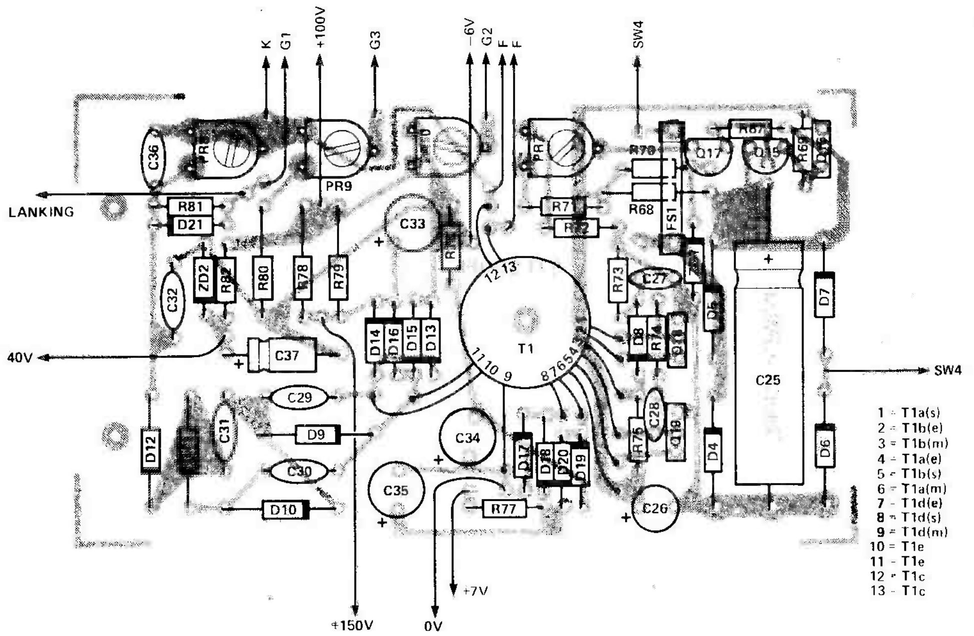


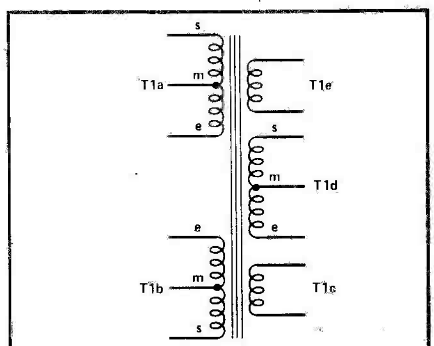


OOPS: There were a couple of errors in the circuits given last month. The corrected sections are shown above.

Q19. This should be a 25 kHz square wave with an amplitude of 20 V peak-to-peak and an overshoot of less than 10 V. Due to tolerances in the pot core, the frequency may vary from 25 kHz.

Check the tube heater voltage: a 12-13 V peak-to-peak square wave. The heater voltage cannot be measured with a simple multimeter! The relatively high frequency of 25 kHz will cause false readings. Check the +7 V, −6 V, +150 V and −460 V (on C36) supplies. Set the working point of the X-output stage, with PR6, to give 6 mA in the 150 V line. Set the working point of the Y-output stage, with PR3, to give +100 V 'after' R78/79. Set the beam to sufficient brightness with PR8 (not too bright, or the trace will be blurred). Adjust the trace for optimum sharpness in the middle of the screen with PR9 and PR10. Set the picture width with PR5. Rotate the tube so that the X-axis is exactly parallel to the drawn scale. Fix the tube in this position using adhesive tape. Turn the Y-position potentiometer to its mid-position, and adjust the trace to the middle of the screen using PR1 (on the preamplifier board).





TRANSFORMER WINDING DETAILS
CORE: TWO POT CORE HALVES P18/11-3H1
WITHOUT AIR GAP, VALVO NO. 4322-022-04200
BOBBIN: 4322-021-30280
SECTION 1
T1a: 2 x 8 TURNS OF 0.4mm ENAMELLED COPPER WIRE
T1b: 2 x 2 TURNS OF 0.1mm ENAMELLED COPPER WIRE
SECTION 2
T1c: 5 TURNS OF 0.3mm ENAMELLED COPPER WIRE
T1d: 2 x 7 TURNS OF 0.1mm ENAMELLED COPPER WIRE
T1e: 130 TURNS OF 0.1mm ENAMELLED COPPER WIRE

WIND ONE LAYER OF INSULATION AFTER EACH WINDING LAYER

T1a, T1b AND T1d ARE WOUND BIFILAR; IE TWO WIRES WOUND SIMULTANEOUSLY

Fig. 11 Component overlay for the power supply board.

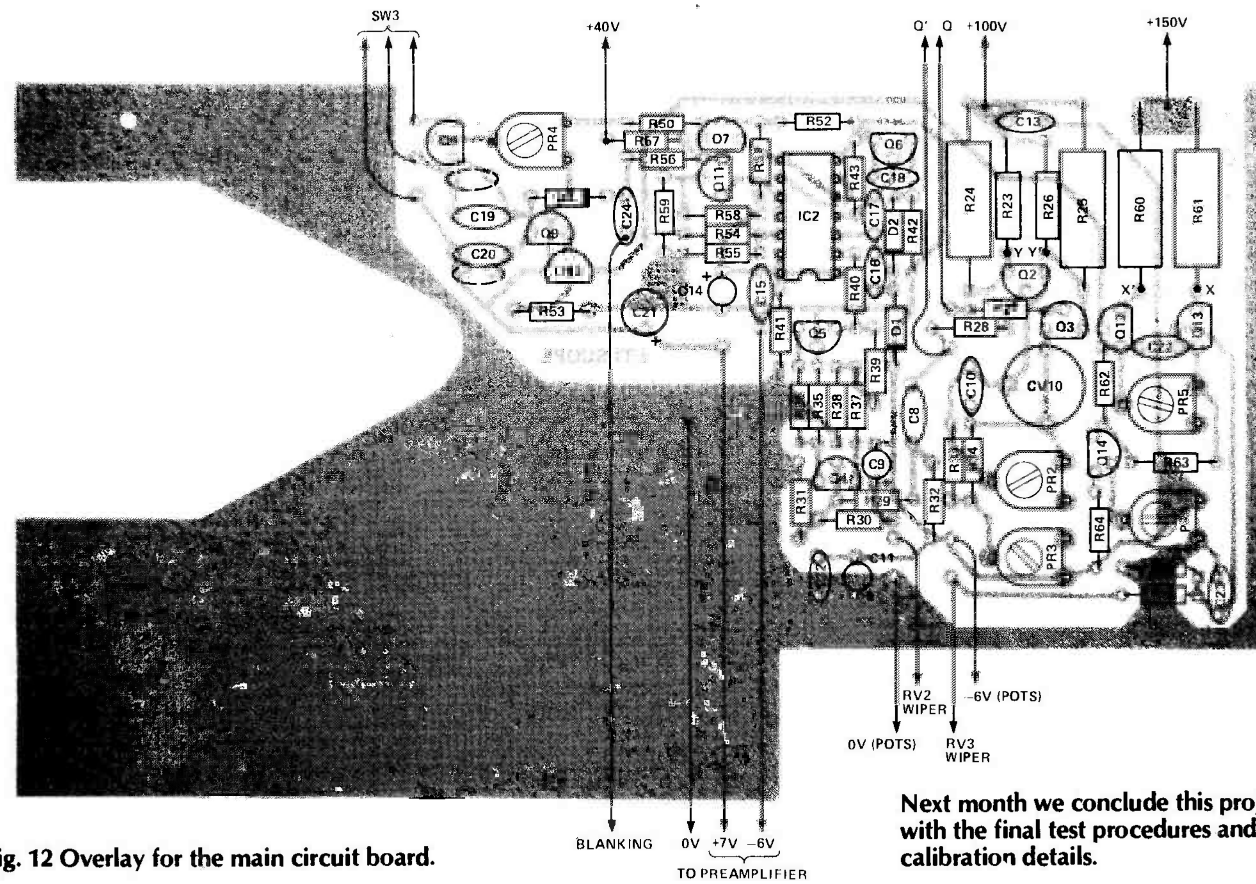


Fig. 12 Overlay for the main circuit board.

Next month we conclude this project with the final test procedures and calibration details.

ETI

Step-by-step fully illustrated assembly and fitting instructions are included together with circuit descriptions. Highest quality components are used throughout.

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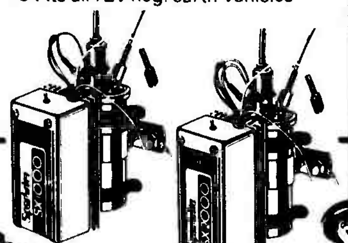
- Over 65 components to assemble
- Patented clip-to-coil fitting
- Fits all 12v neg. earth vehicles



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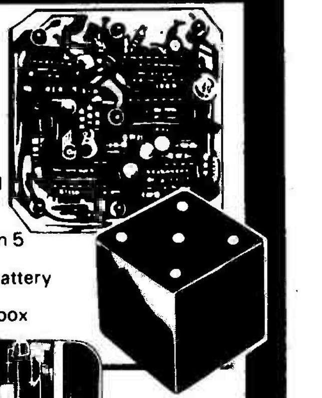

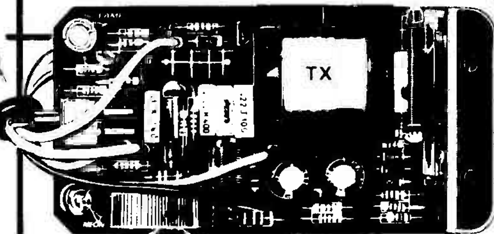

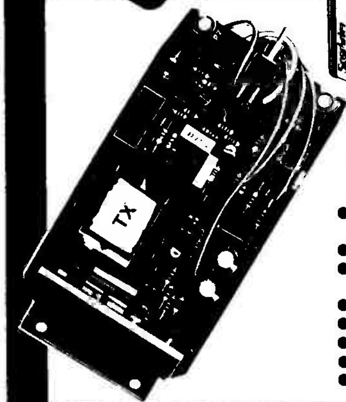

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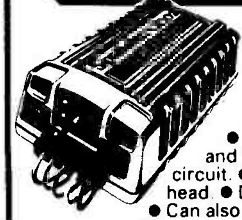
- Three position changeover switch
- Over 130 components to assemble
- Patented clip-to-coil fitting
- Fits all 12v neg. earth vehicles



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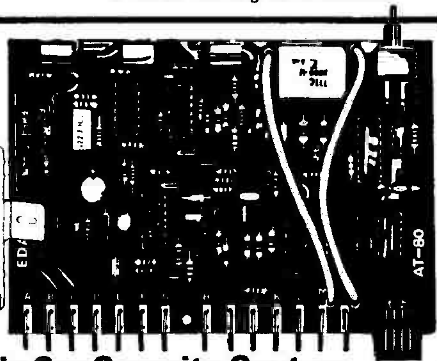

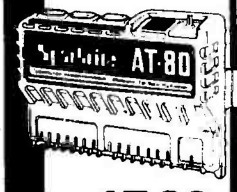

AT-80
Electronic Car Security System
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DESIGNER'S NOTEBOOK

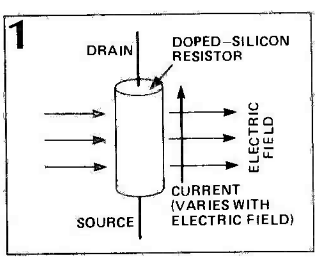
It's definitely a MOSFET month; we've shown you how to design big with our 150 W amp, and now Don Keighley provides a counter-balance with lots of smaller applications.

Field effect transistors (FETs) are peculiar brutes. If you've used them you'll know what I mean — negative bias voltages, depletion layers, pinch-off voltages and so on, ad infinitum. If you haven't used a FET before, the theory is simple enough: a FET is essentially a doped-silicon resistor (Fig. 1), much like a normal carbon resistor. The doped-silicon, however, exhibits a change of resistance if an electric field through the resistor varies. The electric field depends on the voltage present at the gate of the FET (Fig. 2), so a change of gate voltage changes the current through (and hence the resistance across) the device. Essentially a FET forms a voltage controlled resistance. In the example shown in Fig. 2 (a P-channel FET) a gate voltage of 0 V will produce a resistance of approximately 100R and a gate voltage of 5 V will produce a 1M0 resistance. For an N-channel FET the opposite is true; a gate voltage of 0V will give a resistance of 100R, −5V gives 1M0. For low drain-source voltages and low drain-source currents, the resistance change is linearly related to the gate voltage.

FETs have two enormous advantages over bipolar transistors. First, the gate input resistance is very high, meaning that virtually no current needs to be drawn from preceding circuitry. Second, FETs can exhibit very fast switching speeds — they can be used quite easily up to frequencies of many megahertz.

Problems, Problems

So, everything is fine — as long as you follow the rules. In low-power applications there is no reason why FETs can't be used anywhere a bipolar transistor can (they are, in fact, more versatile than bipolars — in low-power applications). But, therein lies the rub — *power*. It is very difficult (and expensive) to make a FET which can pass large currents: the main reason being the horizontal make-up of ordinary FETs. Bipolar transistors have *vertical* current flow and can pass larger currents because of it. Figure 3a shows the theoretical cross-section of a bipolar transistor and a similar cross-section of a FET is shown in Fig. 3b. Current flow in the bipolar is vertically upwards from collector to emitter and the large area through which the current passes allows large currents. FET current flow is from left to right (drain to source) and the small area of current flow means smaller currents than in a similar-sized bipolar transistor.



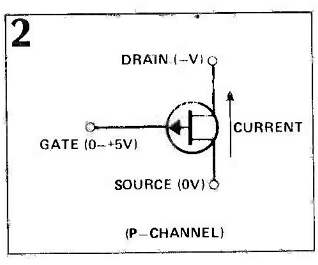


Fig. 1 A field effect transistor (FET) is a doped-silicon resistor, the resistance of which can be varied by changing the electric field through it.

Fig. 2 The symbol for a FET. Current through the FET and hence the resistance across it is controlled by the voltage at the gate.

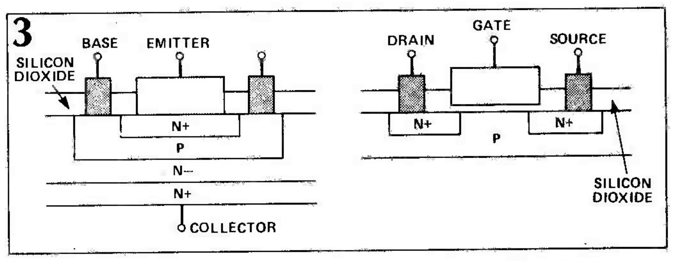


Fig. 3 Cross-sections through a) a bipolar transistor; b) a field effect transistor.

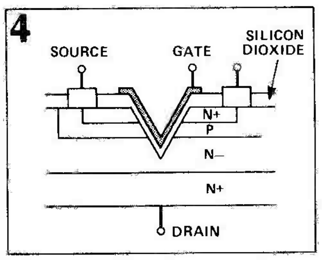
Recently, VMOS FETs have been manufactured which overcome the power problems normally associated with FETs. A typical VMOS FET cross-section is shown in Fig. 4. Current flow is now vertically upwards, from drain to source, in much the same way as in bipolar transistors. The larger chip area means large current. Hence we have transistors exhibiting all the advantages of FETs without the usual power limits. VMOS FETs also have some other very interesting advantages:

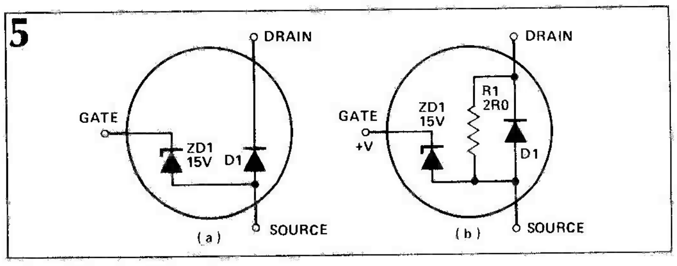
- low ON resistance — good for audio switching purposes.
- power amplification — as high as 10^6.
- positive temperature coefficient on the ON resistance — as the temperature goes up the transistor passes less current, therefore remaining thermally stable.
- easily operated in parallel to increase overall current flow — due to the inherent thermal stability no 'current hogging' by one device occurs.

We'll see applications using these advantages shortly.

The equivalent circuits of a VMOS FET (such as the VN67AF) in its OFF and ON states, are shown in Fig. 5. The zener diode protects the transistor from over-voltage on the transistor gate — it is a feature on many VMOS FETs but *not all!* If a VMOS transistor does not have such a gate-protection zener diode, it must be handled as a CMOS IC. You must take care to avoid static build-up between connections.

In the VMOS FET's OFF state (gate is low), diode D1 is reverse-biased and no current can flow from drain to source. In the ON state the diode is effectively shorted by a 2R0 resistor, allowing current flow from drain to source. With gate-voltages between 0 V and + V the resistor value is within the range 2R0 to ∞.





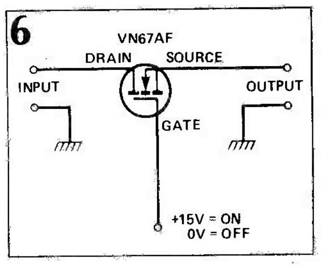


Fig. 4 Cross-section through a VMOS FET. Current flow is vertical, as in a bipolar transistor.

Fig. 5 Equivalent diagrams of a VMOS FET a) in the OFF state; b) in the ON state.

Fig 6. A simple unidirectional audio switch formed by a single VMOS FET.

Applications

Low ON resistances and high OFF resistances make VMOS FETs ideal for use in audio switching networks. Figure 6 shows a simple on/off audio switch controlled by the voltage on the transistor gate: +15 V turns the switch on and 0 V turns it off. Audio signals can only pass in one direction, from drain to source, but any audio voltage of about − ½ V to + 5 V can be switched.

The extremely high gate-input resistance of VMOS FETs means that they can be switched by virtually any control method, such as CMOS, TTL, op-amps and so on. A four-channel audio multiplexer is shown in Fig. 7, which uses a bank of four VMOS FETs as input switches with the transistors being clocked in turn by a 4017 decade counter. The fourth output of the 4017 is connected to the reset pin, giving a 1-2-3-4 count to control the VMOS FETs. As each FET is enabled by the 4017 counter the audio input at its drain is connected, via the source and a 10k resistor, to the op amp.

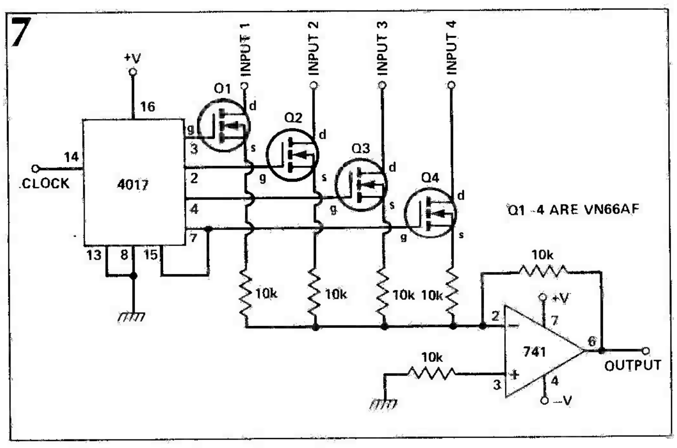
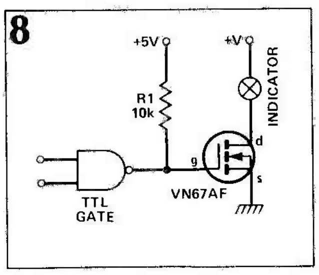


Fig. 7 Four VMOS FETs used in a four-channel audio multiplexer giving a time division multiplexed output signal.



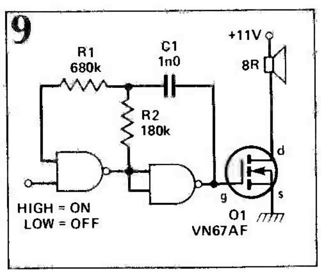


Fig. 8 TTL gate logic can be used to control VMOS FETs but a gate pull-up resistor must be used to ensure that the FET gate reaches a high enough voltage to allow sufficient current flow through the FET.

Fig. 9 Simple audio siren. An astable oscillator provides drive to switch the VMOS FET on and off at an audible rate.

If TTL logic is used to control VMOS FETs, a gate pull-up resistor must be inserted (Fig. 8) to ensure that the gate voltage is pulled up to + 5 V when on — sufficient to give about 500 mA of current through the transistor. Figure 8 also shows the principle of VMOS current control through a load, in this case an indicator lamp. The load can, however, be virtually anything requiring current, eg relays, LEDs or loudspeakers.

Figure 9 shows the circuit of a simple siren using an astable (formed by CMOS gates), a VMOS FET and a loudspeaker. When the transistor is on, its drain to source resistance is about 3R0 so about 1 A (ie V/R = 11/11) passes through the loudspeaker. The average current (assuming a 50% duty cycle from the astable) is therefore about 500 mA. Audio output power is thus about 2 W.

Paralleling two or more VMOS FETs in an output stage easily increases current-handling capacity. The siren circuit of Fig. 9 is redrawn in Fig. 10 with four paralleled output transistors. This more powerful siren will produce an output power in the region of 6 W. You can see that no ballasting resistors are needed (as you would require with a similar circuit using bipolar transistors) because of the positive temperature coefficient of the drain-to-source 'on' voltage. The explanation of parallel operation is very simple: if any one of the VMOS transistors begins to conduct a larger than average current it will tend to get warmer and so current flow will reduce.

Linear Applications

So far we've only considered switching applications using VMOS FETs (ie on or off), but they can just as easily be operated in a linear mode (to act as voltage controlled resistors) in the same way as ordinary FETs.

Linear regulators in power supplies are easily constructed:

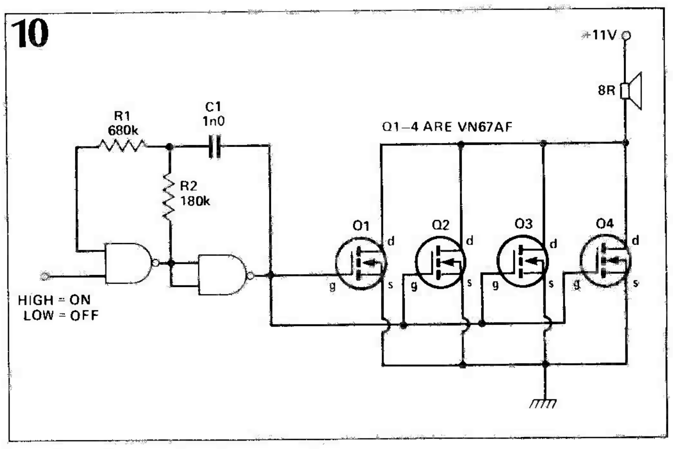
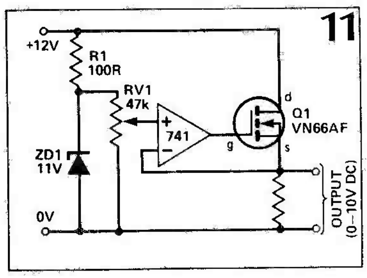


Fig. 10 Paralleling output VMOS FETs can be done simply because they are inherently thermally stable.

such a circuit is shown in Fig. 11. An op-amp compares the output voltage with a reference voltage derived from a zener diode and parallel variable resistance. The reference voltage is thus variable from 0 V to about 11 V. If the output voltage is less than the reference voltage, the op-amp increases the drive voltage to the VMOS FET, and vice versa, in a negative-feedback controlled loop.

Constant-current sources suitable for charging Nicad cells can be made easily using VMOS FETs, and a simple unregulated circuit is shown in Fig. 12. The current output is defined primarily by the gate voltage of the transistor by altering the ratio of the two resistors R1 and R2. By varying the gate voltage between 0 V and 5 V, a range of currents of approximately 0 - 250 mA will be obtained. Although the high output impedance of the transistor (relative to that of a bipolar) provides a level of current regulation, differing loads will produce differences in current flow.



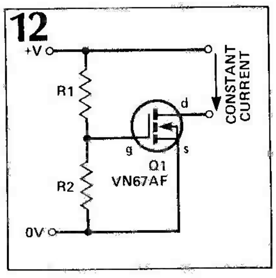
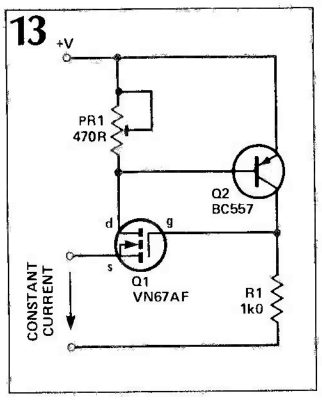


Fig. 11 A VMOS FET used in a linear voltage regulator. An op-amp is used in a negative feedback loop to provide the controlling gate voltage for the VMOS FET.

Fig. 12 Unregulated constant current source formed around a VMOS FET.



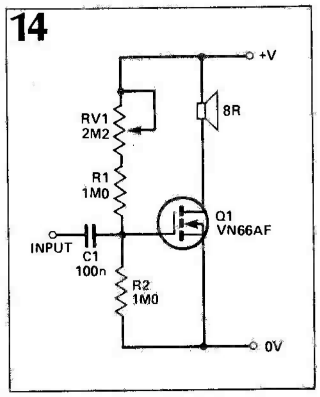


Fig. 13 Transistor Q2 holds the gate-to-source potential of the VMOS FET constant for any load. The current is therefore constant.

Fig. 14 A simple class A power amplifier.

The circuit of Fig. 13 overcomes this problem with a negative feedback loop formed by Q2. This transistor holds the gate-to-source potential of the VMOS FET constant for any load. Thus the current flow is constant whatever the load.

A Class A power amplifier can be constructed with a VMOS transistor and because of the inherent thermal stability of the FET, very few precautions need be taken with the circuit (Fig. 14). The high transistor input resistance allows very high value biasing resistors. Although obviously an audio power amplifier (the transistor load is a loudspeaker!) the circuit itself will operate up to the megahertz regions. **ETI** *introducing*

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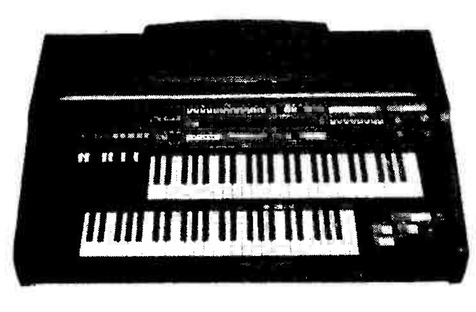

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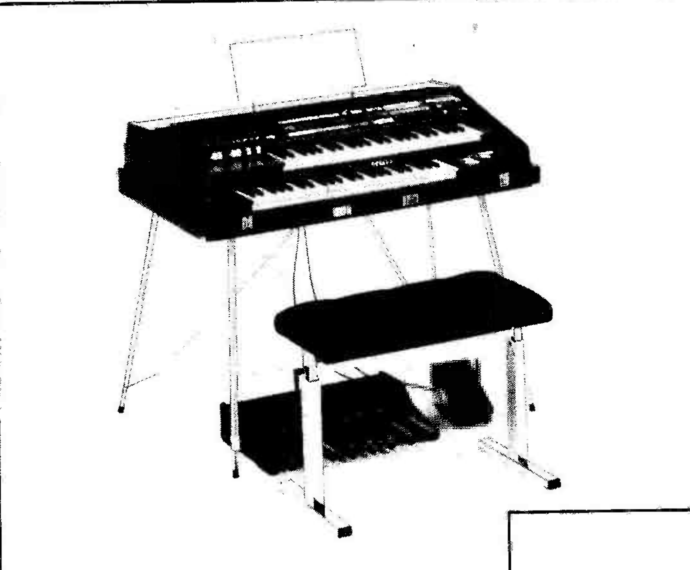

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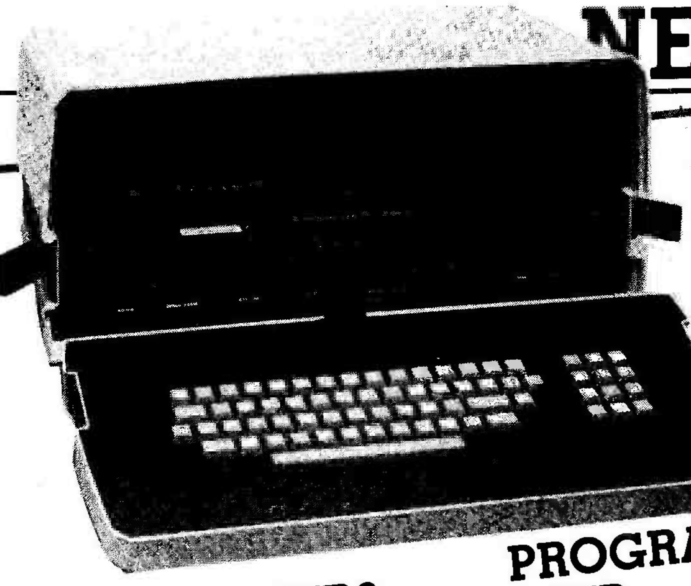

PORTABLE POWER?

After years of writing books on computers and awarding his famous 'White Elephants' to the industry, Adam Osborne finally took the ultimate step and produced the Osborne I. Despite the fact it is portable, well . . . almost, and fairly reasonably priced as hardware goes, the main attraction seems to be the fact that you get several hundred pounds' worth of software thrown in for free.

Having humped the system up hill and down dale and generally put it through its paces, our reviewer will hopefully have recovered sufficiently to put pen to paper and report on his findings.

SIMULATING FORTH

The interest sparked off by our recent series on FORTH has been so great that even we were taken by surprise. As a result, next month we'll be publishing a rather novel BASIC simulator for FORTH operations so those of you who would like to try out the language — without actually having to buy a version of it for your system — can have a go. It certainly won't break any speed records, in fact it is extremely slow, but it does allow you to get to grips with Reverse Polish Notation.

PROGRAMMERS' TWO-STEP

OK, so you've learnt to program in BASIC. Now, perhaps, you'd like to have a go at assembly but you're put off by the fact that you can't alter your programs with the same ease as you can in BASIC. Well, what you need is our two-pass assembler which lets you write and modify the assembly code first and then turn it into machine code **without** destroying your original.

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Or, to be more precise, are your programs? In our next issue we'll be taking a look at a rather clever method of program protection which actually allows your programs to be copied but then won't let them run on any other system . . . frustrating in the extreme! We will also be publishing an extremely ingenious Voting Loader which guarantees perfect loading from cassettes at almost any speed. So, for your own peace of mind and the security of your programs and data, make sure you secure a copy of our June issue.

Articles described here are in an advanced state of preparation but circumstances may dictate changes to the final contents.

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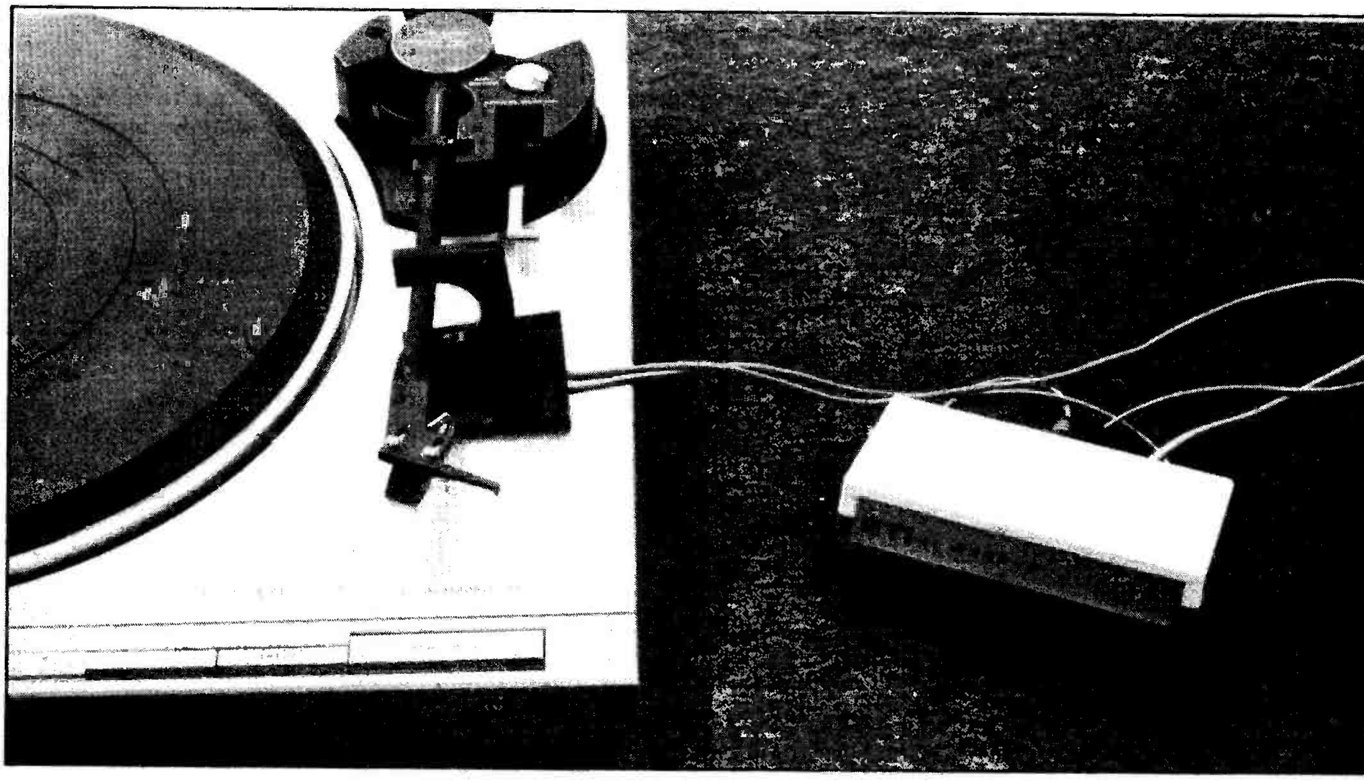
STYLUS TIMER

Do you play your records with a smoothly-contoured, precision-engineered, highly-polished stylus — or a worn-out nail? Check your playing hours with the ETI Stylus Timer. Design and development by Phil Walker.



For modern styli and cartridge combinations the life of the stylus may run to many hundreds or even thousands of hours before replacement is necessary. The trouble is that even at five hours each and every day (which is quite a lot) it will take over six months to accumulate 1000 hours playing time. If you are like us you could easily forget whether you changed the old nail last week or last year, quite apart from knowing how long it has been used since then.

Don't worry, help is at hand — this device is designed to measure the total number of hours your stylus has been in use since you last changed it and give some indication of that measurement.

The device has six LEDs which, in the basic configuration, change every 200 hours. This could be used to indicate that a check on stylus condition should be carried out either at home or by your local dealer. When the last one comes on it will stay on until the device is reset (assuming the power is on).

As mentioned above, the basic design allows for 200 hours per step, the last one occurring after 1000 hours. This can be modified to 400, 500, 1000 or even 2000 hours per step giving replacement times of up to 10,000 hours for the very lightest equipment (or Scrooges), or 100 hours per step if your equipment is a little heavier than some or you want to keep your stylus in tip-top condition all the while.

In order to eliminate dependence on mains supplies when the equipment is not in use, the device contains a rechargeable battery which provides the microamp or so needed to keep the CMOS devices active. Also the LED display is turned off when not required to conserve battery power. To prevent accidents the reset facility is disabled when the device is on standby.

Designs Discussed

The circuit uses standard CMOS integrated circuits for most functions in order to keep the standby power as small as possible. This enables us to use a PP3-sized rechargeable Ni-cad battery, ensuring that with intermittent use the device should operate almost indefinitely. (In fact a normal dry-cell PP3 battery will give a very long life but may not like the charging current flowing into it via R7).

The power for the LED display and the timing signal for the logic are taken from the AC input. This is any 50 Hz voltage source giving between 12 and 20 V at about 50 mA. For preference this supply should be switched with the turntable or equipment mains supply.

There was much discussion in the office about the actual method of detecting stylus use. The first method we considered involved detecting the presence of a music signal from the pickup, in a similar manner to the Watchdog auto-switch-off project we published in October '77. However, if the signal was tapped off after the RIAA preamp we realised the project couldn't be built by readers who lacked the confidence to muck about inside their expensive commercial hi-fi. On the other hand, putting the project between the deck and the preamp would lead to the knotty design problem of not degrading the pickup performance. Thus we opted for a

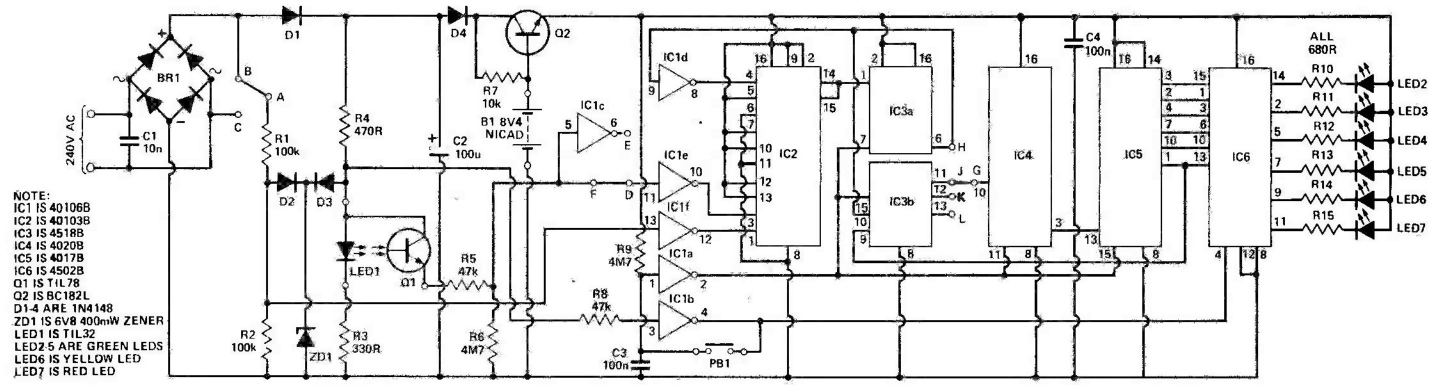


Fig. 1 Circuit diagram of the ETI Stylus Timer. The various lettered links are used to select the timing period (see text).

HOW IT WORKS

The 50 Hz power input is rectified by BR1 and charges C2 via D1. Q2 and R7 form a simple voltage regulator using the battery B1 as a reference. If there is no AC input then D6 isolates the rectifier circuitry from Q2 and B1 supplies the very small bias current needed to keep the CMOS devices active via the base-emitter junction of Q2.

R4, D3 and ZD1 form a moderately stable voltage for the optical sensor and an input to the power detection circuitry IC1b. The output from the optical sensor (LED1 and Q1) is taken via R5 and R6 to IC1e either directly or via IC1c. This allows the circuit to operate with either an open or blocked light path as required.

Depending on the position of link A-B or A-C a 50 or 100 Hz signal will be applied to IC1f. The voltage of this signal is limited by R1, R2, D2 and ZD1 to prevent damage to IC1.

IC2 is connected such that it divides by 220 or 219 as determined by the input from IC1d. This is accomplished by the device loading its internal eight bit counter with the binary number on its inputs each time it reaches a count of zero. In this case the most significant seven bits are wired to $1101101X = 218_{10}$ while the least significant bit (X) is switched between 0 and 1. The output from this stage drives IC3, a dual decade divider. The Q_4 output from IC3a controls the division ration of IC2 as outlined above. As the Q_4 output is only high for two clock periods out of 10 the effective division ratio of IC2 is:—

$$8/10 \times 220 + 2/10 \times 219 = 219.8$$

IC3b is used to divide by 2 in the standard circuit and then drives IC4 which does the rest of the division required (a factor of 2^{14} or 16384) to give a one cycle in 200 hours signal.

IC5 is a decade counter with 10 decoded outputs. Each output is high for one clock period of the 200 hour input signal (or longer if counting is suspended). Only the first six outputs are used to drive IC6 and the sixth output also inhibits IC3b to prevent further counting. IC6 is a hex buffer with three-state outputs which have a fairly high current sink capability and can be forced to a high impedence state by a signal on pin 4. This facility is used to prevent the LED display taking current while the AC supply is off.

The reset switch PB1 is connected in an unusual place so that it can only pull the input to IC1a low when the power sense circuit indicates that the AC supply is present. When operated, the reset circuit applies a high logic level to the reset inputs of ICs 3, 4 and 5 for about a second. IC2 is not reset and will cause an error of two or four seconds in the timing but in a hundred hours or so this is not significant.

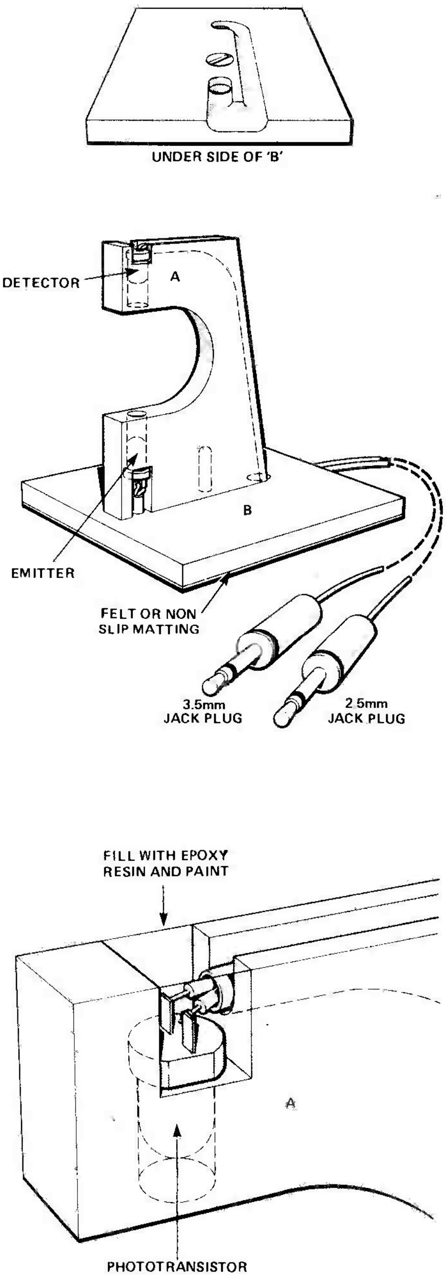


Fig. 2 Constructional details of our sensor. Using different sized jack plugs will prevent incorrect connection.

mechanical solution, but adventurous readers may care to adapt this project and the Watchdog circuit for their own needs. Note that we CANNOT give any technical advice if you do try it.

The circuit operates by detecting when the tone arm is away from its rest position and then allowing the rest of the circuit to count at 50 or 100 Hz. The 50 or 100 Hz is divided by about 72 million in order to drive the final counter at one pulse every 200 hours. The already decoded outputs of this device (IC5) are used by the output driver (IC6) to power the display. The division ratio actually used is 72, 024, 064, this being:-

$$2^{14} \times 20 \times (1/5 \times 219 + 4/5 \times 220)$$

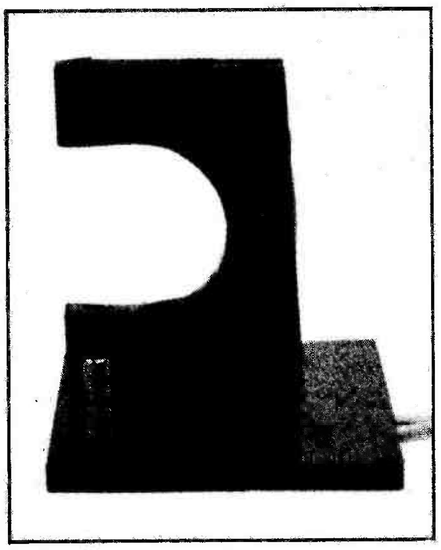
(IC4) (IC3) (IC2)

The error between this figure and the theoretical 72,000,000 is 0.033% or 20 minutes in 1000 hours.

The final counter (IC5) has 10 decoded outputs of which only the first six are used. These control IC6 and thus the display. When the sixth output of IC5 goes high it disables the counter chain causing the sixth LED to remain on indefinitely.

IC6 contains six inverting buffers which have three-state outputs. This facility is used to switch off the LEDs and conserve power.

A transistor (Q2) was used in the standby battery circuit so that when operating from the AC input, the supply voltage to the ICs was little different to that when operating from battery alone. Also the LED voltage can be stabilised at the correct value. The configuration allows the battery to be trickle-charged from the same supply.



Construction

The construction of the main unit is straightforward, if a little fiddly on account of its small size. Assemble the components onto the PCB including the three links but excluding LED 2-7. Place the assembled PCB in the bottom of the box and align it over the wider spaced fixing holes with C2 next to the space for the battery. Mark the positions for the LEDs on the front panel and the jack sockets and PB1 on the back panel. Also mark a position for the power cable grommet. Drill all these holes in sizes to fit your components.

Wire up the switch and sockets. The common connection from R4 on the board should go to the sleeve connections on the jack sockets to prevent accidental short circuits via the panel. The LEDs should now have their leads bent so that they will go into the board while the LED body protrudes through the panel. Finally connect the battery connector and the AC power lead. The latter should be a twin core screened cable terminated in a three pin DIN plug or similar to pick up the supply.

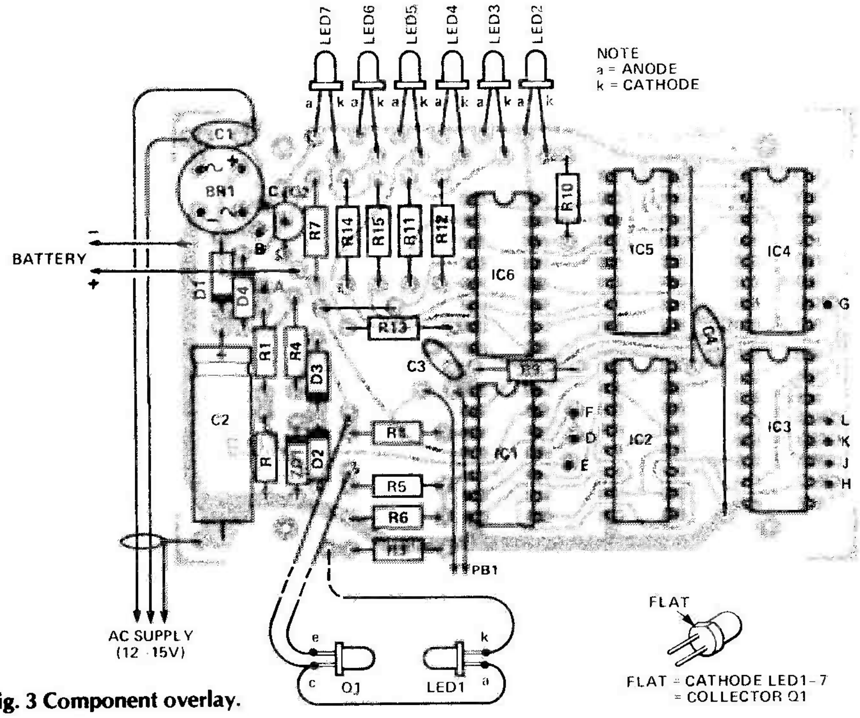


Fig. 3 Component overlay.

The Sensor

The purpose of the sensor housing is to hold the emitter and receiver in line and exclude some of the ambient light. Our sensor was constructed from an offcut of black Perspex about 90 x 55 x 6 mm. This was cut into two pieces (36 x 55 and 52 x 55 mm). A U-shaped slot was cut out of the longer side of the smaller piece; then a hole was drilled in the thickness of the material in both legs of the U to take the optical devices and hold them in line. The back edge of the U was slotted to take the screened wire from the phototransistor.

Three holes were drilled along the centre line of the other piece of Perspex; two to take wires and one to take a fixing screw. The underside of the base piece was channelled out using a rasp attachment in a hobbyist drill to conceal the wires.

The sensor device is mounted in the top hole to reduce the amount of ambient light reaching it. The screened wire from the phototransistor is run along the slot in the plastic and down the hole in the base. The slot can be filled with resin and painted when finished.

If a small three-way connector can be obtained this could be used in place of the two jacks and a single length of screened cable would suffice to connect the sensor.

Power supply

The AC power supply is very simple and consists of a small mains transformer, fuse, neon indicator and three pin DIN socket mounted in a small box. Construction is very straightforward and, if the specified box is used, most small 6 VA transformers will fit onto the moulded pillars in the box, obviating the need for external screws.

Use and Modifications

To use the stylus timer, the sensor should be positioned so that the tone arm interrupts the light beam when it is in the rest position. Make sure that it does not foul the arm at any time if you have any sort of automatic control.

If possible the AC power supply for the device should be obtained from your system. Anything from 12 to 15 V AC may be used without modification.

PARTS LIST

Resistors (all ¼ W, 5%)

R1,2	100k
R3	330R
R4	470R
R5,8	47k
R6,9	4M7
R7	10k
R10-15	680R

Capacitors

C1	10n ceramic
C2	100u 40 V axial electrolytic
C3,4	100n ceramic

Semiconductors

IC1	40106B
IC2	40103B
IC3	4518B
IC4	4020B
IC5	4017B
IC6	4502B
Q1	TIL78 IR receiver
Q2	BC182L
D1-4	1N4148
ZD1	6V8 400 mW zener
BR1	50 V, 1 A bridge rectifier
LED1	TIL32 IR transmitter
LED2-5	2 mm green LED
LED6	2 mm yellow LED
LED7	2 mm red LED

Miscellaneous

PB1	subminiature push-button
B1	8V4 PP3-size Ni-cad (or PP3 — see text)

PCB (see Buylines); PP3-size battery clips; case 125 x 65 x 30 mm (Vero ref. 75-2682A); 3.5 and 2.5 mm jack plugs and sockets; three pin DIN plug (if required to connect to power unit); thin screened twin cable; small grommet; 100 x 55 x 6 mm acrylic sheet.

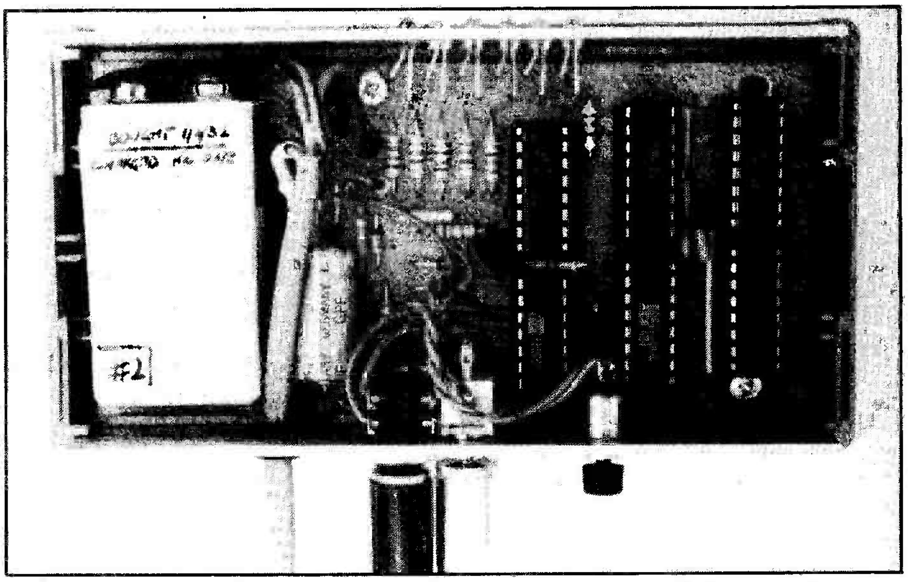
AC POWER UNIT (IF REQUIRED)
12 V, 6 VA mains transformer; 100 mA fuse and fuseholder; mains neon; case 125 x 65 x 50 mm (Vero ref. 75-2684B); three pin DIN socket; three-core mains cable; grommet; solder tags.

Up to 25 V may be used but R4 and R7 should then be 1k0 1 W and 27k respectively. If the supply is greater than 25 V, one side of any available supply is earthed or if you prefer not to tamper with your system then use the simple mains power supply described.

With the sensor in position and a suitable AC supply connected, press the reset button on the unit. The first green LED should light and stay alight for 200 hours of playing time, followed by the next LED until the red LED lights to indicate replacement overdue. If the power supply is switched off at any time the accumulated time is stored until the power is restored.

Other time intervals can be used in the device by changing the link positions. Changing A-B to A-C doubles the time period. Changing G-J to G-K or G-L increases the interval by 2½ or 5 respectively while changing it to G-H halves it, although it will not stop on the last count as before. The link adjustments therefore give a range of 100 to 2000 hours per LED on the display — further reductions could be made by using pin 2 or 1 of IC4 as output instead of pin 3, giving ½ or ¼ of the period. In some of these other positions the intervals between the lighting of each LED may not be as regular as before (especially G-K). If it is desired to have counting enabled when the light path is obstructed then link D-F should be changed to D-E.

We would like to thank Sonic Sound Audio, who live under our offices and kindly dismantled a rack hi-fi system so we could take our lead photograph.



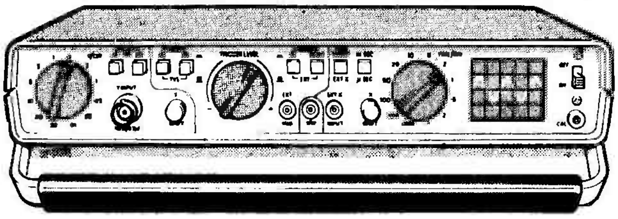
Inside the Stylus Timer. Take care during construction as things are a little cramped.

BUYLINES

None of the electronic bits and pieces should present any problems; try any of the component companies advertising in this issue. The PCB can be obtained from our PCB Service using the order form on page 82; for the Perspex you can try plastics suppliers, arts and crafts shops or DIY emporia.

ETI

SC110 FULLY PORTABLE OSCILLOSCOPE



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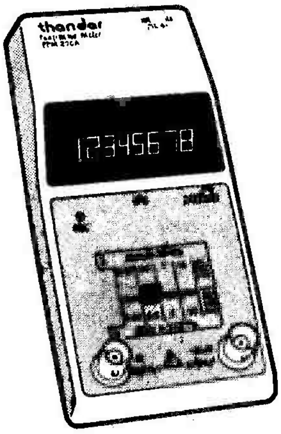

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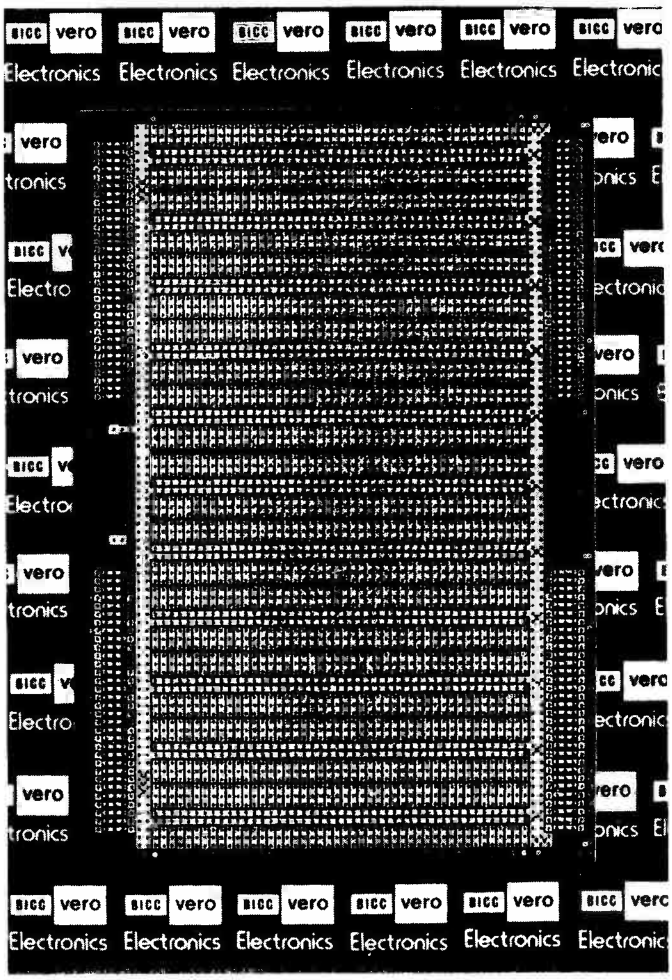

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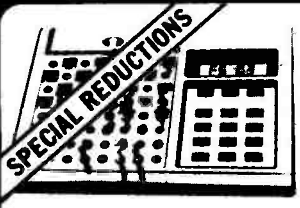

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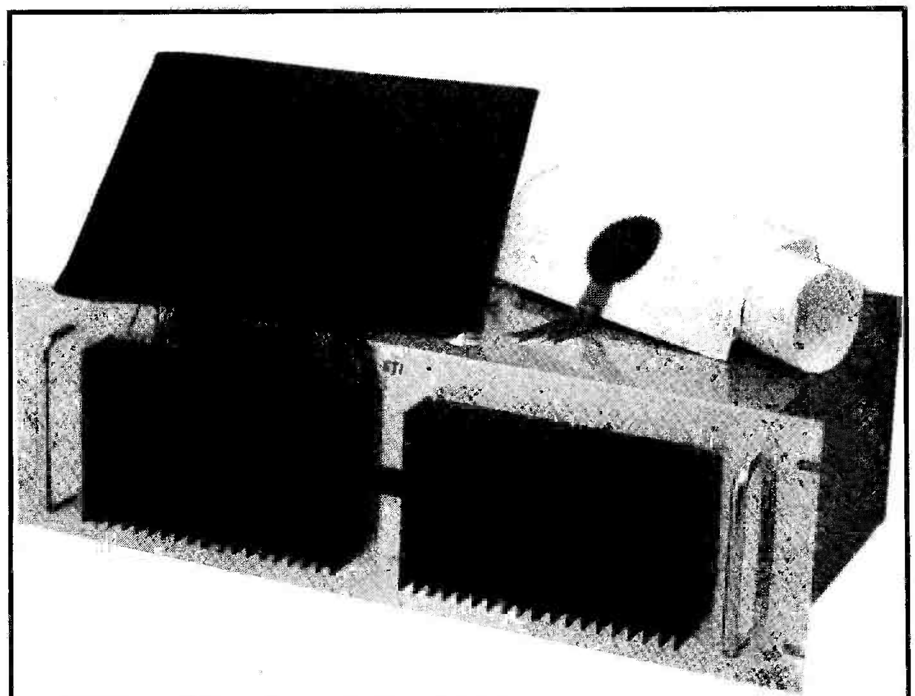
150 W MOSFET AMPLIFER

Employing MOSFETs, this power amplifier features a 'no compromise' design from Dave Tilbrook and is rated to deliver 150 W RMS maximum; it features extremely low harmonic, transient and intermodulation distortion. This is achieved by overcoming the many basic problems encountered in the use of MOSFETs for audio amplification.

The objective of this project is to provide a power amplifier module of the highest possible performance. Ideally the power amp should produce an amplified version of its input signal and contribute no sound of its own. In order to design a practical amplifier that will come as close as possible to this ideal, it is necessary to 'define' limits on the input signal characteristic and then ensure that the power amp exceeds these limits.

The problem of amplitude overload cannot be eliminated, since no practical power amplifier has access to infinite supply voltage. In order to overcome this problem, the ETI-5000 module has been designed to handle in excess of ± 50 V rails, giving it a conservative power rating of 100 W RMS into 8 ohms. The output stage has been designed so that the MOSFETs will not operate outside their safe operating area on any load in which the effective series resistance does not drop excessively below 8 ohms. Increasing the supply rails will increase the audio power output (up to 150 W RMS max.) but for normal use, we recommend sticking to ± 55 V.

Similarly, since no power amp has an infinite slew rate or infinite frequency response, the input signal has been limited by a passive input filter. It can be easily demonstrated by experiment that the introduction of a passive filter that does not excessively affect the frequency response within the audio passband will not affect the sound of the input signal. This filter will define a maximum possible input slope. It is therefore only necessary to design the amplifier with a slew rate that exceeds this by a sufficient margin to ensure freedom from slew-induced distortion. Since the amplifier is operated below its slew rate limit, the application of negative feedback will decrease distortion produced as a result of the signal slope approaching the slew rate (TIM).

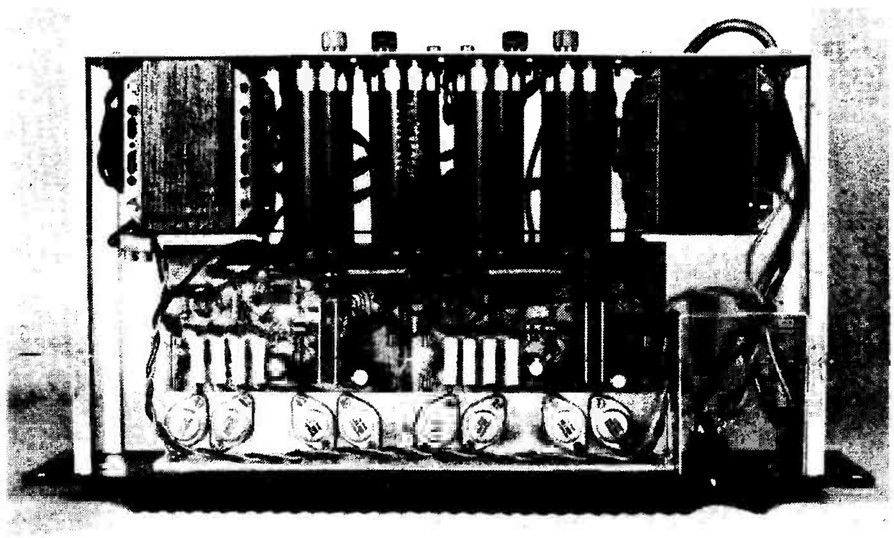


Build this amplifier and go to the top of the class.

Pair Difference

Differential pairs have been used throughout the design to form not only the input stage but also the voltage gain stage. This ensures that the distortion characteristics of the input and voltage gain stages are low enough so that the open loop characteristics of the amplifier will be determined by the output stage. The improved frequency and phase linearity of the differential pair make it considerably easier to ensure that the amplifier meets the Nyquist stability criterion. Another advantage of the differential pair is its relatively high supply rejection, a parameter which is often not given sufficient attention in power amp design.

Careful control of the feedback loop and the use of a passive filter/load on the output of the module, coupled with the design points mentioned above, have yielded an amplifier with particularly low dynamic distortion characteristics. An amplifier that has been designed with these objectives in mind will automatically have low THD and TID figures. The ETI-5000 is no exception, with a THD at 1 kHz and 10 W RMS of less than 0.001%, rising



A general view showing the internal layout of the amplifier. Toroidal transformers can be used instead.

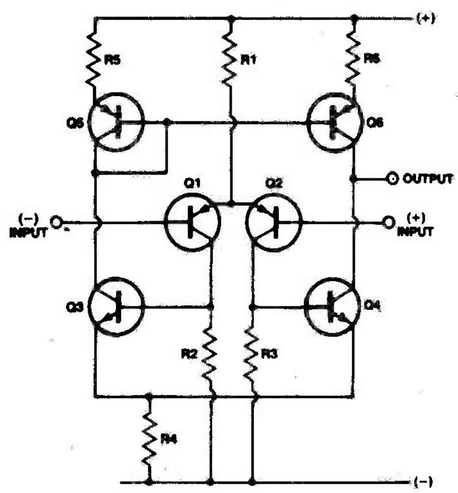


Fig. 1 The basic voltage gain stage of the ETI-5000 MOSFET amplifier.

SPECIFICATIONS

Power output
100 W RMS into 8 ohms
(± 55 V supply)
(up to 150 W with suitable PSU)

Frequency response
8 Hz to 20 kHz, +0 −0.4 dB
2.8 Hz to 65 kHz, +0 −3 dB
NOTE: These figures are determined solely by passive filters.

Input sensitivity
1 V RMS for 100 W output

Hum
−100 dB below full output (flat)

Noise
−116 dB below full output
(full, 20 kHz bandwidth)

2nd harmonic distortion
<0.001% at 1 kHz
(0.0007% on prototypes)
at 100 W output using a
± 56 V supply rated at 4 A continuous
<0.003% at 10 kHz and 100 W

3rd harmonic distortion
<0.0003% for all frequencies less than 10 kHz and all powers below clipping.

Total harmonic distortion
Determined by 2nd harmonic distortion (see above).

Intermodulation distortion
<0.003% at 100 W
(50 Hz and 7 kHz mixed 4:1)

Stability
Unconditional

slightly to around 0.003% at 10 kHz (top end distortion figures are a function of bias current). It should be remembered, however, that obtaining low THD figures should not be the prime objective of a good power amplifier design, but results from the reduction of dynamic distortion mechanisms.

Tested And Trying?

The module has been tested exhaustively and all prototypes have performed with negligible differences.

When attempting to measure distortion figures as low as these, great care must be taken with the earthing arrangement to the test equipment. The amplifier module will give its lowest distortion figures only when measured with respect to the correct earth. It may be necessary to remove the connection between mains earth and signal earth inside some distortion analysers. This problem will not arise when the amplifier is connected to a loudspeaker. This condition is not unique to the 5000 module, but will occur whenever an alternative earth path is provided to the output signal earth.

The sound is clean with no sign of the aggressive high frequency performance common to many transistor amplifiers. There are some amplifiers that give the subjective impression of being 'over smooth', ie the amplifier on first listening sounds clean and unobtrusive. Further listening test reveals, however, that these amplifiers lack detail, and complex sounds like a symphony orchestra tend to beome a single mass of sound rather than being rendered as single instruments. The ETI-5000 does not suffer from this problem!

Carefully Does It

Particular care has been taken to minimise slew-rate limiting and harmonic distortions. An inspection of the 'How It Works' section will reveal the techniques employed.

Follow the suggested constructional method and no problems will be encountered.

Construction — Module

The construction of the power amp module is not difficult since all the components are mounted on a single board. Since the design employs a fairly large amount of negative feedback, the board pattern is a critical factor in attaining the maximum theoretical performance. It would be virtually impossible to achieve the same performance if the board pattern were altered, without recourse to a distortion analyser with a sensitivity of at least 0.005% and a very good spectrum analyser. The board pattern shown ensures freedom from earth path interaction and therefore does not degrade the distortion performance of the design.

Commence construction by soldering all the resistors onto the circuit board. The 0R22 (0.22 ohm), 5 W source resistors in the output stage get warm if the amplifier is operated for extended periods at high power.

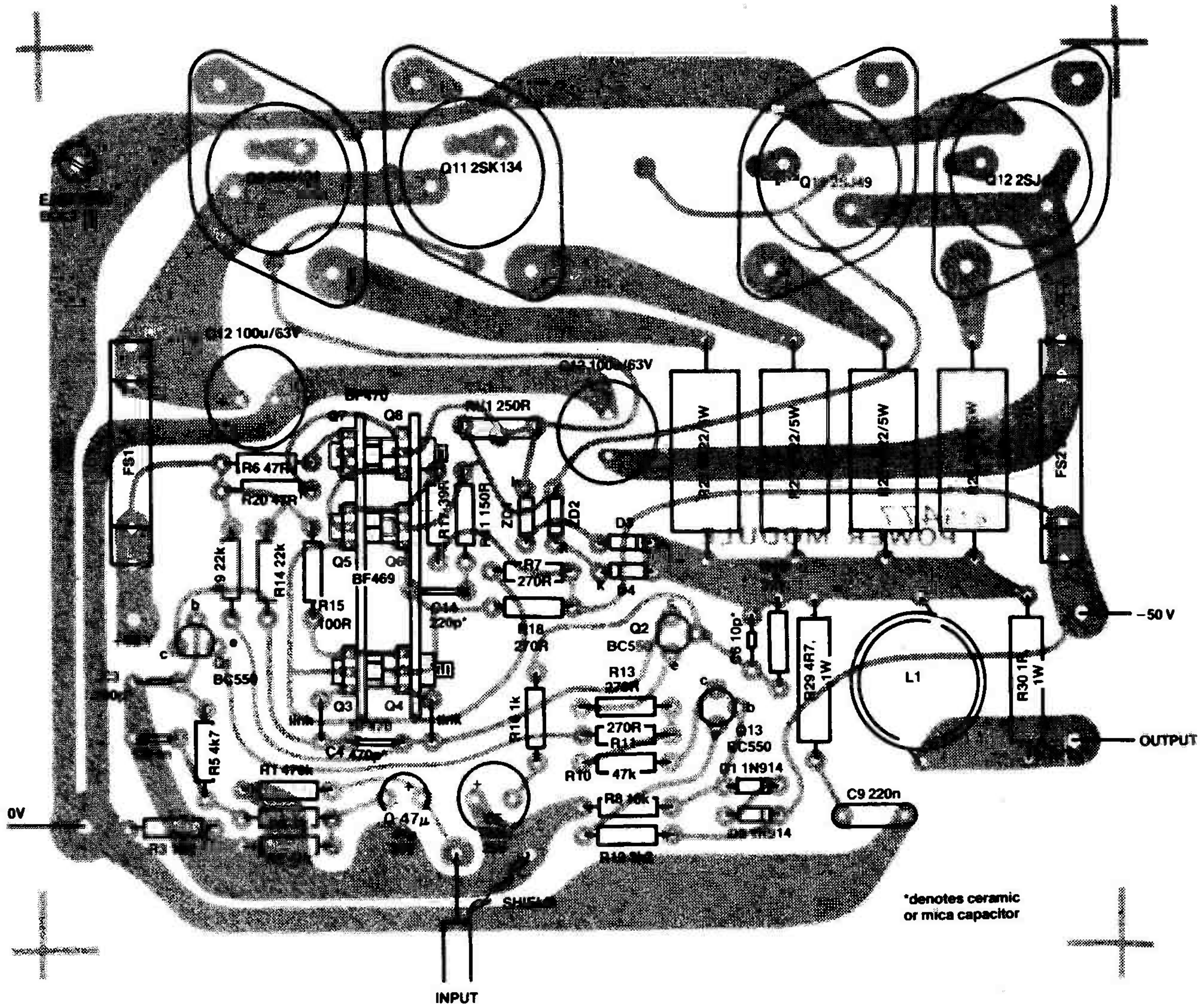


Fig. 2 Component overlay of the MOSFET amp module.

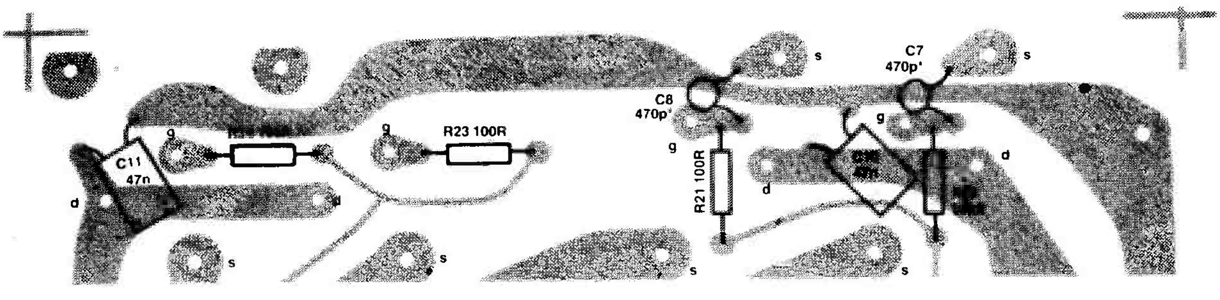


Fig. 3. This overlay shows the components which are mounted directly on the copper side of the PCB.

They should never get hot enough to burn the circuit board, since any fault capable of causing this much power dissipation should blow the supply fuses first. Nevertheless, it is good construction practice to space these resistors a few millimeters off the surface of the board. The 4.7 ohm, 1 W resistor R29 should *definitely* be spaced off the board since it will overheat if a fault condition should cause oscillation of the amplifier at high frequencies. Do not mount the four 100 ohm resistors R21, R22, R23, R24 at this stage. These are mounted on the rear of the circuit board and are best left until after the MOSFETs are mounted.

Solder the four fuse clips into the board next. Now mount all of the capacitors, with the exception of C7, 8, 10, and 11. Once again, these mount on the rear of the board. Make sure the electrolytic capacitors C1, C5, C12 and C13 are inserted with the correct orientation as these are polarised components. Mount the 1N914s and zener diodes, taking care to orient them correctly. Solder the trimpot RV1 into place and then the small-signal transistors, Q1, Q2 and Q13.

Next step is to mount the six voltage amp transistors, Q3 through Q8. These are situated on the board in two parallel rows, each row with three transistors. In the prototype modules, the heatsinks were constructed from two pieces of aluminium, as can be seen from the photographs. The transistors are mounted using 6BA bolts, each passing through a pair of transistors. This forms a very strong assembly which can then be soldered onto the board. Insulating mica or plastic washers should be used between the metal side of the trasnsistors and the heatsink strip, using a small quantity of heatsink compound between each mating surface. When this transistor-heatsink assembly is completed, but before soldering it into the circuit board, check that each transistor is effectively insulated from the heatsink. Using a multimeter on the resistance range, check for shorts between the centre lead (collector) of each transistor and the heatsink strip. Note that the bolts through the six transistors are automatically insulated from the metal rear of the transistor by the plastic body of the device so no additional insulation of the bolts should be necessary.

Before mounting the MOSFET output devices it is necessary to make the heatsink bracket. This is cut from a suitable aluminium extrusion. The board has been designed to suit extrusions with one of the sides at least 40 mm wide. The transistor mounting holes have been placed so that the heatsink brackets used in the ETI 300 W modules (April '80) are compatible, although there will be some unused holes.

The output assembly should now be checked for shorts. Remove the earthing bolt first (see overlay). The resistance between the case of each MOSFET and the bracket should be checked with a multimeter. If any device shows a short to the bracket it should be disassembled and the short found. Usually it is necessary to replace the TO-3 insulating washer as most faults of this type are the result of small metal burrs cutting through the washer when mounting the device.

Once the MOSFETs are mounted, the last passive components — resistors R21, R22, R23 and R24 plus capacitors C7, C8, C10 and C11 can be mounted on the rear of the circuit board. These are positioned on the rear of the board so that lead length is kept as short as possible. Cut the leads just short enough to mount the components in place.

Set-up Procedure

The recommended supply voltage for the modules is around ±55 V. With this voltage and reasonable supply regulation, the module will deliver around 100 W RMS into a nominal 8 ohm load.

First, re-check that the output devices are not shorted to the heatsink bracket. This is best done with the earthing bolt removed as mentioned earlier. If no shorts are found, replace the earthing bolt.

Do the same check for shorts between the six voltage amp transistor collectors and their heatsinks.

Check the polarity of all polarised components. It is often difficult to tell one end from the other on diodes since the markings are easily rubbed off. If in doubt, check these with a multimeter. Wind the wiper of the trimpot RV1 fully *counterclockwise* (least resistance). This ensures no bias is applied to the output stage. Now, remove the fuses from the board if they have been fitted and replace them with 10 ohm, ½ W resistors.

The module can now be connected to a power supply.

Make sure that the power supply connections are sound, with good solder joints. If you have access to a current limited bench supply it is best to connect the module to this for the set-up and initial test. If you can do this, set the current limit to around 200 mA. *Do not* connect a load to the output of the module at this stage.

If the power is now turned on, the current through the two 10 ohm resistors replacing the fuses should be low. If these resistors start to smoke, this indicates a fault condition — turn the power off immediately.

PARTS LIST

Resistors (all ½W, 5%)	
R1	470k
R2,11	47k
R3	10R
R4,16	1k0
R5	4k7
R6,20	47R
R7,10,13,18	270R
R8	10k
R9,14,19	22k
R12	3k3
R15,21-24	100R
R17	39R
R25-28	0R22, 5 W
R29	4R7, 1 W
R30	1R0, 1 W
R31	150R
Potentiometer	
RV1	250R vertical trimpot
Capacitors	
C1	470n, 25 V PCB electrolytic
C2	1n0 polyester
C3	330p ceramic or mica
C4,7,8	470p ceramic or mica
C5	100u 25 V PCB electrolytic
C6	10p ceramic or mica
C9	220n polyester
C10,11	47n polyester
C12,13	100u 63 V PCB electrolytic
C14	220p ceramic or mica
Semiconductors	
Q1,2,13	BC550
Q3,4,7,8	BF470
Q5,6	BF469
Q9,10	2SK134
Q11,12	2SJ49
D1,2,3,4	1N914 or similar
ZD1,ZD2	12 V, 400 mW zener

Miscellaneous
PCB; four fuse clips; two 3 A fuses; one plastic bobbin or similar former, 15 mm diameter; one metre of 0.8 mm dia. enamelled copper wire; two strips of 20g aluminium, each 15 mm wide by 47 mm long (for voltage amp heatsink); heatsinks, case to suit.

Semiconductors	
BR1	200 V, 35 A bridge rectifier
Capacitors	
C1,2,3,4	10,000 uF, 80 V can electrolytics
C5,6,7,8	100n polyester
C9	470n polyester
Transformers	
T1,T2	two x 35 V secondaries

Miscellaneous
SW1. . . . illuminated rocker switch, 240 V AC rated; 1 off 2A fuse and fuseholder, 1 off 3-pin DIN socket; 2 off 2-way plastic terminal blocks; 2 off phono sockets; 2 off red and 2 off black heavy duty screw terminals; clamp grommet and sundry rubber grommets; hookup wire; nuts, bolts etc; heatsink/front panel, metalwork etc.

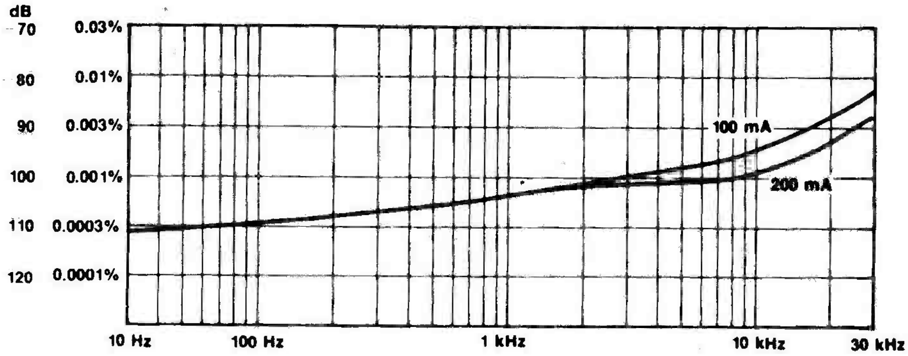


Fig. 4 This graph shows the measured distortion versus frequency for two values of quiescent current in the output stage.

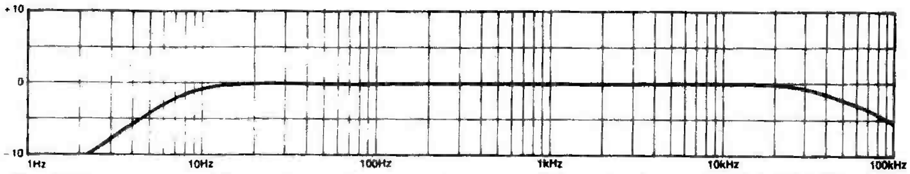


Fig. 5 The measured frequency response of the amplifier (single module). Roll-off points are defined by the input filter (low end) and output compensation network (high end).

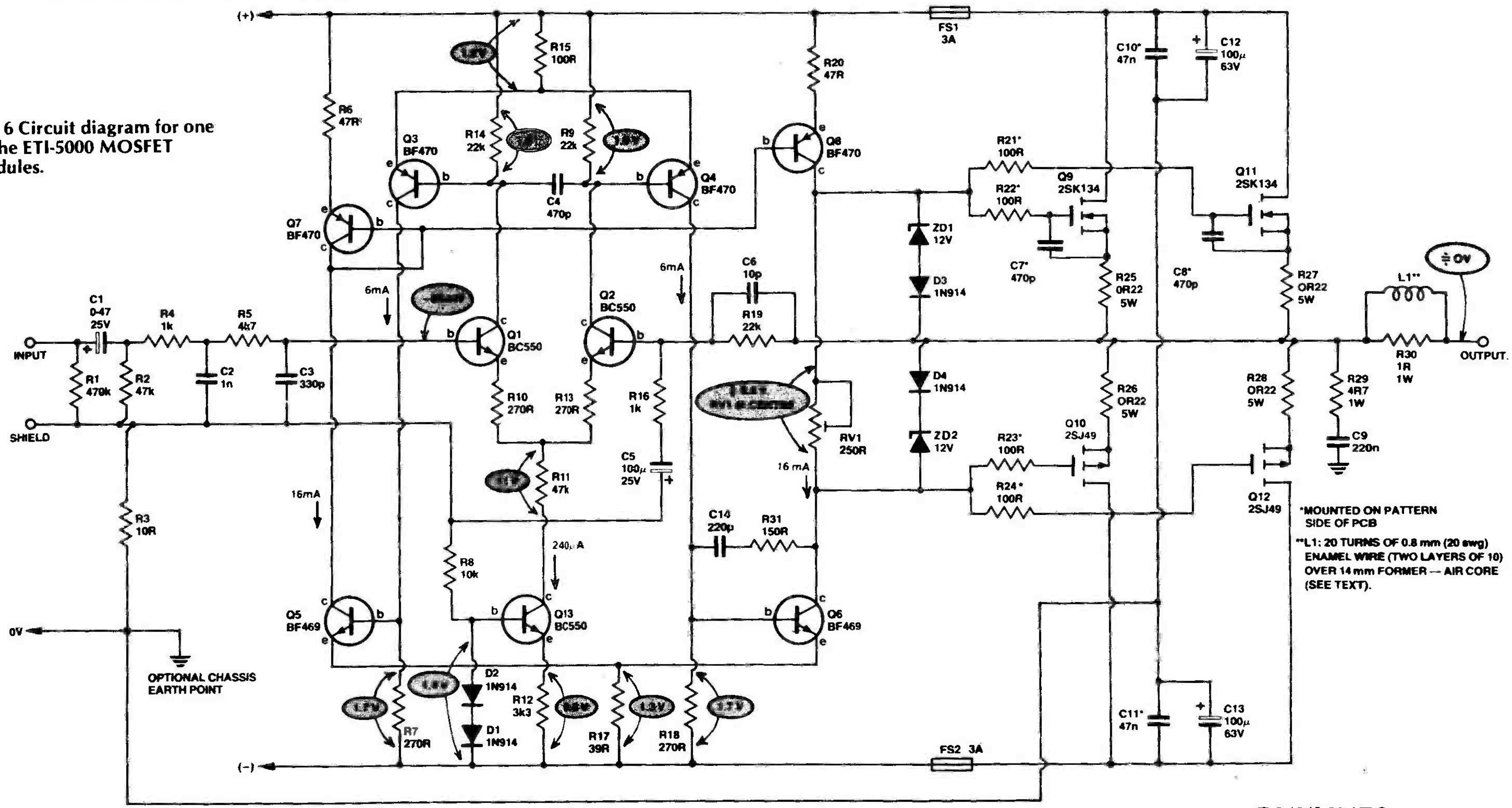


Fig. 6 Circuit diagram for one of the ETI-5000 MOSFET modules.

This very brief DC analysis of the circuit is intended to help the constructor rationalise the voltages quoted on the circuit diagram. The voltages are the result of averaging voltage measurements on a number of prototypes, and slight deviations from these should be expected.

The input signal is fed to three RC filter sections formed by C1/R2, R4/C2 and R5/C3. The C1/R2 filter defines the low end 3 dB point of the amplifier at around 7 Hz, with an attenuation rate below this frequency of 6 dB/octave. The two sections R4/C2 and R5/C3 both have 3 dB points of around 30 kHz defining the top end response of the amplifier. This filter limits the maximum signal slope to less than the slowest stage in the amplifier. It also provides protection against RF interference.

Transistor Q13 and the associated components R8, R12 and D1, D2 form a constant current source (or sink), maintaining a final DC current through the differential pair Q1, Q2 of around 240 mA. Under no-signal conditions this current is shared equally between Q1 and Q2. The resistances of R9 and R14 are in parallel with the equivalent input resistances of the transistors Q3, Q4, decreasing the effective load resistances of the differential pair to around 15k. The voltage drop across R9 and R14, should therefore be 1V8 approximately. This voltage, minus the 0V6 drop of Q3 and Q4, will cause a voltage drop of 1V2 across resistor R15, causing a current of 12 mA to flow in this resistor. This current is shared by Q3 and Q4 and causes a 1V7 drop across resistors R7 and R18. Once again, the effective input impedance of Q5 and Q6 is in parallel with the resistors, but in this case the value of R7 and R18 is very much lower than the base impedances of Q5 and Q6, so this effect can be ignored in a DC analysis like this. The voltage across R7 and R18 minus the 0V6 drop of Q5 and Q6 will cause 1V3 to be dropped across 32 mA through the resistor. Again Q5 and Q6 form a differential pair, and this current is shared equally by the two transistors. The load for these devices is formed by a current mirror, Q7-Q8, that ensures the current through Q5 and Q6 will remain the same. Transistors Q4 and Q5 therefore form the main voltage gain section of the amplifier and have a typical emitter-collector current of 16 mA. The preset RV1 will drop nominally 1 V across it when the output stage quiescent current has been set.

Diodes D3, D4 and zeners ZD1, ZD2 protect the MOSFET output devices from being overdriven, as described in the text. The RC-RL network on the output ensures that the amplifier has a correct load at all frequencies thereby eliminating the problem of oscillation that could otherwise result.

BUYLINES

The MOSFETs and other transistors used in this amplifier can be obtained from Pantechnic who advertise in ETI. If necessary, the 2SK135/2SJ50 complementary MOSFET pair could be substituted (these have a higher breakdown voltage). Pantechnic will also supply the can electrolytics for the power supply (at a cost of £4.75 each including VAT, p&p 40p extra). Various companies supply suitable transformers — browse through the ads in this issue to find them. Our PCB Service will be selling the boards for this project as usual; the 19" rack that we used for a case is available at a reasonable price from Relay-A-Quip Products, Moat Lodge, Stock Chase, Malden, Essex CM9 7AA.

HOW IT WORKS

When designing amplifiers intended, as this project is, for extremely low distortion, it is essential that all stages in the amplifier be designed for as low a distortion as possible. When the negative feedback is applied, truly excellent performance can be expected.

In any practical power amplifier design the bulk of the open loop gain is provided by the main voltage gain stage. The difference amplifier will generally provide some voltage gain but its main objective is to provide a linear difference signal with respect to its two inputs. In some power amps the output stage is a common drain or source follower MOSFET design and consequently has a voltage gain slightly less than unity.

An analysis of the distortion characteristics of the differential pair reveals that it is significantly better than a single transistor operated in common emitter configuration. If we assume that the distortion in a bipolar transistor is due exclusively to the exponential relationship between collector current and base-emitter voltage, the distortion generated by a differential pair and a single transistor can be calculated by techniques of Fourier analysis.

As well as having low distortion itself, a differential voltage amplifier will enable both outputs of the input differential pair to be used, thus giving a balanced output. This overcomes the problem of asymmetrical loading of the input pair by the input impedance of a single-ended voltage amplifier, a problem that would otherwise lead to increased distortion in the first stage.

Figure 1 is a circuit diagram of the voltage gain stage developed for this project. The stage is really a double differential pair with 'current mirror' load. Transistors Q1 and Q2 form the first differential pair with R1 as the common emitter resistor. The output of the Q1, Q2 pair provides a differential drive to Q3 and Q4. The latter pair,however, must be converted into a single-ended stage suitable for driving the output stage. This is the job of the current mirror formed by Q5, Q6, R5 and R6. Transistor Q5 has its base-collector junction shorted and therefore acts like a diode, but with the same characteristics as the base-emitter junction of Q6. The bases of Q5 and Q6 are connected together and therefore the voltage on the bases is identical. Since Q5 forms a 'mirror image' of the base-emitter junction of Q6, the voltage drop across the two transistors will be almost identical, depending on how well the two transistors are matched. Since the voltage on the bases and the voltage drop across the base-emitter junctions is almost identical, the voltage on the bottoms of R5 and R6 will be almost identical. If these two resistors are made the same value, the current through each resistor, and therefore the current in the collectors of Q3 and Q4 will be identical. This ensures the Q3, Q4 pair will operate symmetrically, even when a single-ended load is attached to the pair.

Furthermore, since the collector of Q3 is connected directly to the base of Q6, the transistors Q6 and Q4 combine to form a push-pull pair with very high gain.

In order to achieve good transient performance when drivng the slightly capacitive load of the output stage it is necessary to run a fairly large amount of current through this stage, especially the final differential pair and the associated current mirror. In the 5000 there is approximately 16 mA through these transistors, and the average power dissipation is therefore around 0.8 W.

These transistors will run fairly hot, approximately 60°C on the small heatsink shown, but the transistors are well inside their maximum ratings. The result is a voltage amplifier stage of exceptional linearity and very high gain. Coupled with a well-designed input differential amplifier and a good ouput stage, the phase linearity produced by this voltage stage is excellent, and makes it an easy matter to ensure total stability of the amplifier.

Since the output of the voltage gain stage has been designed to have sufficiently low output impedance to drive the gates of two MOSFETs in parallel, the output stage consists simply of the MOSFETs themselves. If a preset pot is inserted between the collectors of Q6 and Q4 in the voltage amplifier stage of Fig. 1 the voltage across this preset can be used as the bias voltage for the output stage. This is shown in the circuit diagram.

The gates of the output divices are connected to either side of the preset via resistors R21, R22, R23 and R24. As mentioned earlier, these resistors increase the time constant associated with the MOSFET gate capacitance, reducing the frequency response of the output stage slightly but ensuring stability.

Both N-channel and P-channel MOSFETs are used in this project. The important difference is the value of gate-source capactance for the two devices. If this is not equalised the presence of asymmetrical reactance in the output stage makes it almost impossible to ensure stable operation. The only cure is to decrease the open-loop gain of the whole amplifier, so that the negative feedback is reduced, and accept the consequent increase in distortion.

The most common method employed to achieve this is to increase the value of the emitter resistors in the input stage. This reduces the voltage gain of the input stage, at the same time increasing its small-signal bandwidth. Consequently, in a power amplifier employing MOSFETs in the output stage, the relatively small amount of negative feedback available will not be able to linearise the transfer characteristics of the output devices, and the result is an amplifier with only mediocre performance.

The problem of the asymmetry of the gate-source capacitance is cured by the addition of the capacitors C7 and C8 shown in the circuit diagram. With these capacitors in the circuit and with the 100R resistors R21, R22, R23 and R24, the only other component required to ensure total stability of the output stage is the power RLC combination formed by R29, C9, R30, L1 and the supply bypass capacitors C10, 11, 12 and 13.

When a square wave, for example, is fed into a purely capacitive load, the output stage will virtually see a short circuit since the high frequency (>100 kHz) fourier components of the sine wave will see very little impedance in the capacitive load.

The inductor L1 ensures that this does not happen by inserting a reactance that increases at high frequencies. The resistor R30 is placed in parallel with the inductance so the top end frequency response of the amplifier is not unduly affected.

The other two components of this network, R29 and C9, ensure that the amplifier always has a load at high frequencies. Without this 4R7 load the gain of the output stage is slightly greater than unity, due to the presence of positive feedback caused by the effective capacitance around the output devices, and this causes oscillation.

The 220nF capacitor is necessary since the resistor must be removed from the circuit for frequencies inside the audio passband or the high power dissipation in the resistor would destroy it instantly.

Resistors R25, R26, R27 and R28 provide slight emitter degeneration to the output devices. This helps to linearise the output transfer characteristic of the amplifier and thereby assists in ensuring stability of the output stage.

The final components needed to ensure stability of the output stage are the supply bypass capacitors C10, C11, C12 and C13. Capacitors C12 and C13 are 100uF electrolytics that provide general supply bypassing to frequencies inside the audio passband, but have little effect at 1 MHz, where the MOSFET would tend to oscillate.

For this reason capacitors C10 and C11 have been included also. These capacitors must be positioned very near the output devices, since the resistance of only several centimetres of track will greatly decrese their effectiveness.

In the 5000 these capacitors are mounted on the rear of the circuit board with one lead soldered directly to the drains of the output devices.

The gate resistors R21, R22, R23 and R24 and the gate power capacitors C7 and C8 are also mounted on the rear of the circuit board, again soldered directly to the MOSFETs.

The remaining components in the output stage are the zener diodes ZD1 and ZD2 and their associated diodes D3 and D4, and the bias preset RV1. The maximum gate to source voltage of these MOSFETs is 14 V; if this voltage is exceeded the MOSFET can be destroyed, so the zeners and diodes are placed between the gate and the output of the power amp to prevent the drive voltage ever becoming more than 12V6 above or below the output voltage.

This condition would mainly occur when the output is driving a short circuit or a capacitance load big enough to look like a short circuit. Under these conditions the output voltage cannot deviate much from 0 V since it is shorted to 0 V, and the negative feedback loop will drive the output of the voltage gain stage into clipping in an attempt to compensate for the error.

The gate to source voltage is now around ± 50 V, well above the absolute maximum voltage for the output devices. The diodes D3 and D4 are necessary to prevent the zeners from shorting out the gate drive under normal operating conditions.

The current flowing through the preset RV1 will give rise to a voltage drop across the preset that can be varied by adjusting RV1; this acts as the bias voltage for the output devices. If the diodes D3 and D4 are not present, the gates of Q10 and Q12 for example can never go more than 0V6 above the output voltage, due to the 0V6 forward voltage drop of ZD2. Since the voltage drop across RV1 is around 1 V, the drive voltage to the gates of Q9 and Q11 can never go higher than the sum of these two voltages, ie above the output voltage, and this limits drive to the MOSFET. The same occurs to negative-going signals due to the 0V6 forward turn-on voltage of ZD1.

The combination of all these techniques yields an output stage that is totally free of instability and with a bandwidth of a round 5 MHz! Furthermore, the transfer characteristics and phase response of the output stage are predictable, making it relatively easy to ensure stability of the overall feedback loop.

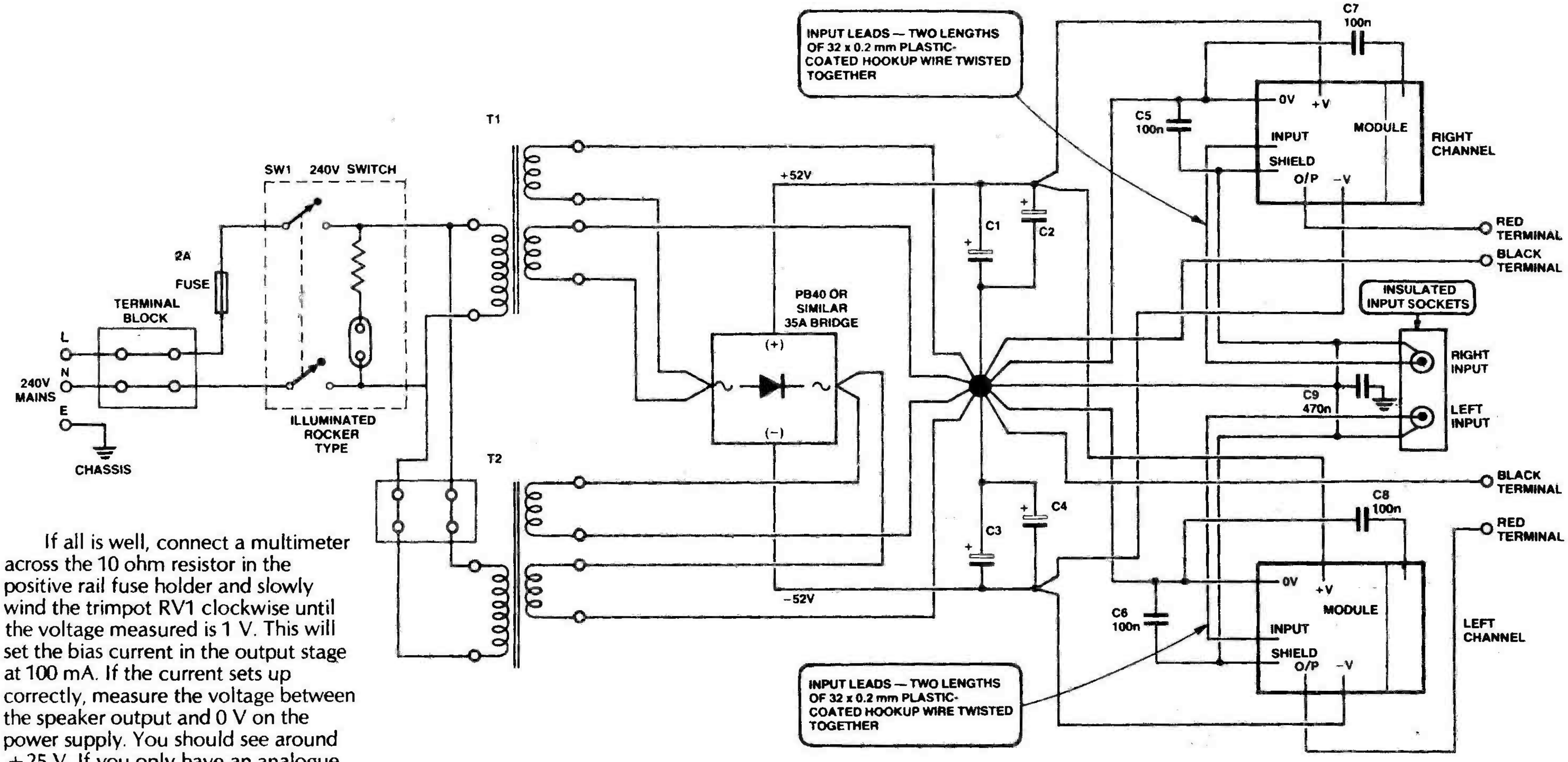


Fig. 7 Interwiring diagram for the complete (stereo) amplifier.

If all is well, connect a multimeter across the 10 ohm resistor in the positive rail fuse holder and slowly wind the trimpot RV1 clockwise until the voltage measured is 1 V. This will set the bias current in the output stage at 100 mA. If the current sets up correctly, measure the voltage between the speaker output and 0 V on the power supply. You should see around ±25 V. If you only have an analogue multimeter, this voltage may be too low to measure; in this case it is sufficient to show that the output is at 0 V.

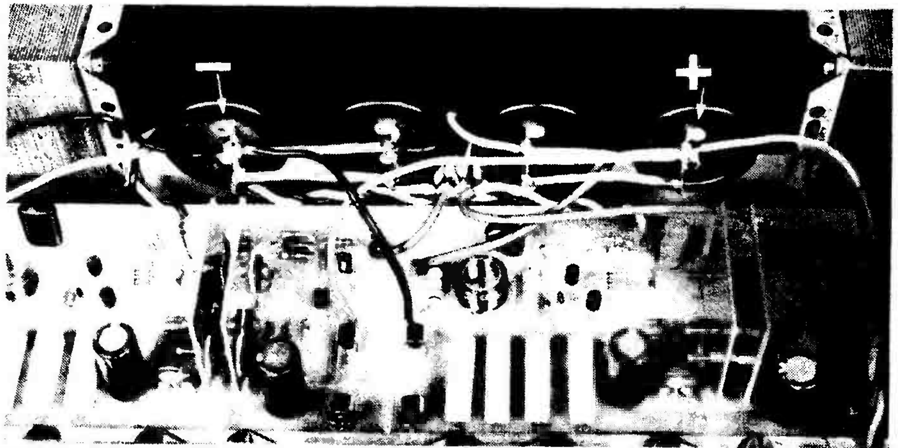
If the module passes all these tests, it is safe to replace the fuses and connect the load.

Construction — PSU

The advantage normally associated with independent power supplies is the reduction of crosstalk between channels. In the case of the ETI module however, the high supply rejection of the design reduces crosstalk to a level that is completely insignificant (ie around the noise level), so independent supplies offer no real advantage. On the other hand the use of two power transformers in a single power supply yields a supply capable of more than 100 V at over 7 A continuous. The transformer we used has two independent 35 V windings. These are connected in parallel to produce a single 35 V RMS winding capable of supplying 5 A RMS. It is unimportant whether these are toroidal or ordinary types — use whatever you can get.

If the same type of transformer cannot be obtained locally, then any type which can supply 35 V at 5 A is compatible.

One terminal of each transformer is connected to the bridge rectifier, a 35 A type. The filtering for the power supply is done with two 8000uF capacitors to form a total of 16 000uF across each half of the DC supply rails. The resulting supply voltage should be approximately ±52 V, unloaded. At full power this will drop to around ±50 V. With a 10 V drop across the output devices the peak signal voltage before clipping is around 40 V, which gives 100 W into a eight ohm load. In reality, the voltage drop across the MOSFETs is not as high as this since the module uses two devices in parallel. The maximum output power of the prototype unit using the power supply shown was 112 W single channel and 105 W both channels driven (RMS).



Wiring of the four filter capacitors. Note the common O V point between the two inner capacitors.

Interwiring

By far the biggest problem in the design and construction of any amplifier is that of earthing. If maximum performance is to be obtained from the ETI-5000 modules great care must be taken to ensure complete isolation of high current earths from low current ones such as the input signal earth. If this is not done the large currents flowing in the speaker return earths, for example, will interact with the input and distortion results. Similarly, if the earth current from the electrolytic capacitors is allowed to interact with any low current signal earth amplifier will have degraded hum figures and may even be unstable. The board layout has been designed to overcome these problems through the use of a *single-point* earthing arrangement. Earth lines from the output devices and power earth lines from the on-board electrolytic capacitors are kept separate until they reach the 0 V point on the circuit board.

The main input signal earth is the most critical. To overcome any problem the input earth is isolated from the 0 V track on the circuit board by the 10 ohm resistor R3, shown on the circuit diagram. The input wiring to the module is done with a twisted pair of 10 amp hookup cable and the connection for the input earth is done at the input sockets. This is shown in the circuit diagram.

The 10 amp hook-up cable is used instead of the more usual shielded cable, since in this application the lower resistance of the hookup cable results in better hum rejection.

The remaining earth problem is the possibility of hum loops caused by the fact that both the power amplifier and the preamplifier used to drive it must be connected to the same chassis ground point via their power cables. If the chassis of both the preamp and the power amp are connected to the 0 V point on their respective power supplies and the two 0 V points are connected together via the shielded cables between the preamp and power amp, a closed circuit is formed. Any hum currents induced into the earth lead of the three-core power cable, for example, can flow through the chassis of the power amp to the power amp 0 V point, down the shielded cable at the power amp input to the 0 V point in the preamp and via the preamp chassis around the loop again. The presence of this hum current in the power amp input earth will be seen as an input by the power amp and output hum results. The cure is to open-circuit this loop so that hum current cannot flow in the input signal earth line. The best way to do this is to break the connection between the chassis of the power amp and the 0 V point on the power supply. In this way the power amp still has a valid earth reference at its input but the possibility of a hum loop is eliminated.

The disadvantage of this technique is that the chassis can no longer act as an effective shield to external electrical noise sources, but this problem can be overcome by capacitively coupling the chassis to the 0 V track at selected places in the power amplifier. The relatively high impedance of these capacitors at 50 Hz still maintains an effective open circuit to prevent the hum loop problem.

The earthing procedure outlined above has consistently given good results both in the prototype and in numerous other power amps, and provides the power amplifier with good earthing that is not affected excessively by the earthing configuration in the preamp.

Lead Astray

The input wires to each module should be attached at this stage. We used a twisted pair of 32 x 0.2 mm plastic-coated hookup wire. This is superior to standard shielded cable for this application. The input wiring must be kept away from the 240 V wiring at the rear of the power switch.

The input 'earth' on each board has to be AC-coupled to the 0 V line on each board for the reasons discussed earlier. This is done by soldering a 100n capacitor on the rear of each board, immediately beneath R3. The 'earthing bolt', which makes connection to the heatsink bracket, is assembled with a transistor mounting insulator on the underside of the board so that the bolt is insulated from the 0 V line on the board. A solder lug is placed under the nut. A 100n capacitor is then soldered between this lug and the 0 V track adjacent.

Follow the interwiring diagram carefully and recheck at each stage.

Do the bridge rectifier and transformer wiring first. Then do the capacitors. The lower terminals of all four capacitors are connected together using heavy braid stripped from a piece of RF type coax cable. The centre of this bus becomes the central 0 V return point (refer to the photograph). The two right hand capacitors also have their terminals bridged by a length of braid, as do the two negative terminals of the left hand capacitors. The positive output terminal from the bridge rectifier then connects to the positive terminal of the innermost right hand capacitor. The negative terminal of the bridge rectifier connects to the negative terminal of the innermost left hand capacitor. Two wires from each transformer secondary are wired directly to the central 0 V point (see wiring diagram).

Next wire in the amp modules, the speaker terminals and the 240 V circuitry.

Check everything carefully once you have finished.

Getting It Going

Having satisfied yourself that all is well, remove the fuses on each board, arm yourself with a multimeter, hold your breath . . . and switch on. Assuming no disasters occur, measure the supply rail voltages. They should be around 52 V. If you have previously set up your modules then you can replace the four fuses and proceed with listening tests. Before replacing the fuses allow sufficient time for the electrolytic capacitors to discharge. This will take several minutes.

Once you have completed the set-up procedure, your amplifier is ready for listening tests.

The top and bottom covers can be screwed in place once you've confirmed all is well. We recommend you use aluminium for these items as steel plates will react with the field of the transformers and produce quite a loud hum.

ETI

READ/WRITE

Letters for this page should be addressed to Read/Write at our Charing Cross Road address.

Dear Sir,

I am writing to you about two separate matters. First, a friend of mine recently purchased a kit for the ETI System A preamp from Jelgate, as recommended in Buylines. The screened cable supplied for the internal wiring was the kind which has a semiconducting layer between the screen and the inner conductor insulation. My friend did not know of such cable and, as a result, his preamp had several strange 'faults.' This could, of course, be blamed on my friend's inexperience, but I think that the same mistake could be made by other constructors. I leave the matter to your judgement, but respectfully suggest that you contact Jelgate with the suggestion that they include a note in future kits making the special nature of the cable quite clear.

Second, I refer to the articles on Pickup Amplifier Design (ETI Jan. and Feb. 1982). Mr Tilbrook makes reference in the first article to a resonance which is "a function of both the mass and the compliance of the cantilever and suspension system," which occurs around 10 Hz. As far as I am aware, there is a resonance which occurs around 10 Hz, and it is a function of the cartridge compliance. However, the mass involved in this particular resonance is the mass of the whole cartridge plus the effective mass of the pickup arm (as 'seen' by the stylus tip). This mass is of the order of 5-10 grams. The effective mass of the cartridge cantilever and suspension system will be (at a guess!) 5-100 milligrams. This would lead to a resonance around 100 Hz according to Mr. Tilbrook's equation ($F = (2\pi\sqrt{mC})$, where m is the mass of the cantilever and suspension system and C is its compliance).

I was also under the impression that the RIAA roll-off point around 50 Hz was defined by a time-constant of 3180 uS, and not 3150 uS, as published. Perhaps this was changed by RIAA at the same time as the 20 Hz roll-off was added?

Signetics data shows the input current of the NE5534 to be less than 2 uA, typically 0.5 uA. My own experiments have lead me to believe that the operation of a moving-magnet cartridge is not affected by a current of this order flowing through it. However, in a preamp which must suit all cartridges, a DC blocking capacitor must be a good idea.

To sum up then, thanks for an article which treats the cartridge preamp very well indeed, despite some small confusion over resonances.

Yours faithfully,
S J Merrick,
Lancashire

David Tilbrook has been contacted about these points and we hope to be running a reply from him very soon.

Dear Mr Harris,

I advertised in ETI for 18 months but have never received any editorial comment.

We are THE UK specialists in pocket computers. This is a very exciting field which has not been taken seriously. We started by selling the PC-1211 and recently the CASIO FX-702P and at last the new SHARP PC-1500. This really is a fantastic machine. We really look after our customers with hardware software and consumables. Our mailing list has grown and we are selling all over the world.

We have the only range of books on pocket computing in the UK. Our new book "POCKET COMPUTING MADE EASY" has sections on the PC-1211 — FX-720P and the new PC-1500. This is the most comprehensive book available on pocket computing. We are giving it FREE on all orders for the PC-1500. Our 1982 catalogue is being printed and we will send free copies to your readers.

CAN YOU IGNORE ALL THIS EFFORT?

Give a small dedicated company a break. Mrs Thatcher will be grateful.

Yours faithfully,
Barry Elkan,
Elkan Electronics,
28 Bury New Road,
Prestwich,
Manchester M25 8LD

O.K. You've had a mention. So stop moaning!

Dear Sirs,

May I ask you to consider the following as the basis for a future article.

It is widely known that high sound levels can cause temporary, even permanent hearing damage. However, although this fact is widely known it is not properly understood by the public. have not seen any 'in-depth' articles on the subject in the magazines that I take.

This seems to be a glaring omission when magazines such as yourselves devote pages and pages to the production of sound in ever-increasing variety and power. I am not immediately involved in this subejct at the moment, but my colleagues are, and frequently bemoan the lack of understanding they encounter.

Would you consider publishing an article to clearly explain the hearing process and subsequently explain the effects of abnormal sound levels. This could be supported by details of audiometrics, possibly even a circuit (or project) of an audiometer.

When you consider that many of your readers are interested in the beauty of sound, from Bach to The Police, would it not be a great benefit to help them to continue to enjoy their pleasures for as long as possible, by not having those pleasures diluted by unnecessary hearing loss?

I hope you feel that this idea has sufficient merit to result in the printed word being published.

Yours faithfully,
G.M. Francis,
Ipswich

We have published a project for a SPL meter recently, but the point on high levels is well taken and we'll look at the idea for an article in more detail.

Dear Mr. Harris,

I am writing to say how delighted we are with Peter Freebrey's article on building the Wharfedale E70 speakers using our flatpack cabinet kit!

Just a point, though, — the article refers several times to "chipboard". Our cabinet kits are made from MDF board which is much finer grained, smoother and more consistent in texture and density than the highest density chipboard. Being ideal for speaker enclosures, this material is now being used by a number of up-market manufacturers (in spite of being more expensive than chipboard).

We found the April 82 issue of ETI interesting and enjoyable.

Yours sincerely,
R.F.C. Stephens,
Managing Director,
Wilmslow Audio Ltd.

To be honest no-one here had ever heard of MDF before and even now we can't find out what 'MDF' stands for!

Never was any good at woodwork anyhow.

ETI

ELECTROMUSIC TECHNIQUES PART 3

In the final part of this electronic extravaganza, Tim Orr tidies up the loose ends with details of ADSR and signal input circuits, plus controllers and sequencers.

The ADSR unit has become industry standard for generating envelope contours and for filter sweeps. Curtis produce an entirely voltage controlled device, the CEM3310(Fig. 1). The A, D and R inputs have an exponential sensitivity; these time constants will vary an octave for a 18 mV voltage change(or 60 mV per decade) at the input pins of the IC. The control voltages are externally attenuated by a resistor pair (30k and 470R). The time constants are controllable over four decades, that is from 2 milliseconds to 20 seconds. The sustain level is variable from 0% to 100%, again using voltage control (0 V to + 10 V, linear law). The CEM3310 is ideally suited to polyphonic systems where one set of ADSR pots will control 5 or 10 independent ADSR units, by use of voltage control. An ADSR unit that employs a separate pot for each parameter is shown in Fig. 2. Time constants from three milliseconds to two seconds are available. This unit can be used in monophonic synthesiser systems.

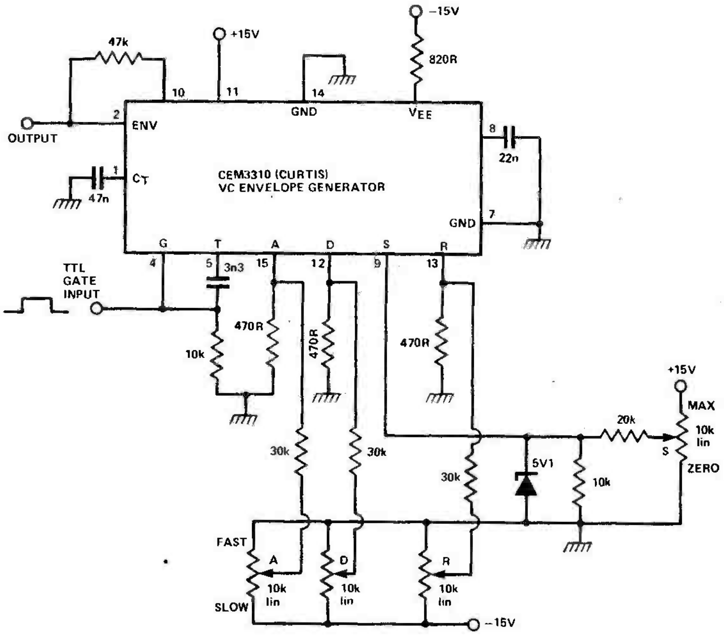
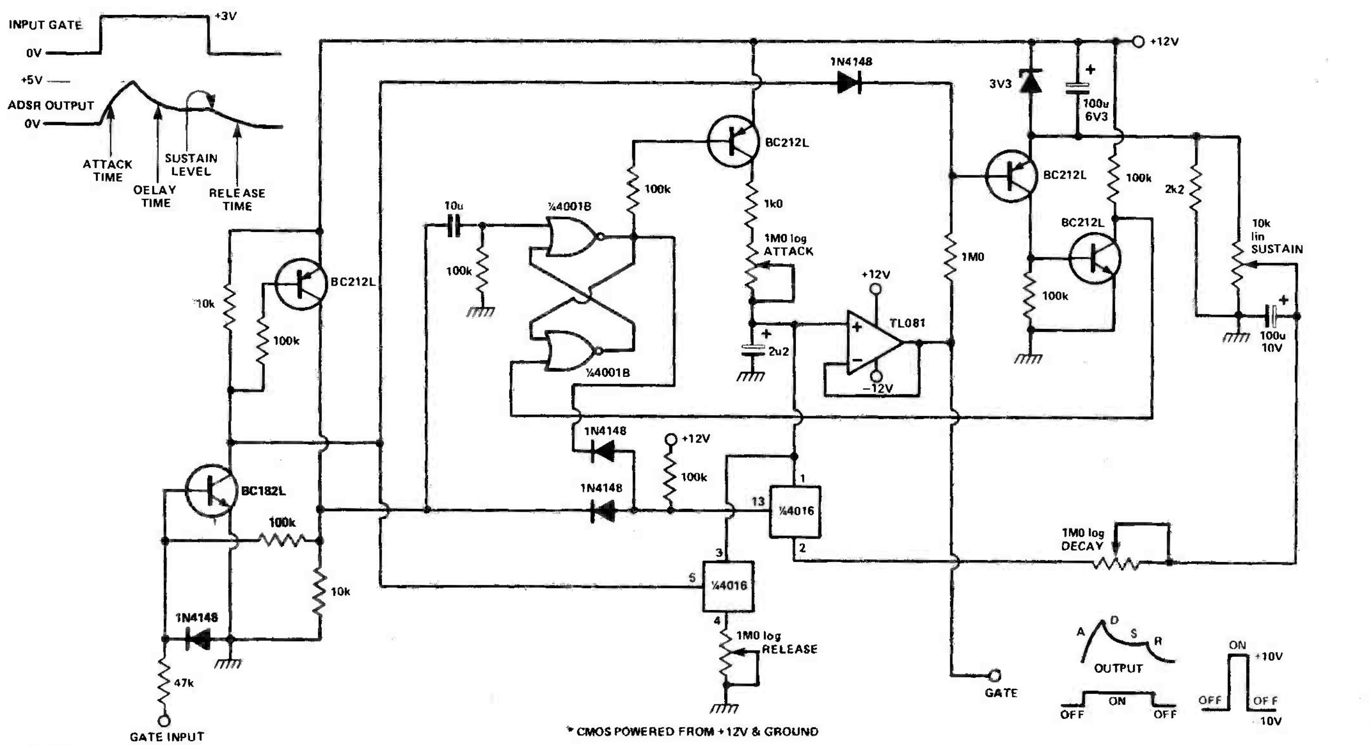


Fig. 1 (Right) A monolithic ADSR circuit using the Curtis chip. The A, D and R time constants are variable from 2 milliseconds to 20 seconds.

Fig. 2 (Below) An ADSR unit using discrete components (courtesy of Powertran Electronics).



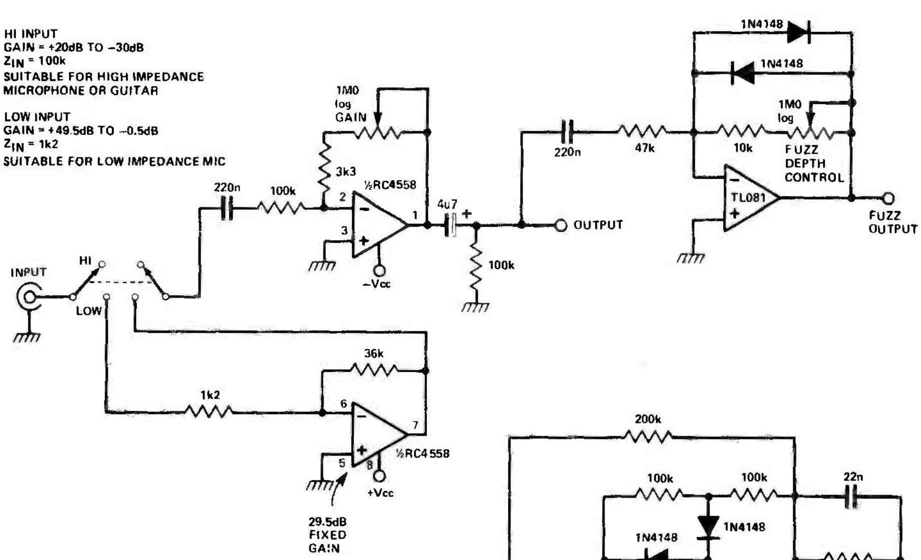


Fig. 3 (Left) An input amplifier suitable for a synthesiser, with both high and low level inputs.

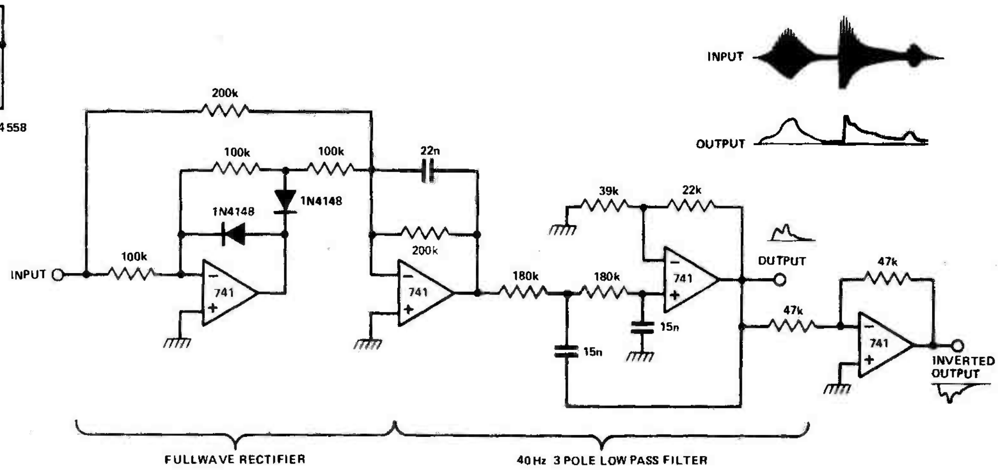


Fig. 4 An envelope follower using 741s.

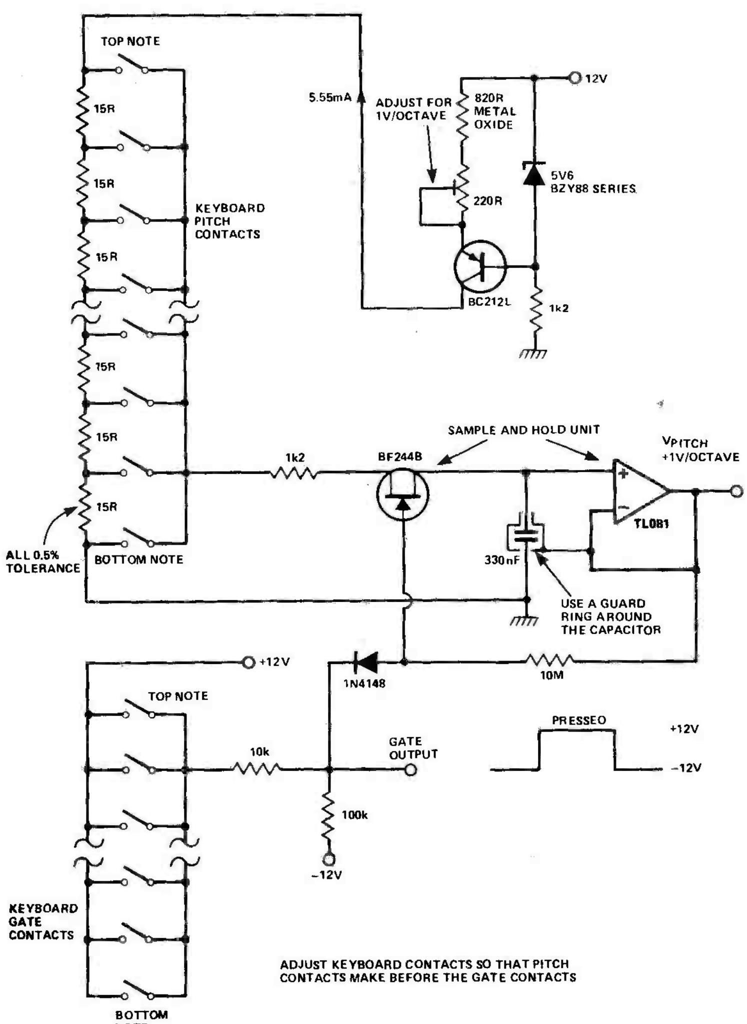


Fig. 5 Typical monophonic synthesiser keyboard unit.

Signal Input Circuits

Synthesisers are often used as signal processors, and so a variable gain input amplifier is needed (Fig. 3). This circuit has a high level high impedance input, which makes it suitable for guitars, plus a low level impedance input suitable for a low impedance microphone. A fuzz circuit has also been included so that severe harmonic distortion can be introduced to the signal. Another useful device is the envelope follower (Fig. 4). This is a fullwave rectifier followed by a lowpass filter. The envelope is often used to sweep a VCF or a VCO, to produce dramatic effects.

Controllers

Most synthesisers are controlled from a musical keyboard. The keyboard has to generate and remember a pitch voltage (+ 1 V/octave) plus a gate signal to indicate that a note is being pressed (Fig. 5). The pitch circuit is a stable current source that drives a resistor chain. A potential of 83.3 mV is set up across each 15 ohm resistor. When one note is pressed, the potential of that note is stored in a sample-and-hold unit. When the note is released the potential is retained. If more than one note is pressed, then the lower note is selected.

A sample-and-hold unit cannot retain its information for ever; it droops. A no-droop solution to pitch generation is to use a digital system, as in Fig. 6. The 74C922 is a keyboard encoder; it scans a keyboard and generates a digital code representing the last note pressed. Unfortunately it can only define 16 notes (the 74C923 can define 20) and so must be limited to rather small keyboards. The digital code is converted into a pitch voltage with an eight bit DAC, only using the most significant top four bits. Some keyboards have a dynamic feature, so that the faster you play the note the louder it sounds. This is done by timing the key transition, but it is very difficult to get a natural feel to the keyboard. Some keyboards are pressure sensitive; the harder you press down, the more pitch bend or vibrato you add to the VCO pitch. Other manual controllers such as pitch bend/vibrato wheels and joysticks are also employed (Fig. 7). The wheels are always mounted on the left hand side of the keyboard so that the musician can operate them with his left hand and play the music with his right. The pitch voltage from a

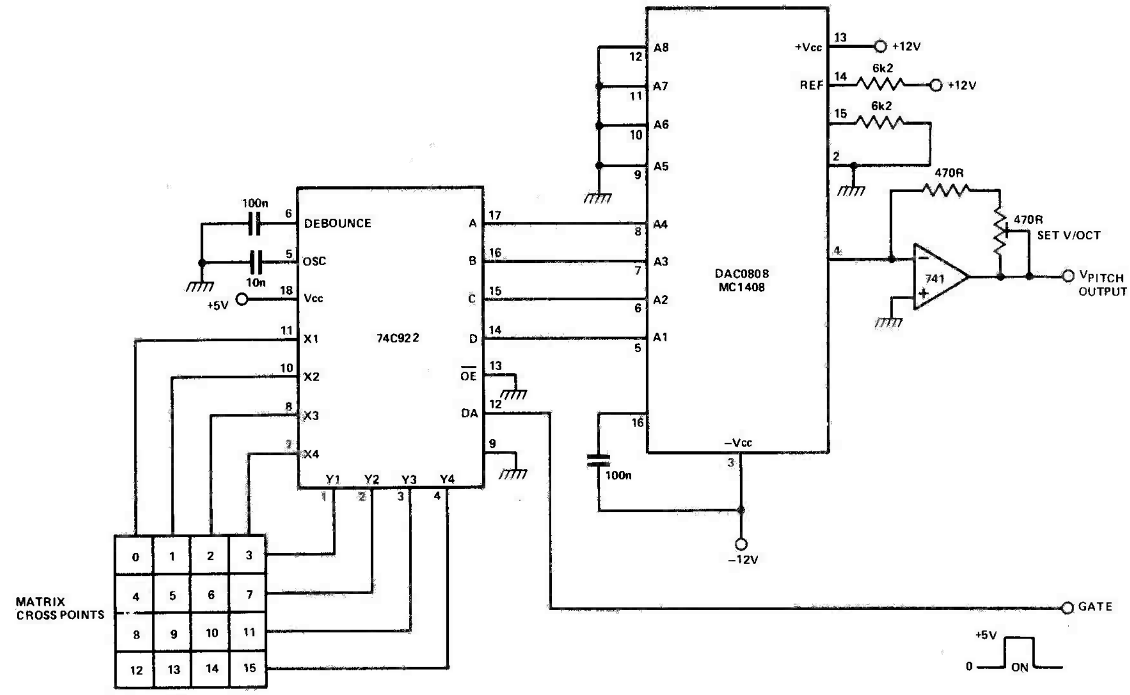
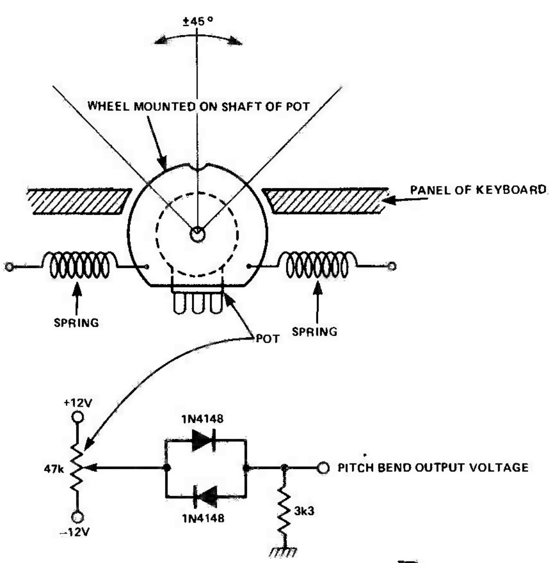


Fig. 6 A digital keyboard, in this case for a 16-note range.



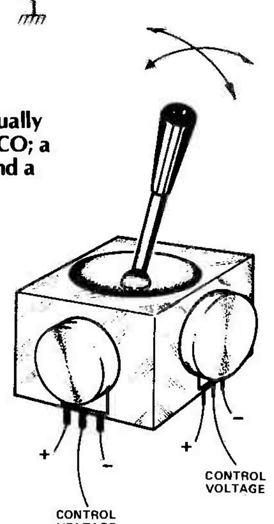


Fig. 7 Two methods of manually controlling the pitch of a VCO; a pitch bend wheel (above) and a joystick controller (right).

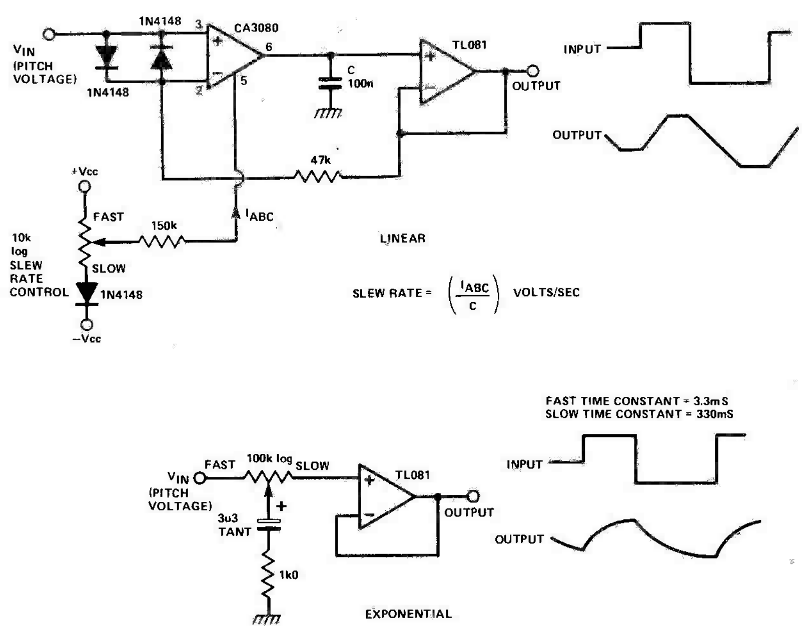


Fig. 8 Two portamento circuits; one linear (top), the other exponential (bottom).

keyboard is often processed by a portamento unit (Fig. 8). The pitch then glides from its last note to the next. Some people prefer exponential glides, others linear.

Sequencers

Electronic music often has a background rhythm, which is generated by some sort of sequencer (Fig. 9). A sequencer generates a string of pitch voltages which change on the beat. These are used to control a VCO which is perhaps passed through an ADSR and VCA unit. The result is a rhythmic string of notes. In the circuit, the clock is externally generated, although

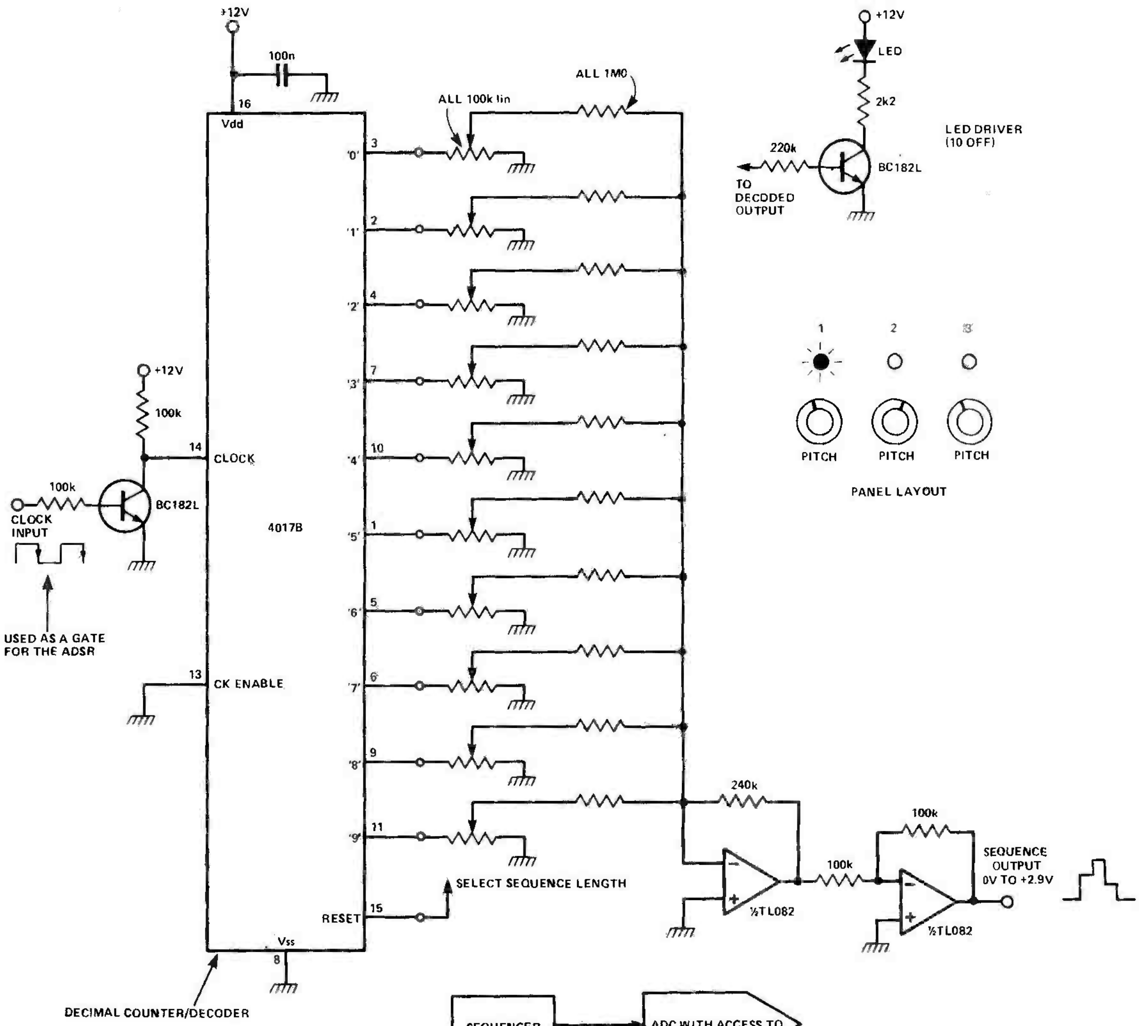


Fig. 9 A simple sequencer.

there is no reason why the sequencer should not have its own dedicated oscillator. The sequence length can be modified by connecting the reset line to any output; if you connect it to the '8' output the sequence length will be 8. An LED indicates which decoded output is active. The pitch pots have been given a three octave range, which might make tuning rather difficult; 0.1% of the pot rotation equals 3.6 cents of pitch (100 cents = 1 semitone). Either a smaller pitch range could be used or multiturn pots could be employed, but these are rather expensive. Some sequencers quantise the pitch into semitone steps so that 2.7% of the pot rotation would equal one semitone. During this 2.7% rotation, the output pitch remains fixed. This can be done by inserting the pitch voltage into an ADC, using the beat signal to start the conversion and taking the DAC output as the quantised pitch output voltage.

Final Points

A modular synthesiser should have one or two simple audio mixer circuits (Fig.10,). These can be used to mix the final output signal or to send the signal to external treatments such as reverberation units, phasers or chorus units, and electronic or tape echoes.

A synthesiser relies heavily on stable and clean power supply rails. A good rule is never to dump large currents down the ground rail, as this is used as a voltage reference throughout the system. If you are going to turn lamps on and off, run them between the positive and negative rails. Ordinary 78XX and 79XX voltage regulators can be used, but if they get hot then their output voltage will drift and will give the system a long warm-up

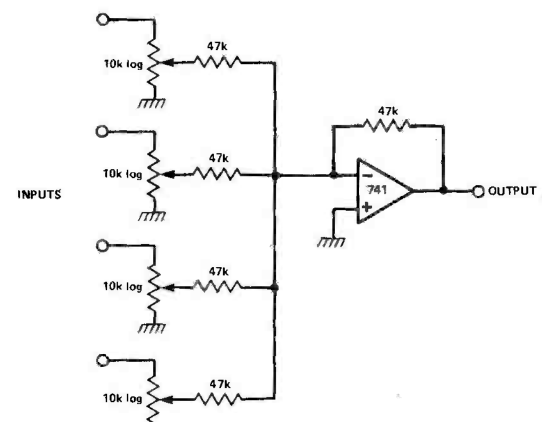


Fig. 10 A simple audio mixer with four inputs.

time. A 723 regulator plus a power bypass transistor will give better temperature stability performance. Any hum on the supply rails will frequency modulate all the VCOs.

Good Books

Musical Applications of Microprocessors — Hayden Book Company.
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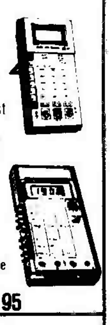

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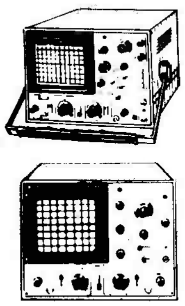

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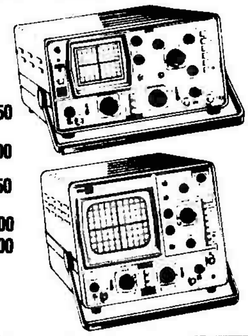

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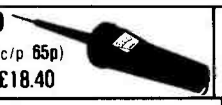

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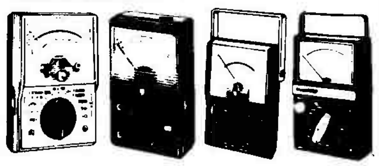

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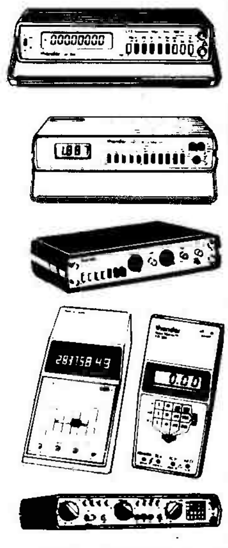

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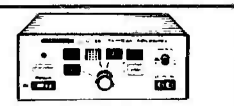

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ROBOT MODULES

A brace of projects for our mobile this month; a digital PWM interface board for the motor controller so your computer can take your robot for a walk, and an optical sensor so it won't run over your cat/budgie/kids. Here's the first one. Design and development by Rory Holmes.

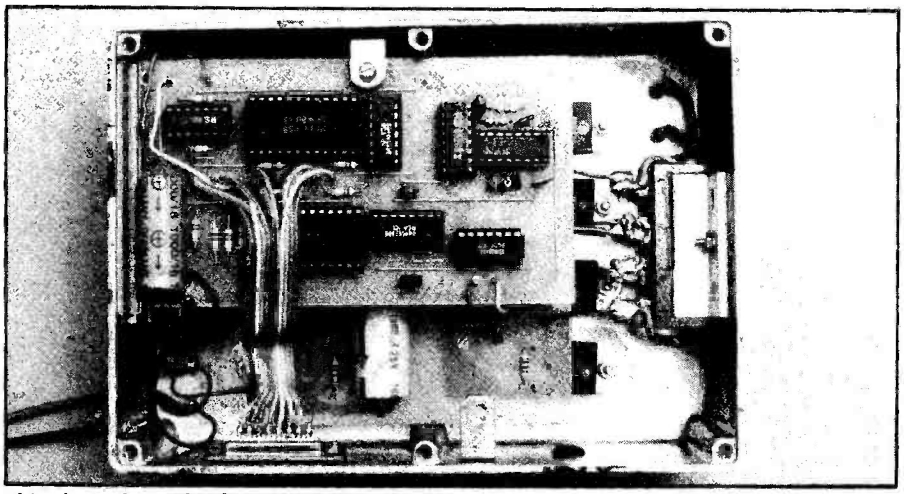
The digital pulse width modulator is constructed entirely from CMOS logic ICs to provide pulse control of two independent channels. Pulse width modulation can be used to control a variety of analogue functions; this design is offered to allow computer control of ETI's Dual Motor Switching Amplifier, featured in part 1.

Binary counters are used to count both the ON and the OFF periods of the mark-space cycle; thus the duty cycle is independent of the timing circuitry, being an exact ratio of two numbers.

The duty cycle data for either channel is loaded through an eight bit port common to both, and is addressed to a particular channel by the use of two strobe lines. When a strobe line is taken low the input data is latched into the associated control channel, which generates a pulse width corresponding to the input value. The pulse width will remain at this value after the data has changed and until its strobe line is activated again. The minimum strobe pulse required is 50 uS; thus both motor speeds can be changed in about 100 uS.

To suit the standard eight bit data bus of most microprocessors we have allowed seven bits for controlling the pulse width, with a further bit for setting the forward/reverse motor direction. Pulse widths can thus be obtained with a resolution of one part in 128. With the modulation frequency set at 20 kHz (just above audibility), the pulse width can be increased from zero in 390 nS increments up the maximum of 50 uS; this represents 100% duty cycle modulation (50 uS = one cycle at 20 kHz).

Timing signals for pulse generation can, of course, be implemented directly with software from the controlling microprocessor; however, this creates large overheads on processor time. Furthermore, any application software must be designed around these timing routines which can soon become a nightmare of interactive real-time programming.



This photo shows the digital PWM board mounted above the motor driver board from Part 1 of the series.

Our design strategy has been to dedicate external hardware circuitry to the mundane and repetitive tasks, thus freeing the controlling processor for running the more sophisticated command programs.

Figure 2 shows the circuit diagrams of both channels with the accompanying description. The unit is assembled on a PCB which fits inside the existing motor driver amplifier case and runs off the same 12 V power source. A 15-way D-type cannon socket mounted on the side of the diecast box provides input for the programming data.

Construction

The PCB should be assembled as illustrated in the overlay diagram. We recommend soldering in the 14 links first, followed by the resistors and IC sockets. Veropins should be inserted at all the input and output terminals, 17 in all, and finally the capacitors can be soldered in. Before plugging in the ICs, connect a 12 V power source at the supply points shown and check the ground and positive rail voltages at all the IC sockets. If all is well, a short length of 11-way ribbon cable can be wired up to the eight input bits, ground, and the two strobe lines.

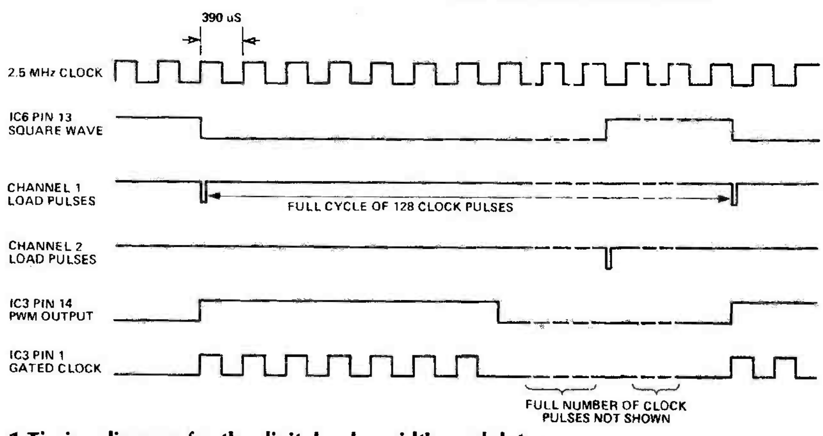


Fig. 1 Timing diagram for the digital pulse width modulator.

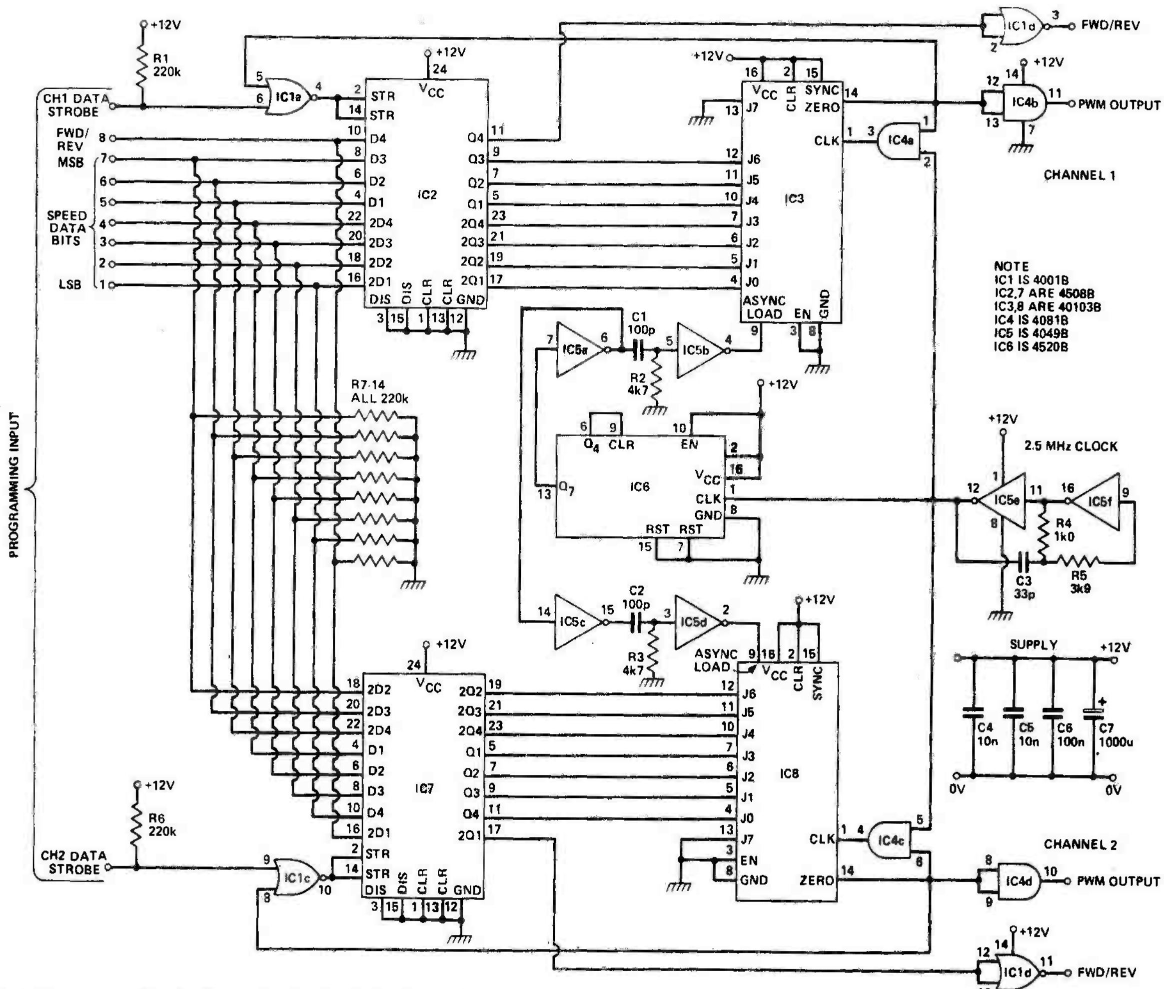


Fig. 2 Circuit diagram for both channels of the digital PWM.

HOW IT WORKS

Each of the two control channels operates in an identical fashion with some circuitry common for both. We shall describe the basic circuit action referring to the upper half of the circuit diagram in Figure 2. IC3 is the heart of this circuit, being an eight bit binary down counter with presettable data inputs; it is used to generate the variable pulse widths. The eight data bits presented at the preset inputs J0 to J7 are loaded into the counter when the synchronous load input on pin 9 is pulsed to logic low. If a clock is now fed to pin 7 the counter will start counting down to zero from this preset value. When zero is reached the previously high zero detect output on pin 14 goes low. In our configuration this zero output is used to gate the clock input via AND gate IC4a. Thus, as soon as zero is reached the clock is disabled, leaving pin 1 low and so allowing the zero output on pin 14 to remain low also. The counter IC3 can only be restarted by another load pulse to pin 9, which presets the count start value and returns the zero output to logic high, thus enabling the clock for the down count. A look at the timing diagram of Fig. 1 should clarify this sequence.

The 'zero detect' output on pin 14 directly provides the required PWM signal and is buffered by AND gate IC4b before driving the power switching stage. The load pulses are produced by the edge detector implemented using inverter gates IC5a and b. These negative-going pulses are very narrow, with a width set by differentiator C1/R2 of about 200 nS; they are derived from the negative-going edges of a square wave produced by the counter IC6. The load pulses for the other channel are generated in a similar fashion, but from the positive-going square wave edges. This ensures the 180° relative phase offset of the two PWM signals, necessary for reducing the peak supply current.

This square wave determines the full period of each pulse width cycle and thus sets the constant frequency of the PWM output. The counter IC6 is a dual four-bit binary counter; the stages are wired in cascade for ripple counting, and the square wave is taken from the seventh output bit. A 2.5 MHz astable clock built around IC5e and f drives both IC6 and the down counter IC3. IC6 will thus divide the master clock by 128, providing load pulses at a repetition frequency of 20 kHz which is the required modulation frequency. For a maximum duty cycle modulation of 100% the down counter must have a maximum start count of 128, giving a resolution of one part in 128. This is achieved by using only the first seven input bits of IC3 and taking the eighth to logic low. The pulse width is thus variable from 0 to 50 uS in 400 nS increments. The eighth bit of the input port is used to set the foward/reverse direction of the motor.

The pulse width data for the preset inputs of counter IC3 must be continuously available, since it is loaded afresh for each cycle on the negative-going edge of the asynchronous load pulse. The eight bit data port from the 'outside world' is thus latched by IC2, a dual four bit hold-follow latch (the CMOS 4508). When the 'store' inputs on pins 2 and 14 are logic high the data appearing at the Q outputs will follow the data on the inputs; when 'store' is taken low the current data is held internally and remains on the Q outputs to control the down counter.

The corresponding data input bits of each control channel on IC2 and 7 are wired together to form a common input port; data is thus altered for a particular motor channel by taking its associated store input to logic high. Strobing in new speed data is achieved using IC1a, a NOR gate. One input, the strobe line, is held normally high by R1, and the other input is taken from the PWM output.

When the strobe line is now taken low the store input will only go high as the PWM output signal goes low. This arrangement ensures that any new data will be stable when it is loaded into the down counter; it also prevents the forward/reverse control from changing state while the motor driver transistors are turned on. Once the required data has been set up on the inputs, the data strobe line must be taken low for a minimum period of 50 uS to ensure the data has been latched. NOR gate IC1b is used to buffer the forward/reverse control line before it leaves the PCB. The 12 V power requirement is taken from the motor driver stage described in Part 1, with C7 providing smoothing and C4, 5, and 6 decoupling the fast switching pulses.

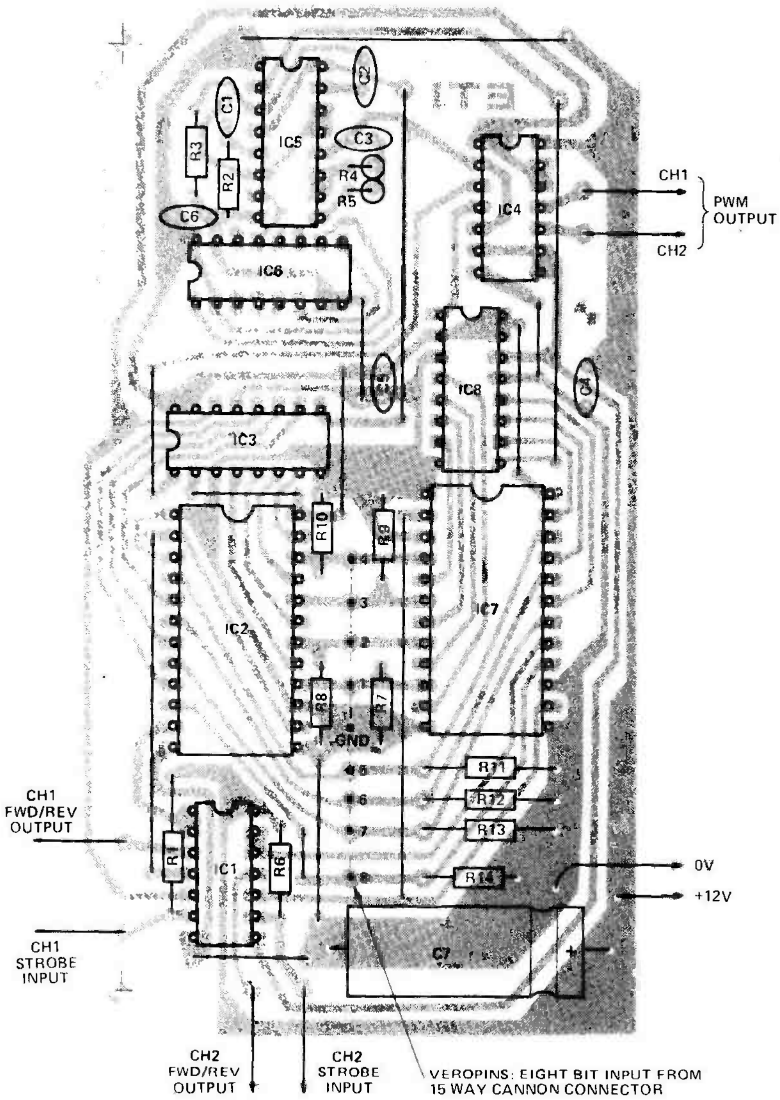


Fig. 3 Component overlay for the PWM board.

PARTS LIST

DIGITAL PWM

Resistors (all ¼ W, 5%)

R1,6-14	220k
R2,3	4k7
R4	1k0
R5	3k9

Capacitors

C1,2	100p ceramic
C3	33p ceramic
C4,5	10n ceramic
C6	100n ceramic
C7	1000u 16 V axial electrolytic

Semiconductors

IC1	4001B
IC2,7	4508B
IC3,8	40103B
IC4	4081B
IC5	4049B
IC6	4520B

Miscellaneous

PCB (see Buylines); Veropins.

BUYLINES

No problems at all here; most mail order companies advertising in this issue should be able to supply the components. See page 82 for the price of the PCB.

Testing Times

With nothing connected to the ribbon cable inputs, the two pulse width modulation outputs should be continuously low and the two FWD/REV outputs should be high (you may need to briefly touch the strobe input wires to a ground terminal). These outputs may be observed with either a 12 V FSD meter or a scope. If a scope is used, the 2.5 MHz clock can also be checked; a square wave should be observed on pins 2 and 5 of IC4.

Pulse width control for each channel may now be verified. Wire bit seven of the ribbon cable to the positive terminal. When either strobe is now taken briefly to ground, the corresponding PWM output line will change to a square wave. The duty cycle is now 50%, this ratio being 64 (bit 7) divided by 128 (full cycle), and the meter will read 6 V. If a scope is being used the square wave pulse trains from each channel can be observed; they should be 180° out of phase with each other (in the case of square waves this looks like inversion).

This process can be repeated, taking only bit 1 positive, to give the minimum pulse width of 1/128th of the full 50 uS cycle (about 390 nS). This very small pulse cannot be detected by the meter but can be seen on an oscilloscope. Further bit combinations can be strobed in, to provide varying pulse widths in increments of 390 nS.

Modifications

The eighth bit of the data input port is used to set the forward/reverse signal line. For applications that do not require a separate direction signal, ie a computer-controlled pulse generator, this bit may be utilised for higher resolution pulse width control; the full eight bits give a resolution of one part in 256. To implement the modification the following changes can be made.

The tracks to pins 1 and 2 and pins 12 and 13 of IC1 should be cut; this provides two unused NOR gates, whose input pins should be connected to the nearest ground track via insulated links. The tracks to pins 13 of both IC3 and IC8 should be cut; pin 13 of IC3 is now linked to pin 11 of IC2 and pin 13 of IC8 to pin 17 of IC7. Pin 7 of IC5 should be cut from its track and linked to pin 14 of IC6. The forward/reverse input line, bit 8, now becomes the most significant bit of the pulse width control.

The pulse width modulator now works in exactly the same way as before but with an output frequency of 10 kHz, exactly half the original value.

Once the board has been tested it can be mounted using brackets or adhesive PCB slots directly above the motor driver board in the diecast box. The two supply pins are wired to the existing 12 V input terminals, while the FWD/REV and PWM outputs are connected to the corresponding inputs of each motor driver channel. We used a 15-way D-type Cannon socket bolted onto the case side for the eight bit data input. The two strobe lines and ground wire should also be wired to this connector. **ETI**

PROXIMITY DETECTOR

This project will endow your man of steel with infra-red vision; and it's not much bigger than a human eyeball. Alternatively you can use in applications such as batch counting. Design and development by Rory Holmes.

This project provides a very useful means of detecting the presence of *anything* by the reflection of infra-red light, and provides a direct digital output of object detection.

The transmitter and receiver of the infra-red beam are both mounted on the same miniaturised PCB, which is housed in a short length of aluminium tube for screening and protection. By the use of modulation and high power bursts of infra-red at a very low duty cycle, a detection range of over a foot is achieved. The receiving photo-amplifier is tuned to the same modulating frequency of 1 kHz, and thus provides good rejection of stray infra-red interference. Bright lights will not affect the operation of the module.

The module features a wide supply voltage range, with an LED to indicate correct operation. A preset adjustment pot at the rear of the sensor allows the detection range to be preset at any distance between 1 and 35 cm.

Construction

Although the PCB layout (Fig. 2) is quite dense, with several vertical mounting resistors, the assembly should be straightforward. The only component of note is PR1, a ¾" 20 turn rectangular cermet preset. These are readily available, though, and should fit the board exactly. The power transistor Q3 is mounted flat, with the metal side face down; likewise, observe the orientation of the other transistors. Photodiode D1 has a chamfered edge on one side; this is mounted to face the infra-red emitter LED2, so allowing the sensitive surface to face outwards. The infra-red LED should be mounted with the flat side facing away from the photodiode (the flat identifies the cathode). After assembly of the board it is important to mount a small guard between the infra-red emitter and detector, to prevent infra-red light passing directly to the detector before it has been reflected. The guard should be a 7 mm square, cut from un-etched PCB or a piece of aluminium. It can be stuck between the two diodes and directly in front of C4 with a blob of superglue.

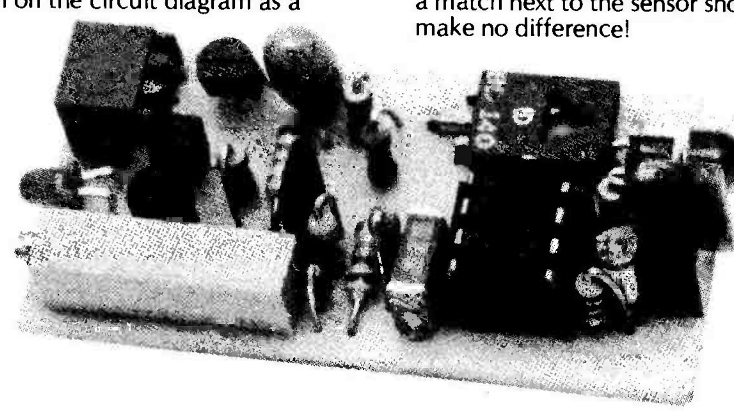
The board is mounted in a 55 mm length of aluminium tube, of internal diameter 27 mm or greater.

The diagram of Fig. 3 illustrates how a 6BA nut is soldered sideways onto the PCB track directly beneath the 3-way connector socket. Holes are drilled in one end of the tube to mate up with the indicator and preset adjustment screw. A rectangular hole also needs to be cut, allowing access to the connector socket. A 6BA bolt can now be used to tighten the board against the tube end. The sensing end of the tube may be covered with anything that is transparent to infra-red (red filter plastic polarising sheet, or just clear plastic). If openings are cut for the emitter and detector then an aluminium disc could also be used. The disc should be cut to fit the tube and mounted flush against the small guard plate with epoxy. The sensor tube may be mounted with a circular clamp that tightens round the tube; this can be seen on the photographs of our prototype.

C2, the smoothing capacitor, is shown on the circuit diagram as a 100uF 10 V tantalum electrolytic. This value was chosen to fit on the PCB and consequently limits the supply to 9 V maximum, although the circuitry is capable of operating up to 35 V. To allow higher supply voltages, change C2 to 22uF 35 V tantalum. An additional electrolytic of 100uF 40 V should be mounted underneath the board and soldered to the same pads as C2.

The sensor is now ready for testing, and the three way connector plug should be wired to a suitable power source capable of providing 100 mA (this is for the benefit of the bulb, if used; the circuit itself only takes 20 mA). A PP9 9 V battery is adequate. One of the test circuits illustrated in Fig. 4 should be adopted; if the LED arrangement is used, for example, the LED will be on when the sensor points into free space. Start with the preset fully anticlockwise; this gives minimum sensitivity and the sensors should not trigger at all.

Keeping the sensor pointed at free-space, the preset should be turned clockwise to increase the sensitivity until the LED just goes out. The preset should now be backed off until the LED just comes on again, thus setting the maximum range. Placing a hand about 12" in front of the sensor will now turn off the test LED, while striking a match next to the sensor should make no difference!



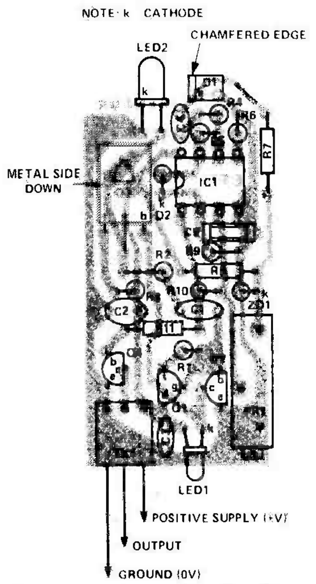


Fig. 1 Component overlay for the optical sensor. The photos overleaf show how small the unit is.

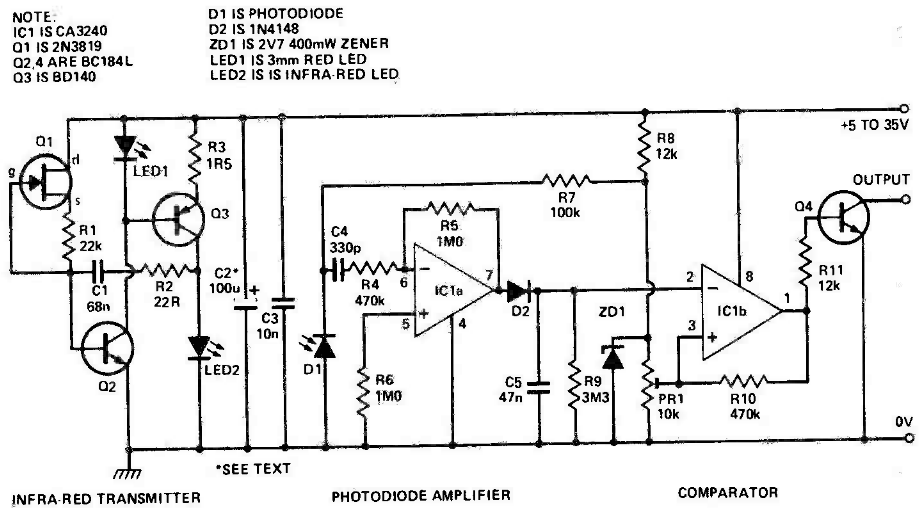


Fig. 2 Circuit diagram for the sensor.

HOW IT WORKS

The proximity sensor works on the principle of transmitting a beam of modulated infra-red light from the emitter diode LED2, and receiving reflections from objects passing in front of the beam with a photodiode detector D1. The circuit can be split into three distinct stages; the infra-red transmitter, the photodiode amplifier, and a variable threshold comparator.

The transmitter provides 1 A peak current pulses for 10 uS through the infra-red emitter diode, at a repetition rate of 1 kHz. Q1 is arranged as a constant current source to supply the base of Q2, and to charge up C1. As C1 charges up, the base voltage of Q2 rises until it reaches about 0V6 relative to ground. Q2 then turns on, so turning on another constant current source formed by Q3 and LED1. This current source sets a temperature compensated voltage of about 1V5 across R3, thus defining a current of 1 A through the infra-red emitter LED2. After Q3 turns on, a negative pulse through C1 turns off Q2 again, thus re-starting the oscillation cycle. The current pulse, determined by C1 and R2 is set at 10 uS. A 10 uS pulse every 1 mS is equivalent to a duty factor of 1:100, so that although 1 A peak pulses are generated, the average current required is only 10 mA. Capacitors C3 and C2 are there to provide power supply smoothing to decouple the fast current pulses.

The detector is built around IC1, a CA3240 dual op-amp. IC1a is configured as an inverting amplifier with a gain of −2. It amplifies the infra-red signal picked up by photo-diode D1. C4, which couples the diode signal to IC1a, acts as a high-pass filter in combination with the input impedance of the amplifier. Positive-going pulses of 10 uS duration are fed from the output, via rectifier D2, to a smoothing filter C5 and R9. This provides the signal voltage reference for the inverting input of comparator IC1b. A 2V7 reference, formed by R8 and ZD1, provides the biasing voltage for the photodiode through R7. It also provides the reference voltage for the non-inverting comparator input, set by potential divider PR1. R10 creates positive feedback round the comparator, to improve the switching, and introduce a small amount of hysteresis. Thus, if a reflected light signal received due to the presence of an object rises above the threshold set by PR1, the comparator output will go into negative saturation. The comparator output is used to turn Q4 on or off, thus providing an open collector output for digital interfacing to logic circuits.

PARTS LIST

Resistors (all ¼W, 5%)

R1	22k
R2	22R
R3	1R5
R4,10	470k
R5,6	1M0
R7	100k
R8,11	12k
R9	3M3

Potentiometers

PR1	10k ¾" 20 turn cermet trimmer

Capacitors

C1	68n ceramic
C2	100u 10 V tantalum
C3	10 n ceramic
C4	330p ceramic
C5	47n polycarbonate

Semiconductors

IC1	CA3240
Q1	2N3819
Q2,4	BC184L
Q3	BD140
D1	Photo-diode (TIL100 or similar)
D2	1N4148
LED1	3 mm red LED
LED2	infra-red LED (TIL38 or similar)

Miscellaneous

PCB (see Buylines); three-way PCB plug and socket (see Buylines); aluminium tube (27 mm diameter, 55 mm long).

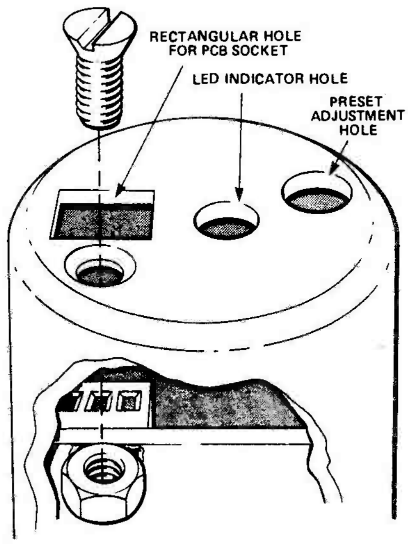


Fig. 3 This is how we mounted the PCB in the aluminium tube. The nut is soldered to the ground track under SK1.

BUYLINES

The only out-of-the-ordinary thing used in this project is the inter-PCB plug and socket (also known as the KK system). This, of course, is not essential, but if you want to use it for neatness it can be obtained from Watford, or via your local supplier from RS Components. We are selling the PCB; the order form is on page 82.

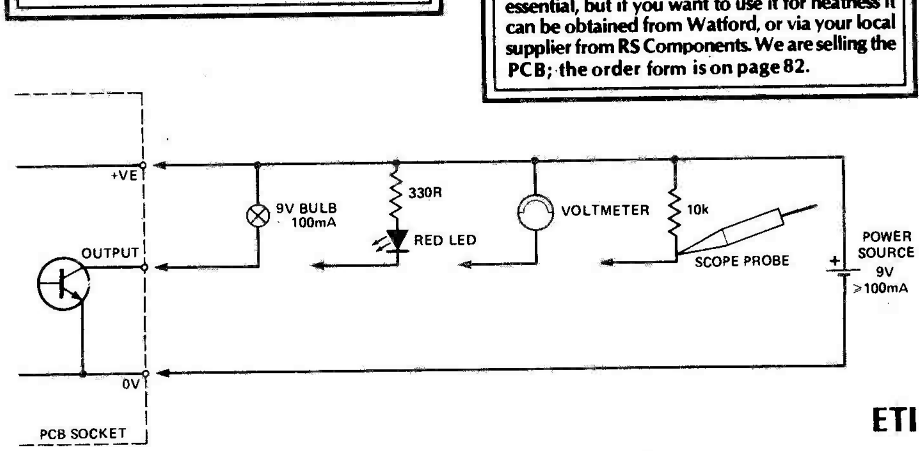


Fig. 4 Any of these test circuits may be used to check out the sensor.

ETI

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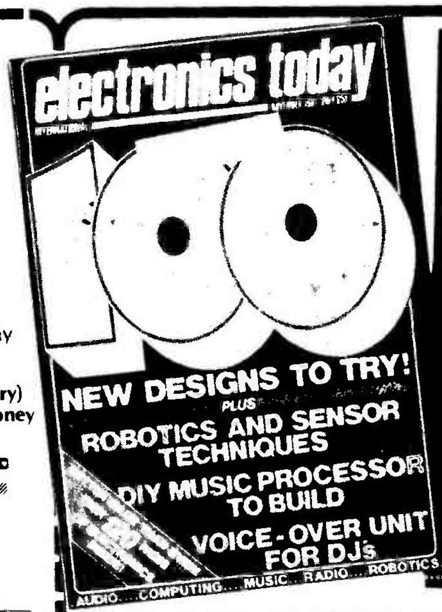

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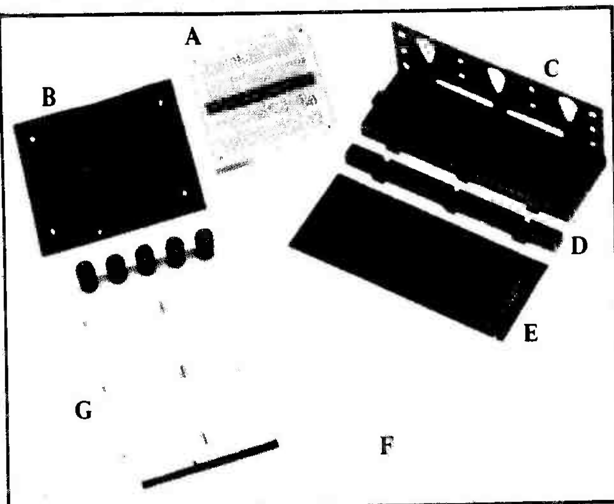

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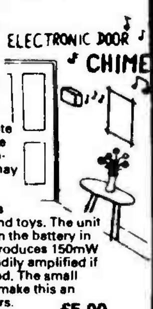

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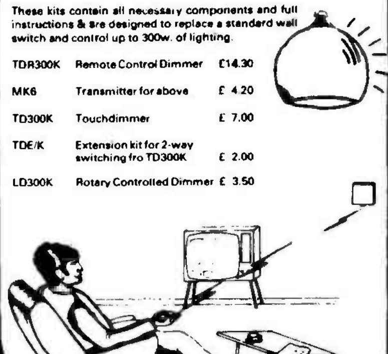

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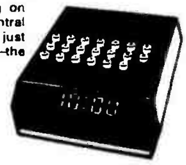

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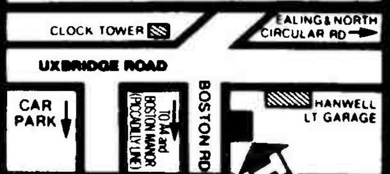

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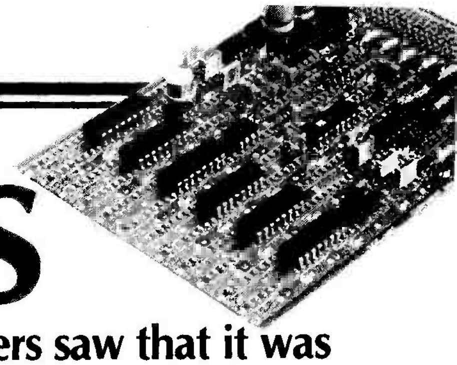


BREADBOARDS

In the beginning there was the bird's nest; and engineers saw that it was bad. Since then a great many systems for prototyping and small scale production of electronic circuits have been developed, and Peter Green has been getting his hands on some of the latest ones.

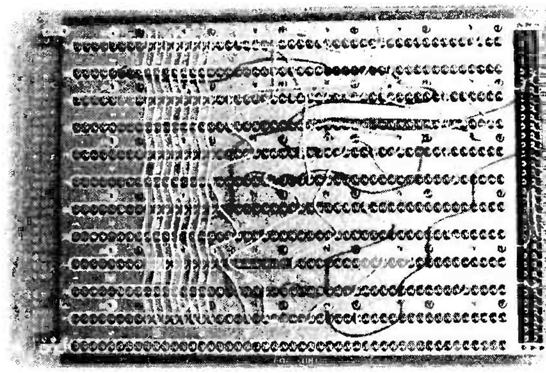
Breadboards have come a long way since the days when a prototype circuit was an impenetrable jungle of wires soldered to nails banged into a piece of wood. (Honest, it really was like that once!) When the plug-in type of breadboard arrived on the scene it was a great advance; components could be unplugged and swapped around with great ease if the circuit didn't work, and if you needed to build larger circuits you simply linked more boards together. However, connections still had to be made with loops of wire all over the place, and the boards were no use for small scale production; this had to be done by track cutting on Veroboard, which can get a bit tedious, or by designing a PCB, which can get expensive.

The new generation of breadboarding systems have been designed to overcome these disadvantages. They fall into two general categories; a 'wrap-and-solder' type where enamelled wire is wrapped around the component pins and then soldered to make the connection, and the IDC types. Insulation displacement connection involves forcing plastic-coated wire between tines of some sort which pierce the insulation and make an electrical connection to the conducting core without breaking the wire. Both types have the same attractive features — that is, the boards are low-profile with neat wiring and no unsightly loops to be pulled off accidentally. Furthermore, all three systems that we looked at come in standard board sizes and are capable of being plugged into a card frame, etc, and used in the same way as a normal PCB.

Quick/Connect

Quick/Connect is an IDC system sold by Dage Eurosem, and many readers will have seen it on their stand at the Breadboard Exhibition last November. A handheld wiring pen is used to push 30 awg solid copper wire into two-pronged tines on the wiring side of the board. The tines pierce the insulation to make a gas-tight joint without soldering; up to two wires will fit into a single tine, giving the equivalent of four levels of wire-wrapping. Components are then inserted into the sockets which form the other end of the the tined pins.

The Quick/Connect wiring pen and bobbin.



This photo shows the underside of a Quick/Connect Eurocard. Interwiring of the components is done between the tines and a data bus, for example, is easily wired (left of board). At the top of the page you can see the component side of this board; ICs are especially suited to the system.

The Quick/Connect pen is metal and plastic and consists of a tube which terminates in a guide channel/insertion head. Wire is fed down the tube from a bobbin held between offset metal prongs at the top of the pen. This bobbin is also made of metal and is quite large (4 cm in diameter); consequently the pen feels somewhat unbalanced and awkward and doesn't handle easily. At first the prongs held the bobbin so tightly that wiring up was heavy going, but flexing them outwards to give a looser fit cured the problem and made the pen almost effortless to use. The wire itself is available in a wide range of colours so that colour-coding may be employed on complicated boards.

Boards are available either fully populated with sockets or blank for the user to insert sockets as and where he requires. We were provided with a fully populated single Eurocard for this review, so we cannot comment on the ease or otherwise of socket insertion; but it would appear from the catalogue that only industrial users would be interested. A variety of expensive tools, including a press are required (unless you fancy your chances with a mallet), and the hobbyist wouldn't want that sort of outlay; however, in industry people might well prefer this capital outlay to paying for full boards with lots of pins they'll never use. A large range of standard boards either exist or are planned, including various Eurocard sizes and boards compatible with Apple, S-100, Dec Unibus and other microcomputer buses.

Apart from the balance aspect, once the tension in the bobbin is correct the tool is very easy to use; very little pressure is required to force the wire between the tines. However, you need good light and lots of concentration because misalignment of the insertion head over the tines means you sever the wire instead of connecting it (as I found to my dismay on several occasions). When you *want* to cut the wire, at the end of a wiring run, you'll have to use side-cutters — no built-in cutting device is provided.

Component insertion depends on what you're actually trying to plug in, and is easiest for ICs — after all, this system is primarily designed for digital applications. The IC simply plugs into the sockets on the component side of the board, where it is firmly held. The manufacturer recommends the use of a special tool but we found insertion fairly easy without one. The problems start when you want to use other types of component. Tantalum, ceramic and polycarbonate capacitors fitted OK, as did 3 mm LEDs and small signal transistors. We found that some ¼ W resistors fitted while others had leads just a little too thick; 1N4148s are OK but not the 1N400X series; while 5 mm LEDs, electrolytics, polyesters and anything in a T0220 package were much too big. The catalogue suggests that such components be soldered to the sockets (bye bye reuseability) or soldered to DIL 'component carriers' (ie header sockets) which are then plugged into place. However, we found a simpler solution; all you have to do is plug in ordinary DIL IC socket into the board sockets and then plug your large components into the IC socket. The photograph shows an example. This would be useful if you wanted to put a 7805 voltage regulator on a computer card, for example.

Quick/Connect is a system which will obviously have a lot of appeal to industrial users, as it offers easy, reliable wiring in development work and a low profile finished board which can be stacked in a card frame on a ½" pitch. However, it's unfortunate that the pen has the odd 'feel' to it (at least it did to me), and of course the price will not be any help to it as regards sales to the hobbyist market.

Distributed by: Dage Eurosem Ltd, Rabans Lane, Aylesbury, Bucks HP19 3RG.
Prices: Fully populated Eurocard £59.00 + VAT. Wiring pen £10.00 + VAT. Reel of wire (50ft) £3.36 + VAT.

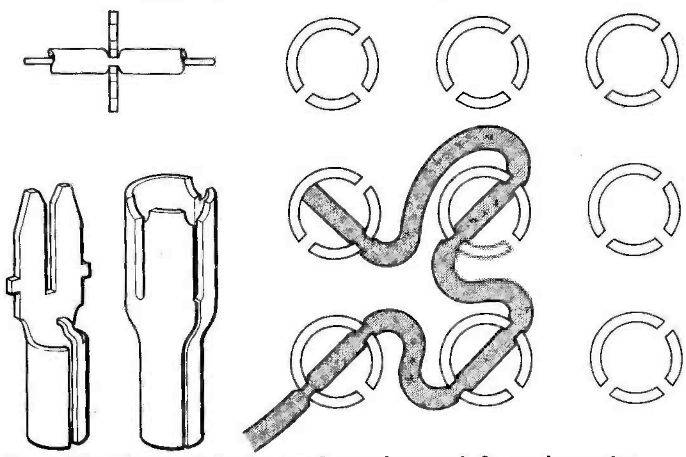
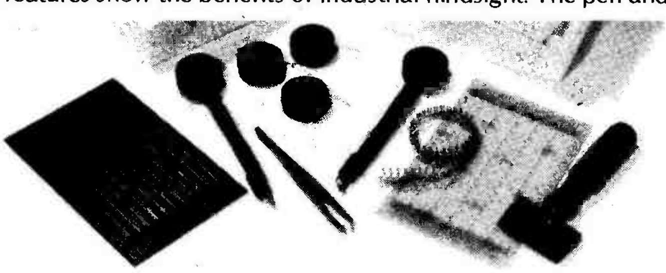


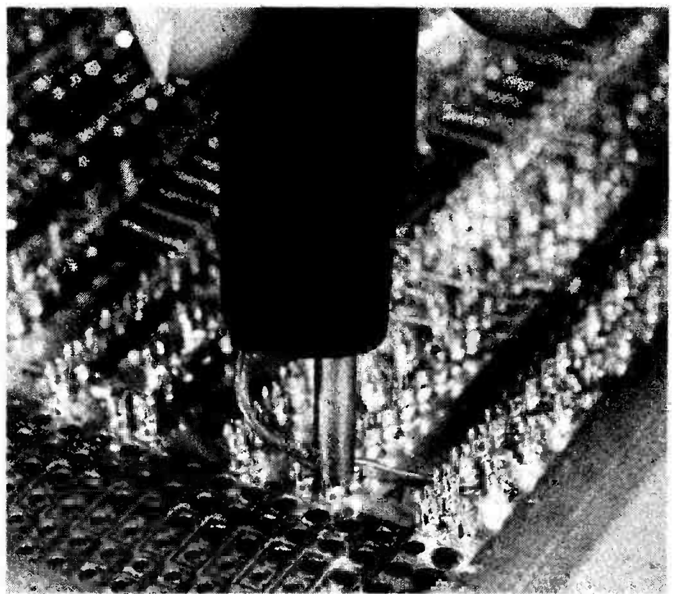
Fig. 1 Working anticlockwise from the top left, we have the IDC principle, the Quick/Connect and Speedwire pins, and a diagram showing the Speedwire termination technique.

Speedwire

This is so new that the sample we played with is one of only five pre-production sets in the country, and jealously guarded it was too! However, we were informed that the launch was to be at the All-Electronics Show here in London; this should have been a few days ago as you read this, so if you went you may have seen the system on the BICC-Vero stand.

Speedwire is a similar system to Quick/Connect but some features show the benefits of industrial hindsight. The pen and





Close-up of the Speedwire pen.

bobbin are plastic with a central metal guide tube, and consequently very light, while the bobbin itself is pivoted on the pen axis rather than off-centre, so that balance and handling are better.

The wiring tines are quite innovative, being a castellated tube — rather like the top of a castle turret, with slots cut on three sides but not the fourth (see the diagram). The pins are arranged in the board so that their slots are all orientated in the same direction. To daisy-chain terminals together, the tool is held so that you insert the wires through the pair of opposing slots, which make the IDC connection as usual. You work across the board in this manner, holding the tool at the same angle to the board, until you reach the endpoint of the signal chain. The tool is then rotated 90° so that the wire is forced through the single slot on the final insertion; this makes the last IDC connection while the unslotted pin face opposite automatically severs the wire. Damn clever, these British . . .

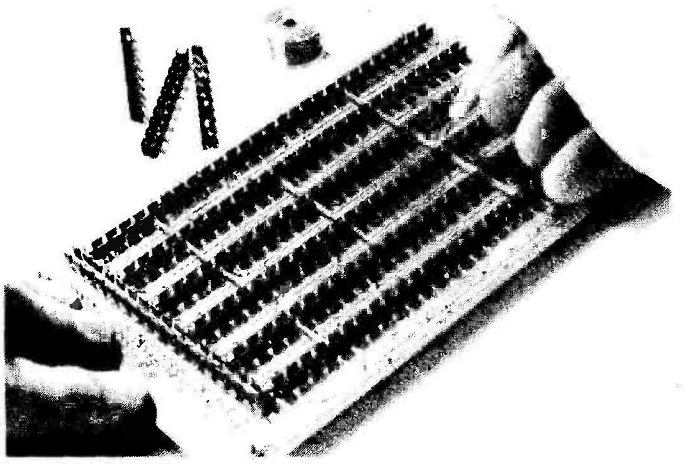
The Speedwire sockets suffer from the same problem as Quick/Connect, namely that large component leads won't fit; but the same solutions apply and in any case, the Speedwire sockets are slightly larger (all the ¼ W resistors fitted).

When Speedwire becomes available it will be sold both with fully populated boards (again, we saw a single Eurocard), and as drilled boards with fit-them-yourself pins. However, the process is easier than for Quick/Connect as only one tool is required, looking rather like a safety razor. You open it up and insert the pins (which are supplied on a strip like Soldercon sockets), then push them home into the required holes and snap off the carrier strip. The tool ensures that the pins are inserted to the correct depth, and we found it quite easy to use. This is obviously much more economical for the small-scale user, or the large-scale user with only a small amount of components per board.

Initially there will be two kits available. The first contains a plain unpopulated Eurocard, contacts and insertion tool, wiring pen and spare wire, while the second has fully populated Eurocard, a wiring pen and spool of wire, spare wire spools and a pair of Speedwire cutters.

Although we didn't have our hands on it for more than two hours before it was whisked away again, we were impressed by the quality of this system. Indeed, once the kits are available we'd like to have another go with it (that's a hint, Mike!).

Distributed by: BICC — Vero Electronics (Retail Dept), Industrial Estate, Chandler's Ford, Eastleigh, Hants SO5 3ZR.
Prices: Not yet known. Apply to BICC-Vero for further information.

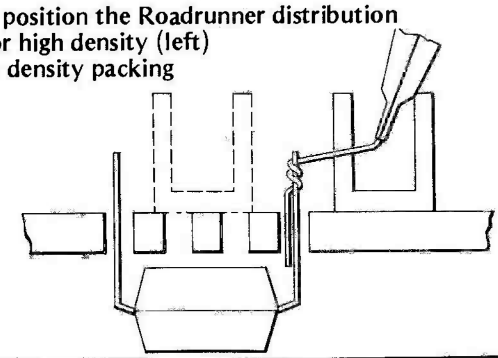


Roadrunner

This is the sole 'wrap-and solder' system of the three mentioned in this article. The system is based around two components; a distribution pen for feeding out the wire, and plastic distribution strips which act as guide channels. In use, this method is quite different from the others under consideration; it is also well established, and was on show at Breadboard 81. The wire used is 36 swg quick soldering enamel (or QSE); the bobbins are only 2 cm in diameter and so the pen is smaller and lighter than the other types.

Before using the pen, the distribution strips must be secured to the wiring side of the board. The manufacturers supply two specially designed "Roadrunner" boards, a single height Eurocard and a double height Eurocard; however, the beauty of the system is that any type of board is suitable since connections are made directly to the component pins rather than to special sockets. For example, Veroboard, bare matrix board (no copper) or even a bit of scrap paxolin you've drilled a few holes in, can all be used if circumstances demand. The plastic strips are of two types; 2" press-fix for use on boards with 1.02 mm diameter holes on a 2.54 mm pitch matrix, and 6" lengths which must be glued in place with a contact adhesive. The photos show the castellated nature of the strips, which can hold a large number of wires while allowing easy routing to the component pins and maintaining a low profile.

How to position the Roadrunner distribution strips for high density (left) and low density packing (right).



A word of warning on the location of the strips is in order here. The pins on the press-fix type automatically locate the strips correctly relative to the matrix, but more care is needed with the other sort. The first time I used Roadrunner I glued down the strip centred on a row of holes, then discovered it was unusable. The strip should cover *two* rows of holes, so that the strip is equidistant from the rows on either side, otherwise half the IC legs are too close for the tool to wrap. (The diagrams explain all). If you're bothered by this, don't worry — just fit the strips after the ICs are in place and you can see exactly what you're doing.

Naturally Roadrunner is not restricted to ICs or components with thin leads, as are the other systems. Wrapping the wire round the component lead means you can use anything that will fit through the holes in the board, just like ordinary PCB construction. To use the system most effectively, a wiring schedule should be prepared; this will not only act as a point-to-point wiring guide but also encourages thought about the optimum arrangement of the components. Wire runs should be kept to a minimum for efficient operation.

With all the strips and components in place, wiring can begin. The protruding wire end (about 4 mm) is bent over slightly to prevent it being pushed back up the guide tube, then inserted into the first hole and wrapped several times around the pin. The wire is routed into the strip through one of the cutouts, then along and out to the next connecting point where another wrap is made. When the first run is complete, press down on the wire against the board with the metal guide tube; this severs the wire. Feed out another 4 mm of wire, bend it over and wire the second run. Continue working through the schedule until all the connections have been made.

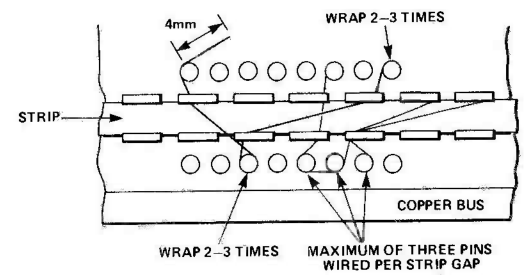
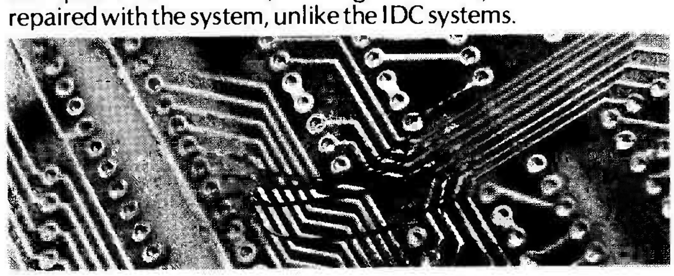


Fig. 3 Plan view of Roadrunner wiring. No more than than three pins should be wired from each break in the strip.

To complete the construction, all the connections are soldered using a high temperature iron and resin cored solder. The solder removes the insulating lacquer on the wire and makes good the joint. Note that a high temperature is very important here, otherwise the enamel will not burn off properly resulting in poor or non-existent electrical contact. The bit temperature should be approximately 420°C, and certainly higher than 400°C. My iron wasn't really up to it, but Roadrunner will supply suitable types.

Although the fact that soldering is involved makes mistakes a little harder to correct than with IDC, it is possible. Incorrect wires should be cut at the component and *left in place* — pulling them out of a tightly packed loom could strip the enamel from adjacent wires and cause short circuits. If you haven't used IC sockets, a faulty IC can be cut away on the component side and a replacement soldered to the original leads.

To sum up, Roadrunner has many advantages. Any type of component or board can be utilised, and in digital circuits a very high packing density can be achieved. The complete boards have a very low profile and may be mounted in card frames on a 0.6" pitch. Furthermore, existing PCBs may be modified or repaired with the system, unlike the IDC systems.



Modifying a PCB using the Roadrunner system.

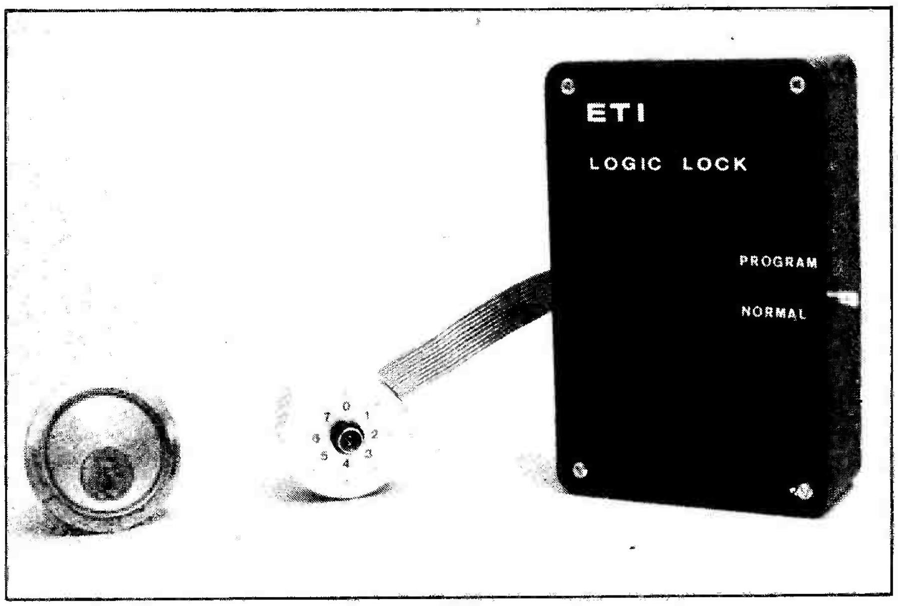
Distributed by: Roadrunner Electronic Products, 116 Blackdown Rural Industries, Haste Hill, Haslemere, Surrey GU27 3AY.

Prices: Euro Introkit £15.99 + VAT. Single Eurocard £4.50 + VAT. Wiring Pencil and bobbin £2.99 + VAT. QSE wire (pack of four) £2.12 + VAT. High temperature soldering iron £5.99 + VAT.

ETI

COMBINATION LOCK

A dazzling digital device, deftly designed to defend your domicile from dangerous desperadoes. Design and development by Rory Holmes.



For almost every lock made there's a thief to match it, and for every set of keys there's always someone to lose them. Such problems of security can now be overcome thanks to ETI's new Logic Lock, where the only moving part is the door latch! The complete device including the keypad and control-box can be built for about £10 and incorporates some very useful features in the design, resulting in total simplicity of operation.

The keypad, pictured above, can be built by anyone using completely standard components. It provides a waterproof and very rugged touch-sensitive input, which will last much longer than mechanical contact switches since there's virtually nothing to go wrong with it.

Programmed Protection

A single switch on the control-box puts the lock into either 'program' or normal 'operation' mode. In 'program' mode new combination sequences of any length from one to 14 digits can be entered directly through the keypad. Any number of repeated digits may be used, and the complete sequence will be stored in CMOS memory. A change of combination can thus be effected in seconds. After programming, the lock is left in 'operate' mode where the 5101 CMOS memory consumes only 10 uA of standby current, allowing long operating life from a 6 V battery.

As soon as the first number is entered the memory receives full power for a 25 second period, allowing the combination sequence to be entered. The front panel LED illuminates for each number received to provide operator feedback, and also gives low battery indication by remaining off when replacement is due. The keypad input has been fully debounced to eliminate false entry errors. When the last digit is tapped in, the solenoid door bolt will activate for a preset time of around six seconds allowing the door to be opened. The LED also comes on during this period to confirm entry of the correct code.

The Logic Lock has well over four million *million* combinations, and an alarm was therefore considered unnecessary. Your local illegal entry operative can tamper with this lock until the cows come home; it won't open. Even a PDP-11 hooked into the keypad cable would take nigh on 6000 years of computing power to crack the code!

An optically coupled solid state relay is used to switch power to the solenoid, again being cheaper and more reliable than its mechanical counterpart. The PCB will accommodate several optional output configurations, for switching either mains or DC solenoid door latches.

Installation

Since the solenoid bolt mechanism is remote from the keypad and control-box, the logic lock may be placed anywhere in the vicinity and is not restricted to door mounting, although this would be more conventional. Obviously, the important factor is mounting the keypad on the outside and the control-box on the inside — the keypad could be mounted next to the bell push, allowing the ribbon cable to take the same route into the house as the bell wires. The control-box is screwed or stuck to the inside of the door and the keypad can be fixed to the outside using a strong epoxy. Alternatively the inside of the keypad can be filled with resin or Araldite and a long fixing bolt allowed to set in the resin. The keypad can then be bolted directly through the door. A hole drilled behind the keypad lets the ribbon cable pass through the door to the control-box. The wires for connecting up the solenoid latch, which are normally tacked across the door and pass across the hinges, should be connected up to the control box as shown in the wiring diagram.

The inclusion of an earth terminal for mains switching applications provides an extra degree of protection in the unlikely event of an opto-isolator fault.

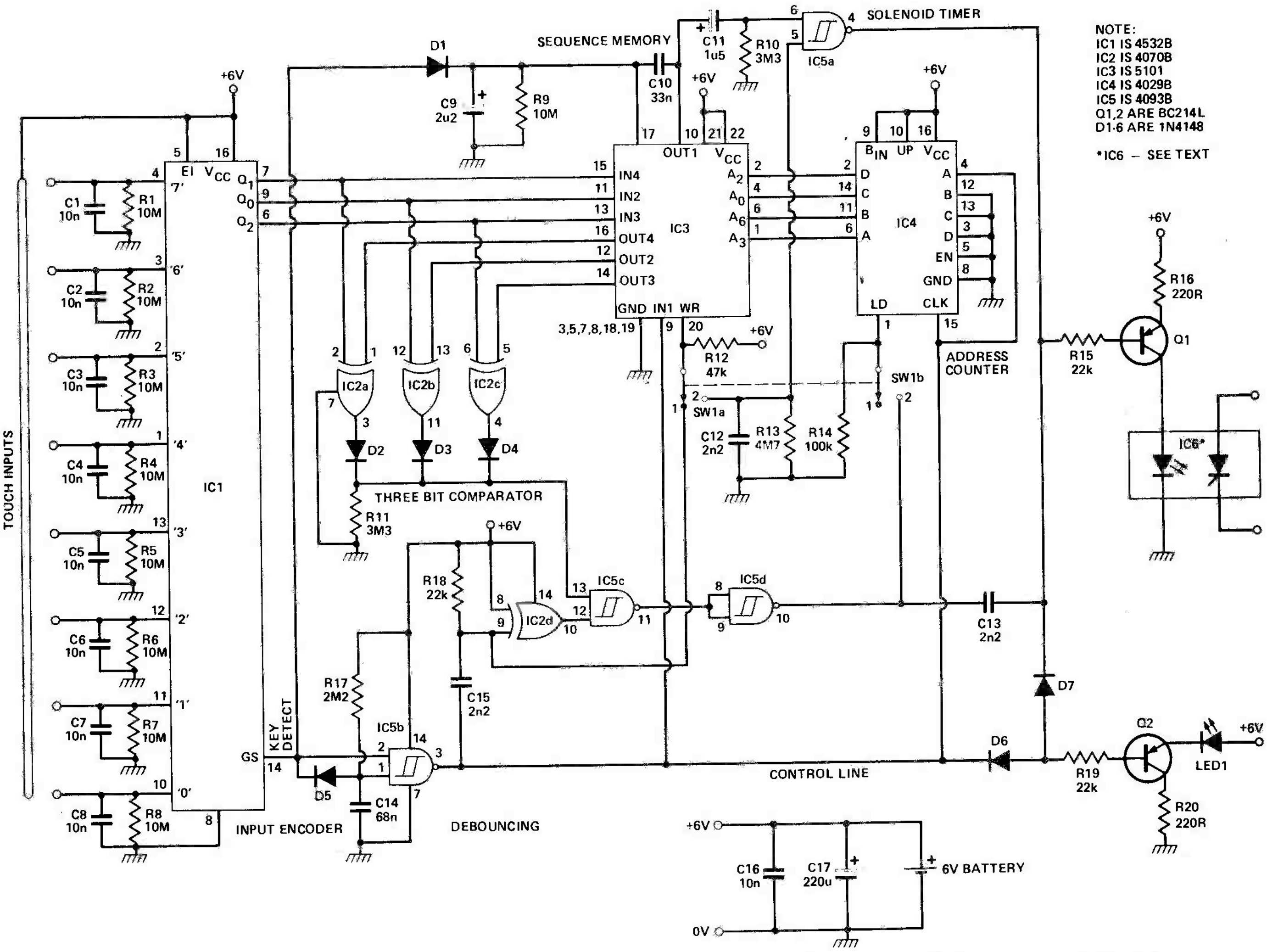


Fig. 1 The complete circuit diagram for the ETI Logic Lock. A general-purpose output is provided; next month several application circuits are given to suit mains or DC solenoids.

HOW IT WORKS

Numerical input to the lock is achieved using IC1, an eight input priority encoder. When one of its input lines is taken high, the corresponding number allocated to this line appears in binary form on its output lines, pins 6,7, and 9. An input key detect signal, GS, is also available on pin 14; this line goes high if any input line is activated.

The eight input lines are activated using a touch keypad. Resistors R1-8 keep the inputs normally low, and they are taken high when the skin resistance of a finger bridges the input pins to the central +6 V rail. Capacitors C1 to 8 debounce this switching action to provide a measure of stability and the key detect output is further debounced to give completely reliable operation of the sequencing logic.

The rest of the circuitry consists of a four-bit counter IC4, which addresses part of a 256 x 4 bit CMOS memory (IC3). The data output of the memory is compared with the three bit keyboard word using EXOR gates IC2a, b and c, to provide an equal (logic low) or unequal (logical high) signal for controlling the subsequent action.

All of this circuitry has two modes of operation. With the switch in position 1, the 'write' mode is selected for programming a new combination sequence; position 2 is the 'operate' mode where the circuit waits for a valid combination sequence to activate the lock.

To explain the 'write' mode we shall assume that the counter IC4 is on count 1 (ie only output A is at logic 1), and there are zeroes in all memory locations.

IC5b, a NAND Schmitt trigger, provides a debounced control signal from the GS line. GS is normally low, thus pin 2 of IC5b is low; also C14 is discharged via D5, so holding pin 1 low. Thus the output on pin 3 is normally logic high. When any input number is touched the GS line goes logic high, taking pin 2 of IC5b high and allowing C14 to charge up through R17 with a 150 mS time constant.

Now, as long as the GS line is still high when the pin 1 voltage reaches the trigger threshold, the gate output will switch low. When the touch input is released, GS goes low, C14 discharges through D5, and the Schmitt trigger output returns high again.

The control output from pin 3 is taken to five different circuit points. The negative-going edge is differentiated by C15 and R18 to produce a brief negative pulse as an input number is activated. During the 'write' mode this pulse is routed via SW1 to the write line of the memory, IC3 pin 20. As this pin is taken low the current data on pins 11, 13 and 15 (corresponding to the input number) is recorded at the present address. The IN1 memory input on pin 9 is also taken directly from the control line and will thus always be zero when the 'write' pulse occurs. This data bit is used to indicate the end of a correct combination sequence during the 'operate' mode (a necessary marker, since any length of sequence is permissible). The control line is taken directly to the clock input on pin 15 of IC4 and also to the preset input A at pin 4. As the control line returns to logic high when the touch input is released, the address counter IC4 is clocked on by one count on the positive-going edge.

The cathode of D6 is also taken low by the control line, thus turning on Q2 via R19 to illuminate the front panel indicator LED1. This shows that an input has been received to give a measure of operator feedback. As the timing diagram of Fig. 2 indicates, the above recording process repeats for each number that is selected on the touch pad, with the corresponding binary values being stored sequentially in consecutive memory addresses.

After entering the required digits, the sequence is terminated by moving SW1 to position 2, the 'operate' mode. As the switch closes, one last write pulse is

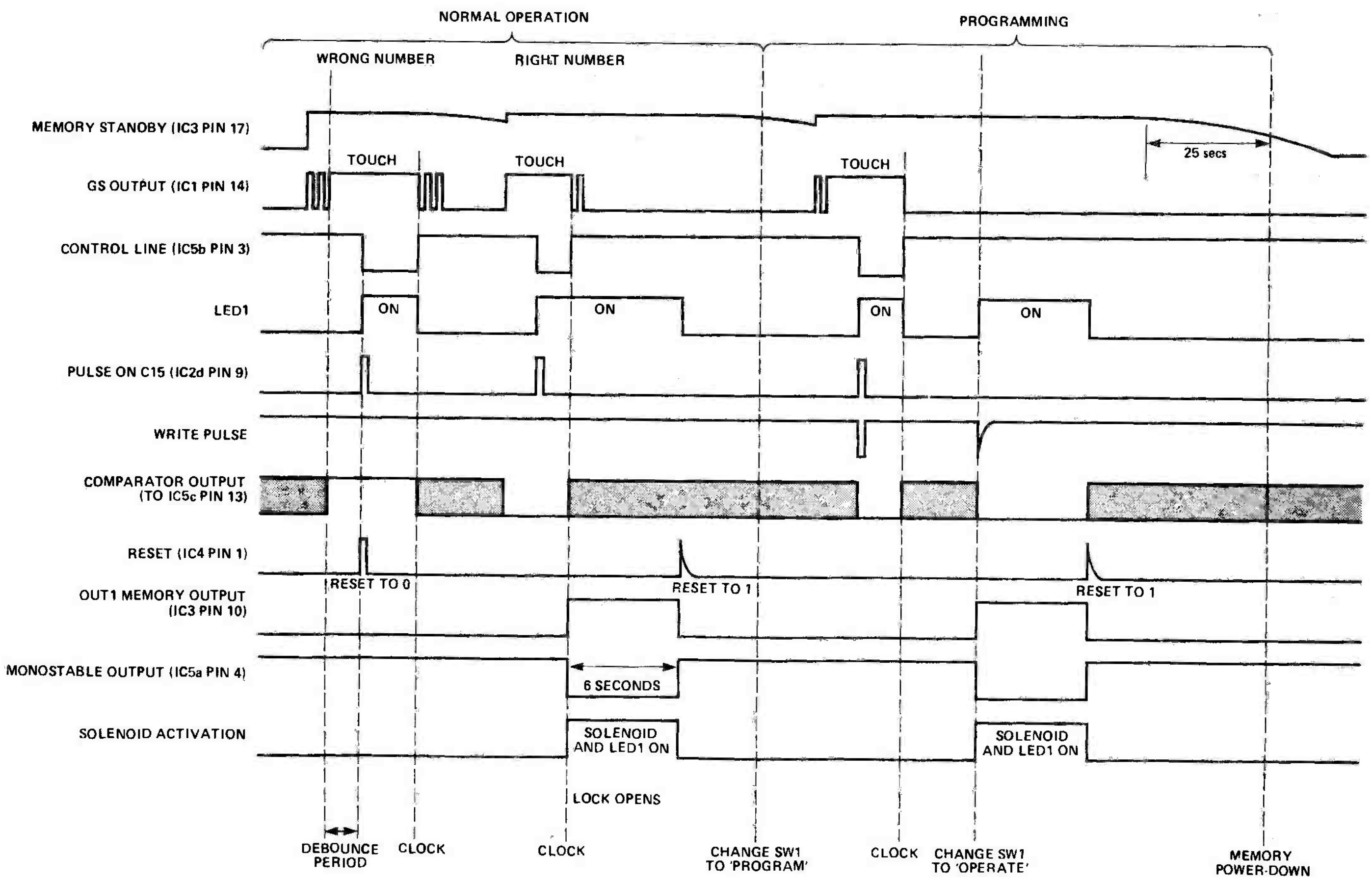


Fig. 2 Timing diagram for the Logic Lock logic! It will repay careful study in conjunction with the circuit diagram and How It Works section.

Next month we conclude this project with the component overlay and application circuits.

generated as C12 charges up through R12 (C12 was previously discharged via R13). No touch inputs are activated so the IN1 memory input is held at logic 1 by the control line. When the logic 1 is written to memory the associated OUT1 output also goes high, activating the solenoid timer monostable built around IC5a. (The solenoid is energised by this monostable for both normal lock operation and at the end of a write sequence. Although the door must already be open during re-programming, the solenoid provides a useful indication of successful re-programming.)

The pin 5 input of IC5a is normally held low by R13, thus disabling this gate. However, after the brief write pulse caused by changing SW1, pin 5 is taken high via R12. Pin 6 was also held low by R10, but as the OUT4 data output goes from low to high, the previously discharged capacitor C11 takes pin 6 high. The gate output on pin 4 will thus go low for a period set by the R10-C11 time constant. This time period is about five seconds and is used to turn on both the front panel indicator (via D7), and the solenoid lock mechanism, thus allowing plenty of time to open the door.

The monostable signal turns on transistor Q1, which applies current to the LED in an opto-isolator and allows isolated external power to be switched to the solenoid. (Transistor or thyristor opto-isolators may be used).

When the monostable finishes its time period, the output returns high again. C13 differentiates this positive-going edge to provide a load pulse to the counter IC4. The preset A input is held at logic 1 by the control line, so the counter will return to its first state, switching the OUT1 memory output back to logic low.

The lock has now been programmed with the desired sequence and remains in its resting state of count position 1. When a number is now entered, the negative-going pulse produced through C15 appears on pin 9 of the EXOR gate IC2d.

This gate is wired as an inverter and the positive-going output pulse is fed to the pin 12 input of NAND gate IC5c. The other input to the NAND gate comes from the three bit comparator at the junction of D2,3 and 4. These diodes (with R11) form a three input AND gate; thus, if the data from the input encoder wired to one side of the digital comparator has the same binary value as the data currently on the OUT memory outputs feeding the other side, then the pin 13 input of IC5c will remain low via R11. However, if the two values are not equal, there will be a logic high output from at least one of the exclusive OR gates IC2a, b or c, taking the input of IC5c high via the corresponding diode. Thus if a wrong number is entered, the short positive pulse from IC2d will appear in inverted form on the pin 11 output of IC5c. IC5d further inverts this pulse before feeding it to the load input on pin 7 of counter IC4. Since the preset A input of the counter is held low by the control line when this load pulse is received, the counter resets to zero. At the end of the wrong number input the control line goes high to clock the counter on to its count 1 resting state. Every wrong number entered will always return the counter back to the beginning of the sequence, regardless of where it occurs. As long as the correct numbers are entered in sequence, no reset pulses occur and the counter will be clocked on to the next number at the end of each entry.

After the last number in the sequence is entered, the counter will address the terminating location. The previously low OUT1 output goes high, triggering the solenoid timer monostable as described earlier and the door will now open.

ETI

ETI PCB SERVICE

Up until now PCBs were always the hardest component to obtain for a project. Of course you *could* make your own, but why bother anymore?
Now you can buy your boards straight from the designers — us! As of this issue all (non-copyright) PCBs will be available automatically from the ETI PCB Service. Each board is produced from the same master used to build our prototypes, so you can be *sure* it's accurate, and will be finished to the high standard you would expect from ETI.
In addition to the PCBs for this month's projects, we are making available some of the more popular designs from our recent past. See the list below for details. Please note that NO OTHER BOARDS ARE AVAILABLE. If it's not listed, we don't have it!

APRIL 79
- ☐ Guitar Effects Unit **£2.64**
- ☐ Click Eliminator **£6.64**

JUNE 79
- ☐ Accentuated Beat Metronome **£3.60**

FEBRUARY 80
- ☐ Tuning Fork **£2.64**

MARCH 80
- ☐ Signal Tracer **£2.27**

AUGUST 80
- ☐ CMOS Logic Tester **£2.64**
- ☐ Capacitance Meter **£2.93**
- ☐ Ultrasonic Burglar Alarm **£2.87**

OCTOBER 80
- ☐ Cassette Interface **£2.93**
- ☐ Fuzz/Sustain Box **£3.27**

NOVEMBER 80
- ☐ Touch Buzzer **£1.93**
- ☐ Light Switch **£1.93**
- ☐ Metronome **£1.93**
- ☐ 2W Power Amp **£1.93**
- ☐ RIAA Preamplifier **£1.93**
- ☐ Audio Test Oscillator **£3.13**

DECEMBER 80
- ☐ Musical Doorbell **£2.80**
- ☐ Bench Amplifier **£2.53**
- ☐ Four Input Mixer **£2.64**

JANUARY 81
- ☐ LED Tacho **£4.13**
- ☐ Multi-Option Siren **£3.20**
- ☐ Universal Timer **£3.31**

FEBRUARY 81
- ☐ Infra-red Alarm (four boards) **£6.64**
- ☐ Pulse Generator **£3.57**

MARCH 81
- ☐ Engineer's Stethoscope **£2.65**

APRIL 81
- ☐ Musical Box **£2.64**
- ☐ Drum Machine (two boards) **£5.60**
- ☐ Guitar Note Expander **£3.20**

JUNE 81
- ☐ Mini-drill Speed Controller **£2.93**
- ☐ Antenna Extender **£3.20**
- ☐ Alien Attack **£2.64**
- ☐ LED Jewellery: Cross **£1.47**
- ☐ Spiral (two boards) **£2.64**
- ☐ Star (two boards) **£2.65**
- ☐ Waa-phase **£1.53**

JULY 80
- ☐ System A A-MM/A-MC **£2.65**
- ☐ System A A-PR **£5.17**
- ☐ Smart Battery Charger **£1.97**

AUGUST 81
- ☐ System A Power Amp (A-PA) **£4.77**
- ☐ Flash Sequencer **£3.44**
- ☐ Hand-clap Synthesiser **£3.97**
- ☐ Heartbeat Monitor **£1.83**
- ☐ Watchdog Home Security (two boards) **£5.31**

SEPTEMBER 81
- ☐ Mains Audio Link (three boards) **£7.35**
- ☐ Laboratory PSU **£4.53**

OCTOBER 81
- ☐ Enlarger Timer **£3.40**
- ☐ Sound Bender **£2.65**
- ☐ Thermal Alarm **£2.63**
- ☐ Micropower Pendulum **£2.21**

NOVEMBER 81
- ☐ Music Processor **£7.35**
- ☐ Voice-Over Unit **£3.97**
- ☐ Car Alarm **£2.81**
- ☐ Phone Bell Shifter **£2.96**

DECEMBER 81
- ☐ Alcohometer (two boards) **£5.32**
- ☐ Bodywork Checker **£1.97**
- ☐ Component Tester **£1.49**

JANUARY 82
- ☐ Parking Meter Timer **£2.37**
- ☐ Infant Guard **£1.80**
- ☐ Guitar Tuner (two boards) **£5.97**

FEBRUARY 82
- ☐ Ripple Monitor **£2.08**
- ☐ Pest Monitor **£1.85**
- ☐ I Ching Computer (two boards) **£5.31**
- ☐ Moving-magnet stage **£3.80**
- ☐ Moving-coil stage **£3.80**

MARCH 82
- ☐ Infinite Improbability Detector **£3.37**
- ☐ Capacitance Meter (two boards) **£14.19**
- ☐ Robot Motor Controller **£3.80**
- ☐ Light Wand **£1.87**

APRIL 82
- ☐ Contrast Meter **£2.83**
- ☐ Sound Effects board **£2.40**
- ☐ High Impedance Probe **£1.97**
- ☐ Guitar Practice Amp **£7.57**
- ☐ Accurate Voltage Monitor **£2.05**

MAY 82
- ☐ DV Meg **£2.92**
- ☐ Analogue PWM **£3.37**
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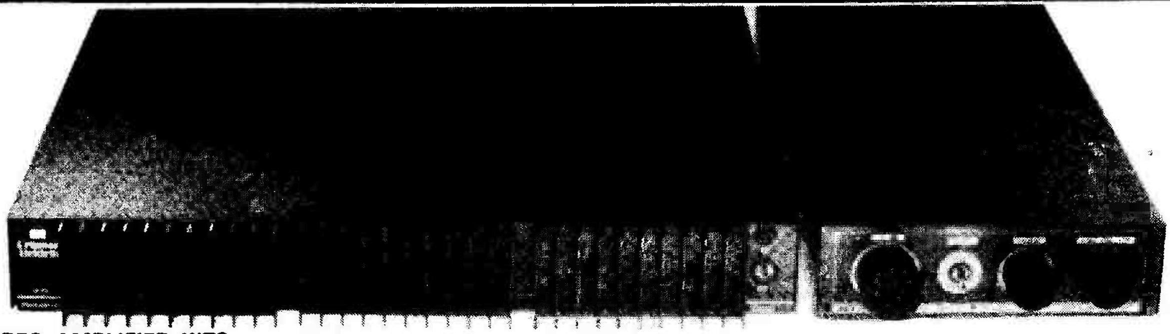

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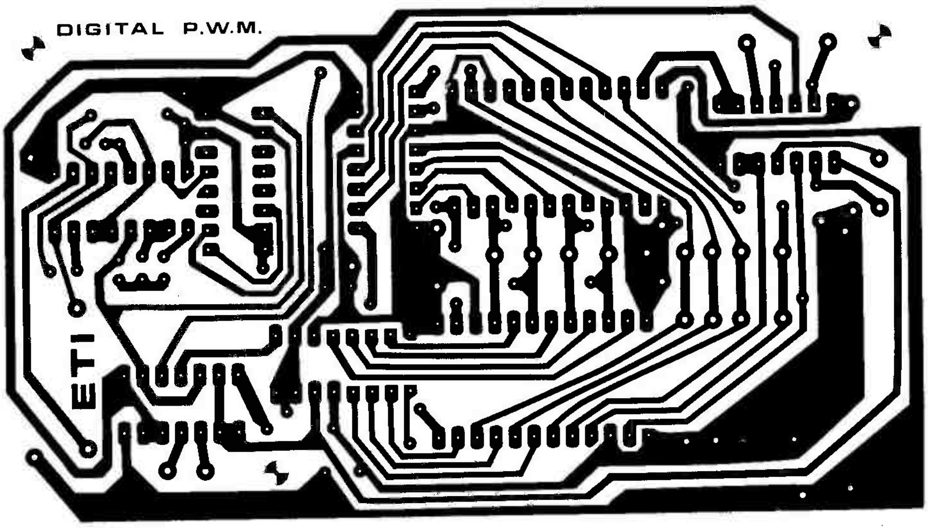
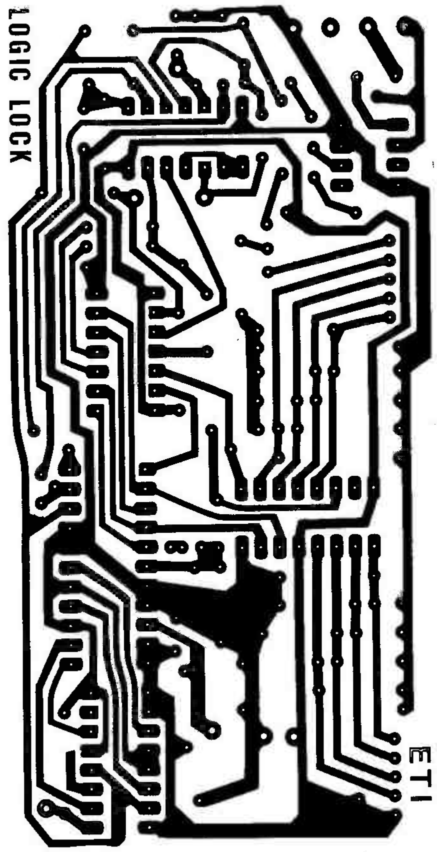
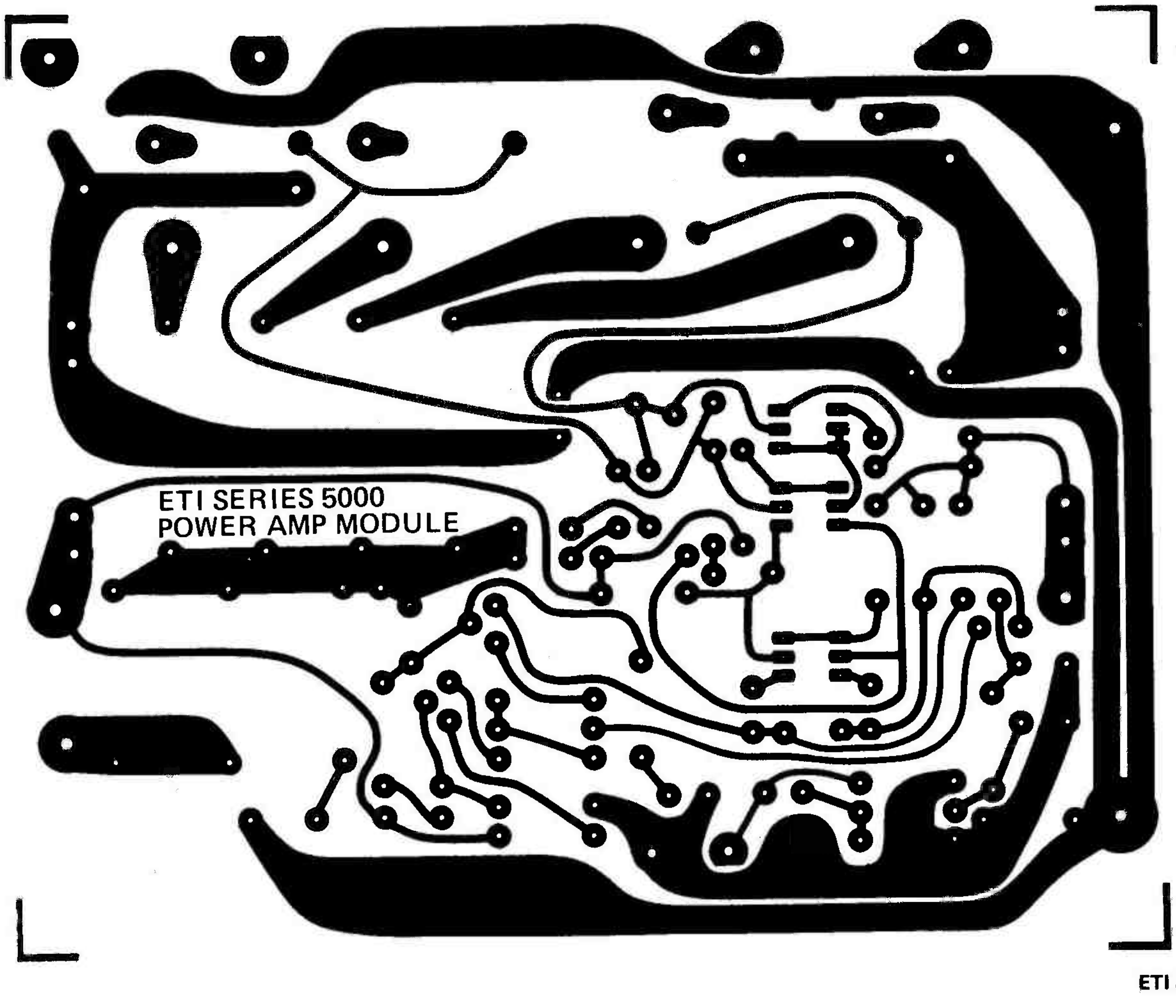


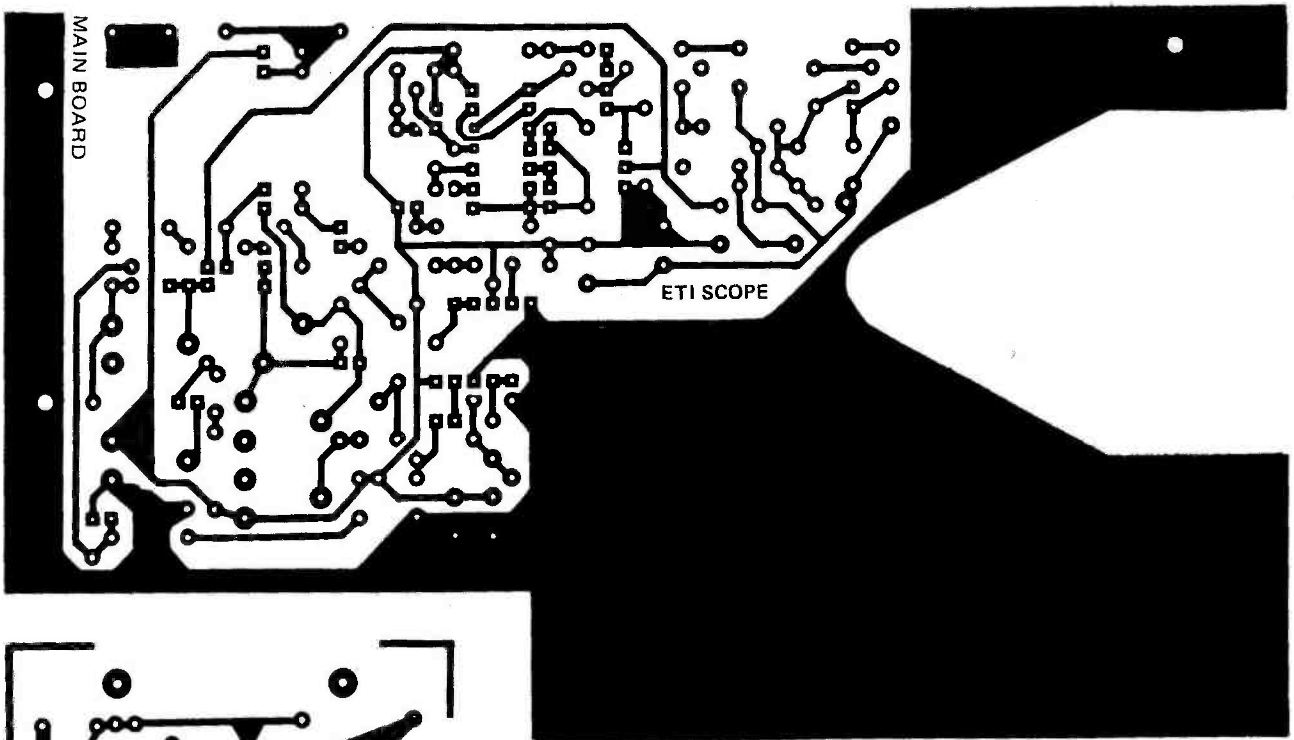
Above: The Digital PWM foil pattern.

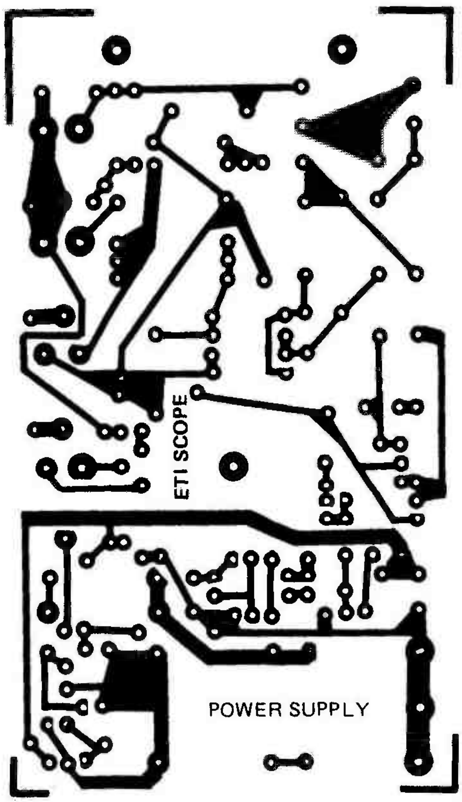


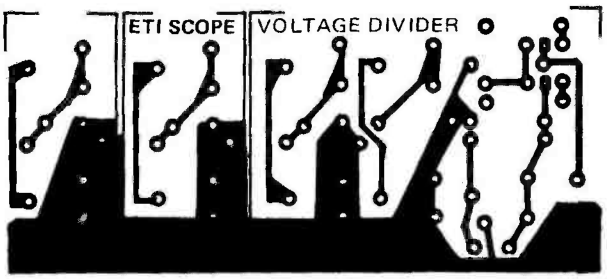
Above: The Logic Lock PCB.

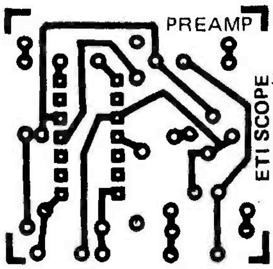
Below: The board for the MOSFET power amp module.



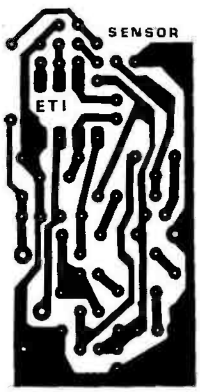






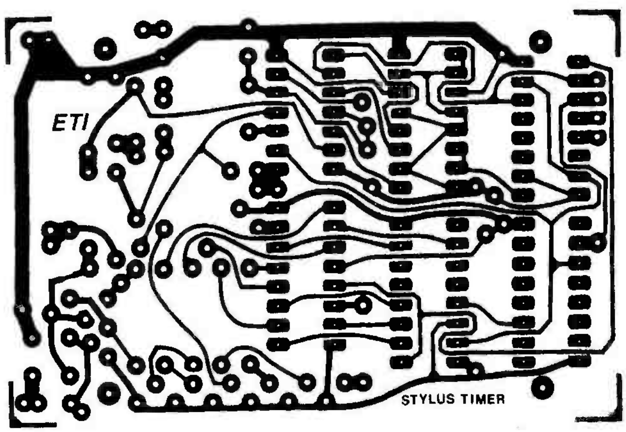


Above and left: The four boards for the Oscilloscope.



Left: The Proximity Detector PCB.

Right: Foil pattern for the ETI Stylus Timer.



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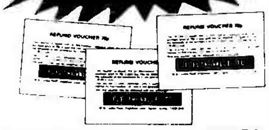

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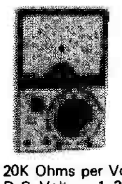

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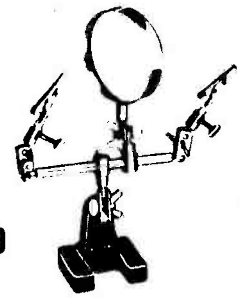

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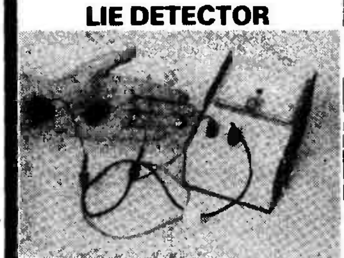

This beautifully made precision instrument is not a toy or gimmick, it was originally used on an Open University course to measure changes in emotional balance by detecting small changes in skin resistance. Full details of how to use it are provided, together with a circuit diagram. Suplied complete with probes, leads and conductive jelly. Needs 2 × 4½V batteries. Overall size 155 × 100 × 100mm. The 100-0-100uA 4" panel meter is worth more than we're asking for the whole unit!! **£7.95**

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SNR	120dB
Slew rate	20 V/uS
Gain	× 23
Rin	30K
Vs max	+ 70V

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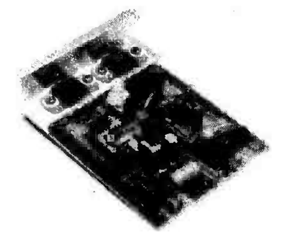
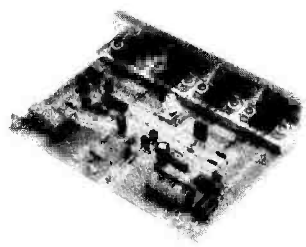


PFA100 120W into 8M



PFA200 Specification

Bandwidth	10Hz-100KHz + 1dB
Output power into 8M	150W (Vs + 60V)
THD (20Hz-20KHz)	0.005%
THD (1KHz at 150W)	0.002%
SNR	120dB
Slew rate	20V/uS
Gain	× 23
Rin	30K
Vs max	+ 70V

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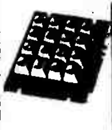

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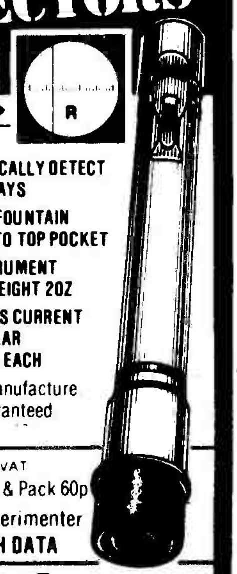

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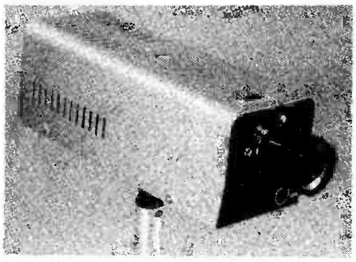

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