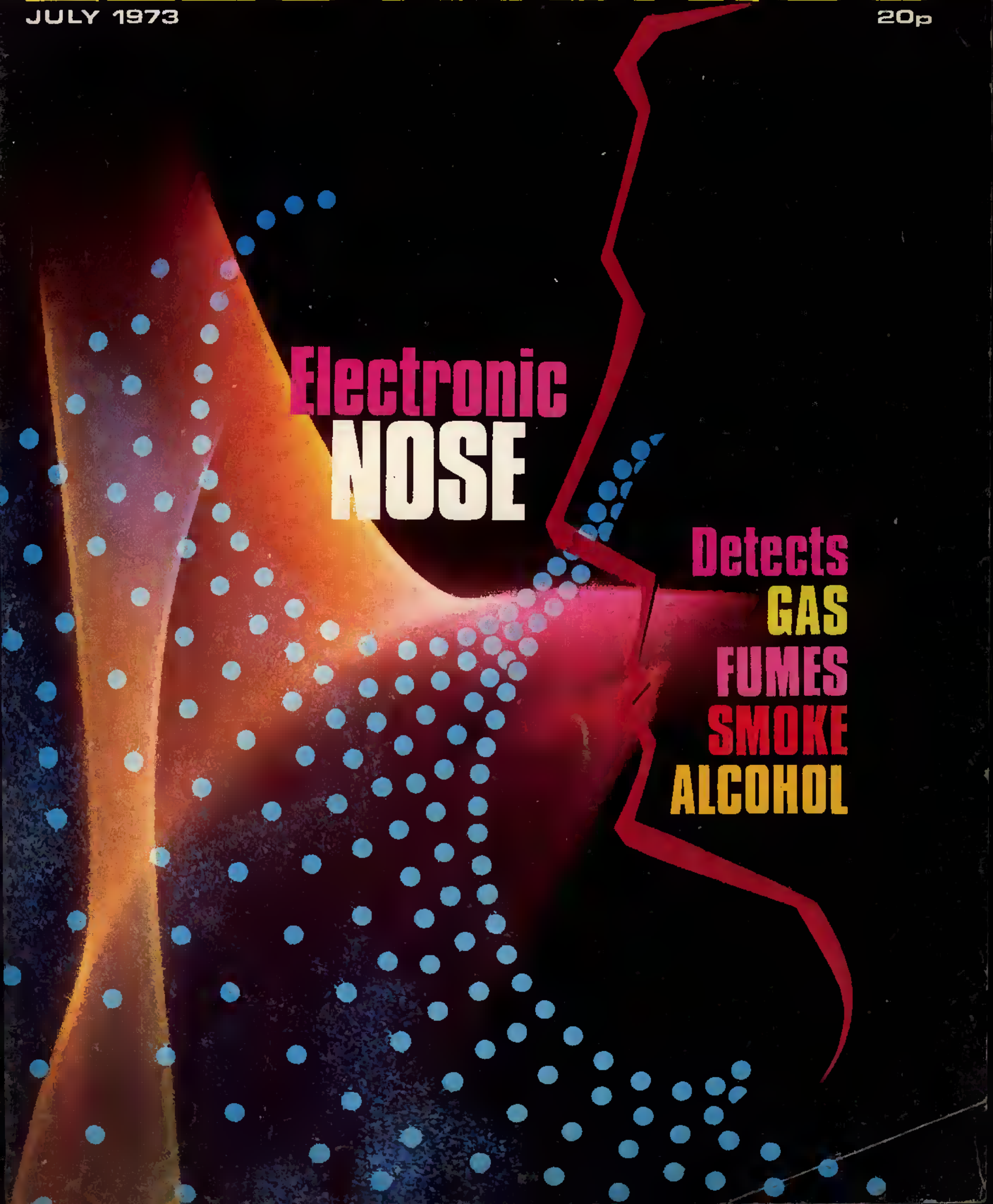
PRACTICAL

ELECTRONICS

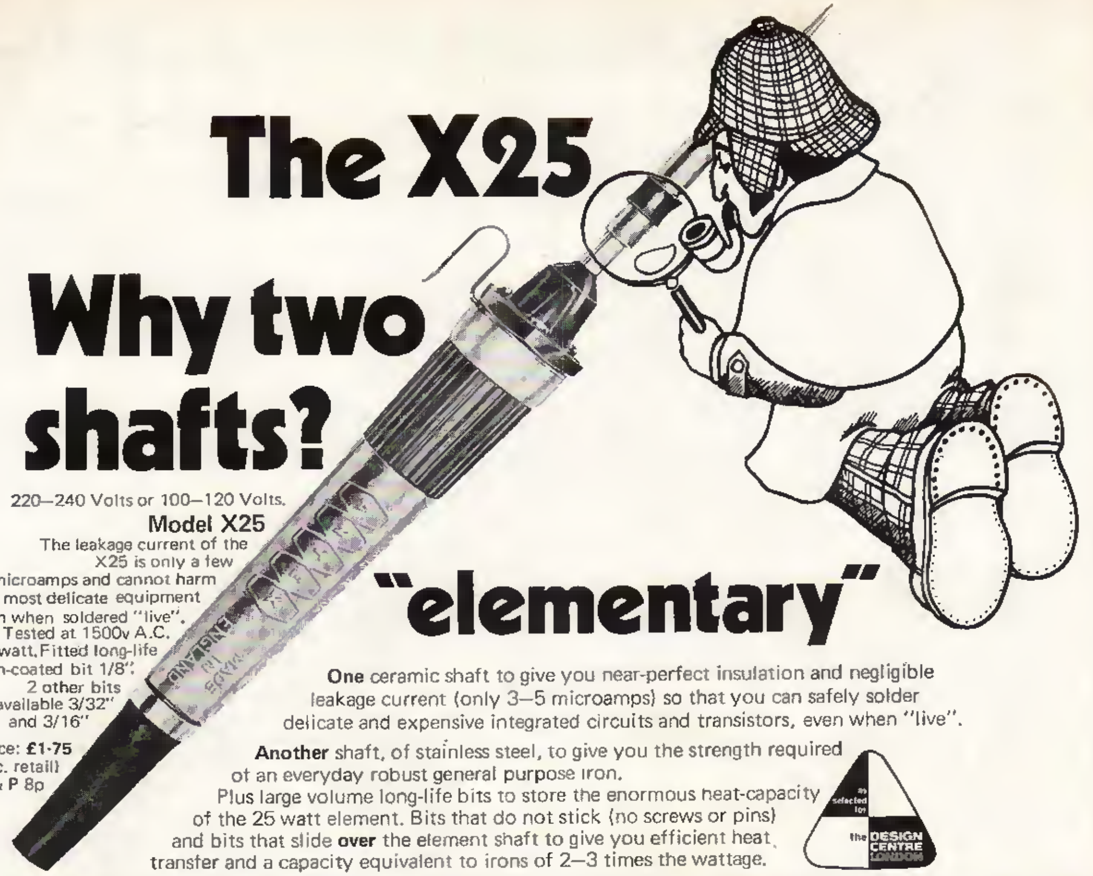
JULY 1973

20p



The X25

Why two shafts?



220—240 Volts or 100—120 Volts.

Model X25

The leakage current of the X25 is only a few microamps and cannot harm the most delicate equipment even when soldered "live". Tested at 1500v A.C. 25 watt. Fitted long-life iron-coated bit 1/8". 2 other bits available 3/32" and 3/16"

Price: **£1·75** (rec. retail) P & P 8p

"elementary"

One ceramic shaft to give you near-perfect insulation and negligible leakage current (only 3—5 microamps) so that you can safely solder delicate and expensive integrated circuits and transistors, even when "live".

Another shaft, of stainless steel, to give you the strength required of an everyday robust general purpose iron. Plus large volume long-life bits to store the enormous heat-capacity of the 25 watt element. Bits that do not stick (no screws or pins) and bits that slide **over** the element shaft to give you efficient heat transfer and a capacity equivalent to irons of 2—3 times the wattage.

as selected for the DESIGN CENTRE LONDON

MODEL CCN

220 volts or 240 volts. The 15 watt miniature model CCN also has negligible leakage. Test voltage 4000v A.C. Totally enclosed element in ceramic shaft. Fitted long-life iron-coated bit 3/32". 4 other bits available 1/8", 3/16", 1/4" and 3/64".

PRICE: £1·80 P&P 5p

MODEL G

18 watt miniature iron, fitted with long life iron-coated bit 3/32". Voltages 240, 220 or 110.

PRICE: £1·83 (rec. retail). P&P5p

All prices mentioned are exclusive of V.A.T.

MODEL CN

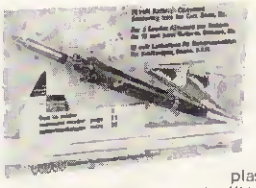
Miniature 15 watt soldering iron fitted 3/32" iron-coated bit. Many other bits available from 3/64", to 3/16". Voltages 240, 220, 110, 50 or 24.

PRICE: £1·70 (rec. retail). P&P5p

MODEL CN2

Miniature 15 watt soldering iron fitted with nickel plated bit 3/32". Voltages 240 or 220.

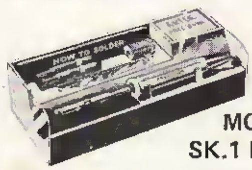
PRICE: £1·70 (rec. retail). P&P5p



MODEL MLX. KIT

Battery-operated 12v. 25 watt iron fitted with 15' lead and 2 heavy clips for connection to car battery. Packed in strong plastic wallet with booklet "How to Solder"

PRICE: £1·95 (rec. retail). P&P 12p



MODEL SK.1 KIT

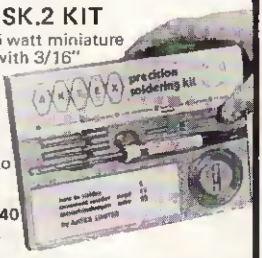
Contains 15 watt miniature iron fitted with 3/16" bit, 2 spare bits 5/32" and 3/32", heat sink, solder, stand and "How to Solder" booklet.

PRICE: £2·75 (rec. retail). P&P 12p

MODEL SK.2 KIT

Contains 15 watt miniature iron fitted with 3/16" bit, 2 spare bits 5/32" and 3/32" heat sink, solder, and "How to Solder" booklet.

PRICE: £2·40 (rec. retail). P&P8p



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NAME ....

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PRACTICAL
ELECTRONICS
VOLUME 9 No. 7 JULY 1973

CONSTRUCTIONAL PROJECTS

GENERAL FEATURES

NEWS AND COMMENT

Our August issue will be published on Friday, July 13, 1973

THIS IS THE FIRST PAGE OF THE GREAT BI-PAK SECTION

BRAND NEW FULLY GUARANTEED DEVICES

AC107	0·22
AC113	0·22
AC115	0·26
AC117K	0·22
AC122	0·13
AC125	0·19
AC126	0·19
AC127	0·19
AC128	0·19
AC132	0·16
AC134	0·16
AC137	0·16
AC141	0·16
AC141K	0·19
AC142	0·16
AC142K	0·19
AC151	0·17
AC154	0·22
AC155	0·22
AC156	0·22
AC157	0·27
AC165	0·22
AC166	0·22
AC167	0·22
AC168	0·27
AC169	0·16
AC176	0·22
AC177	0·27
AC178	0·31
AC179	0·31
AC180	0·19
AC180K	0·22
AC181	0·19
AC181K	0·22
AC187	0·24
AC187K	0·22
AC188	0·24
AC188K	0·22
ACY17	0·29
ACY18	0·22
ACY19	0·22
ACY20	0·22
ACY21	0·22
ACY22	0·18
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ACY31	0·31
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ACY35	0·23
ACY36	0·31
ACY40	0·19
ACY41	0·20
ACY44	0·39
AD130	0·42
AD140	0·53
AD142	0·53
AD143	0·42
AD149	0·55
AD161	0·37

AD162	0·37
AD161 & AD162(MP)	0·61
ADT140	0·55
AF114	0·27
AF115	0·27
AF116	0·27
AF117	0·27
AF118	0·39
AF124	0·33
AF125	0·28
AF126	0·31
AF127	0·31
AF139	0·33
AF178	0·33
AF179	0·55
AF180	0·55
AF181	0·50
AF186	0·50
AF239	0·41
AL102	0·72
AL103	0·72
ASY26	0·28
ASY27	0·33
ASY28	0·28
ASY29	0·28
ASY50	0·28
ASY51	0·28
ASY52	0·28
ASY54	0·28
ASY55	0·28
ASY56	0·28
ASY57	0·28
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2S325	0·77
2S326	0·77
2S327	0·77
2S701	0·46
40361	0·44
40362	0·50

DIODES AND RECTIFIERS

AA119	0·09
AA120	0·09
AA129	0·09
AAY30	0·10
AAZ13	0·11
BA100	0·11
BA116	0·23
BA126	0·24
BA148	0·16
BA154	0·13
BA155	0·16
BA156	0·15
BY100	0·17
BY101	0·18
BY105	0·19
BY114	0·18
BY126	0·16
BY127	0·17
BY128	0·17
BY130	0·18

BY133	0·23
BY164	0·55
BYX38/30	0·46
BYZ10	0·39
BYZ11	0·33
BYZ12	0·33
BYZ13	0·28
BYZ16	0·44
BYZ17	0·39
BYZ18	0·39
BYZ19	0·31
CG62 (OA91 Eq.)	0·06
CG651— (OA70–OA79)	0·07
OA5	0·39
OA5SL	0·23

OA10	0·39
OA47	0·08
OA70	0·08
OA79	0·08
OA81	0·08
OA85	0·10
OA90	0·07
OA91	0·07
OA95	0·08
OA200	0·07
OA202	0·08
SD10	0·06
SD19	0·06
1N34	0·08
1N34A	0·08
1N914	0·07
1N916	0·07
1N4148	0·07
1S021	0·11
1S951	0·07

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C 1	250	Resistors mixed values approx. (count by weight)	0·55
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C 9	3	Micro Switches	0·55
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SN7401	0·17	0·16	0·13	SN7489	6·05	5·78	5·50
SN7402	0·17	0·16	0·13	SN7490	0·74	0·71	0·64
SN7403	0·17	0·16	0·13	SN7491	1·10	1·05	0·99
SN7404	0·17	0·16	0·13	SN7492	0·74	0·71	0·64
SN7405	0·17	0·16	0·13	SN7493	0·74	0·71	0·64
SN7406	0·39	0·34	0·31	SN7494	0·85	0·82	0·75
SN7407	0·39	0·34	0·31	SN7495	0·85	0·82	0·75
SN7408	0·20	0·14	0·13	SN7496	0·96	0·93	0·86
SN7409	0·20	0·19	0·18	SN74100	1·82	1·76	1·71
SN7410	0·17	0·16	0·13	SN74104	1·07	1·04	0·97
SN7411	0·28	0·24	0·26	SN74105	1·07	1·04	0·97
SN7412	0·39	0·34	0·31	SN74107	0·44	0·42	0·40
SN7413	0·32	0·29	0·27	SN74110	0·51	0·59	0·55
SN7416	0·48	0·44	0·42	SN74111	1·38	1·27	1·21
SN7417	0·48	0·44	0·42	SN74118	1·10	1·05	0·99
SN7420	0·17	0·16	0·13	SN74119	1·40	1·38	1·21
SN7422	0·55	0·53	0·50	SN74121	0·44	0·41	0·38
SN7423	0·55	0·53	0·50	SN74122	1·54	1·48	1·21
SN7425	0·55	0·53	0·50	SN74123	3·08	2·97	2·86
SN7426	0·50	0·46	0·44	SN74141	0·74	0·71	0·64
SN7427	0·50	0·46	0·44	SN74145	1·65	1·54	1·48
SN7428	0·77	0·72	0·66	SN74150	3·30	2·97	2·75
SN7430	0·17	0·16	0·13	SN74151	1·10	1·05	0·99
SN7432	0·50	0·46	0·44	SN74153	1·32	1·21	1·05
SN7433	0·88	0·83	0·77	SN74154	1·98	1·87	1·76
SN7437	0·71	0·68	0·66	SN74155	1·54	1·43	1·32
SN7438	0·71	0·68	0·66	SN74156	1·54	1·43	1·32
SN7440	0·17	0·16	0·13	SN74157	2·09	1·98	1·87
SN7441	0·74	0·71	0·64	SN74160	1·98	1·87	1·76
SN7442	0·74	0·71	0·64	SN74161	1·98	1·87	1·76
SN7443	1·43	1·38	1·32	SN74162	4·40	4·13	3·85
SN7444	1·43	1·38	1·32	SN74163	4·40	4·13	3·85
SN7445	1·98	1·95	1·93	SN74164	2·42	2·37	2·31
SN7446	1·07	1·04	0·97	SN74165	2·48	2·42	2·37
SN7447	1·10	1·07	1·05	SN74166	3·85	3·58	3·30
SN7448	1·10	1·07	1·05	SN74174	2·53	2·42	2·31
SN7450	0·17	0·16	0·13	SN74175	1·76	1·65	1·54
SN7451	0·17	0·16	0·13	SN74176	2·75	2·64	2·53
SN7453	0·17	0·16	0·13	SN74177	2·75	2·64	2·53
SN7454	0·17	0·16	0·13	SN74180	2·20	1·76	1·54
SN7460	0·17	0·16	0·13	SN74181	6·05	5·50	5·23
SN7470	0·33	0·29	0·27	SN74182	2·20	1·98	1·76
SN7472	0·32	0·29	0·27	SN74184	3·85	3·58	3·30
SN7473	0·41	0·39	0·35	SN74190	2·15	2·09	2·04
SN7474	0·41	0·39	0·35	SN74191	2·09	2·04	1·98
SN7475	0·50	0·48	0·46	SN74192	2·15	2·09	2·04
SN7476	0·44	0·43	0·43	SN74193	2·20	1·98	1·93
SN7480	0·74	0·71	0·64	SN74194	2·97	2·86	2·75
SN7481	1·32	1·27	1·21	SN74195	2·20	2·09	1·98
SN7482	0·96	0·95	0·94	SN74196	1·98	1·87	1·76
SN7483	1·21	1·16	1·05	SN74197	1·98	1·87	1·76
SN7484	1·10	1·05	0·99	SN74198	6·05	5·50	4·95
SN7485	3·96	3·85	3·74	SN74199	6·05	5·50	4·95

LINEAR I.C.'s—FULL SPEC.

Type No.	Price 1–24	25–99	100+
BP201C—SL201C	0·70	0·59	0·50
BP710C—SL701C	0·70	0·55	0·50
BP702C—SL702C	0·70	0·55	0·50
BP702—72702	0·59	0·50	0·44
BP709—72709	0·40	0·39	0·33
BP709P—µA709C	0·40	0·38	0·33
BP710—72710	0·40	0·46	0·44
BP711—µA711	0·40	0·48	0·44
BP741—72741	0·55	0·50	0·45
µA703C	0·31	0·29	0·27
TAA263	0·77	0·68	0·61
TAA293	0·99	0·88	0·77
TAA350	1·87	1·74	1·65
EA1000	2·90		

ROCK BOTTOM PRICES LOGIC DTL 930 Series I.C's

Type No.	1–24	Price 25–99	100 up
BP930	0·13	0·12	0·11
BP932	0·14	0·13	0·12
BP933	0·14	0·13	0·12
BP935	0·14	0·13	0·12
BP936	0·14	0·13	0·12
BP944	0·14	0·13	0·12
BP945	0·28	0·27	0·24
BP946	0·13	0·12	0·11
BP948	0·28	0·27	0·24
BP951	0·72	0·66	0·61
BP962	0·13	0·12	0·11
BP9093	0·44	0·42	0·39
BP9094	0·44	0·42	0·39
BP9097	0·44	0·42	0·39
BP9099	0·44	0·42	0·39

NUMERICAL INDICATOR TUBES

MODEL	CD66	GR116	3015F Minitron
Anode Voltage (Vdc)	170min	175min	5
Cathode Current (mA)	2·3	14	8
Numerical Height (mm)	16	13	9
Tube Height (mm)	47	32	22
Tube Diameter (mm)	19	13	12 wide
I.C. Driver Rec.	BP41 or 141	BP41 or 141	BP47
PRICE EACH	£1·87	£1·70	£2·09

All indicators 0·9 + Decimal point. All side viewing. Full data for all types available on request.

RTL MICROLOGIC CIRCUITS

Epoxy TO-5 case	Price each 1–24	25–99	100 up
µL900 Buffer	38p	36p	29p
µL914 Dual 2i/p gate	38p	36p	29p
µL923 J-K flip-flop	55p	51p	49p

Data and Circuits Booklet for IC's Price 8p.

DUAL IN LINE SOCKETS

(14 & 16 Lead)	1–24	25–99	100+
TSO14	0·33	0·30	0·28
TSO16 16 pin type	0·34	0·35	0·33
BPS14 14 pin type (low cost)	0·17	0·15	0·12
BPS16 16 pin type (low cost)	0·16½	0·16	0·13

BI-PAK DO IT AGAIN!

50W pk 25w (RMS)

0·1% DISTORTION!
HI-FI AUDIO AMPLIFIER

THE AL50

* Frequency Response 15Hz to 100,000—1dB.
* Load—3, 4, 8 or 16 ohms.
* Distortion—better than ·1% at 1KHz.
* Signal to noise ratio 80dB.

ONLY £3·58 each

* Supply voltage 10–35 Volts.
* Overall size 63mm × 105mm × 13mm.

Tailor made to the most stringent specifications using top quality components and incorporating the latest solid state circuitry and AL50 was conceived to fill the need for all your A.F. amplification needs.
FULLY BUILT—TESTED—GUARANTEED.

STABILISED POWER MODULE SPM80

AP80 is especially designed to power 2 of the AL50 Amplifiers, up to 15 watt (r.m.s.) per channel simultaneously. This module embodies the latest components and circuit techniques incorporating complete short circuit protection. With the addition of the Mains Transformer MT80, the unit will provide outputs of up to 1·5 amps at 35 volts. Size: 63mm × 105mm × 30mm.
These units enable you to build Audio Systems of the highest quality at a hitherto unobtainable price. Also ideal for many other applications including:—Disco Systems, Public Address, Intercom Units, etc. Handbook available, 10p **PRICE £3·25**

TRANSFORMER BMT80 £2·15 p. & p. 28p

STEREO PRE-AMPLIFIER TYPE PA100

Built to a specification and NOT a price, and yet still the greatest value on the market, the PA100 stereo pre-amplifier has been conceived from the latest circuit techniques. Designed for use with the AL50 power amplifier system, this quality made unit incorporates no less than eight silicon planar transistors, two of these are specially selected low noise NPN devices for use in the input stages.
Three switched stereo inputs, and rumble and scratch filters are features of the PA100, which also has a STEREO/MONO switch, volume, balance and continuously variable bass and treble controls.

SPECIFICATION

Frequency Response	20Hz — 20kHz ± 1dB
Harmonic Distortion	better than 0·1%
Inputs: 1. Tape Head	1·25mV into 50K Ω
2. Radio, Tuner	35mV into 50K Ω
3. Magnetic P.U.	1·5mV into 50K Ω

All input voltages are for an output of 250mV. Tape and P.U. inputs equalised to RIAA curve within ± 1dB from 20Hz to 20kHz.

Bass Control	± 15dB at 20Hz
Treble Control	± 15dB at 20kHz
Filters: Rumble (High Pass)	100Hz
Scratch (Low Pass)	8kHz
Signal/Noise Ratio	better than −65dB
Input overload	+26dB
Supply	+35 volts at 20mA
Dimensions	292mm × 82mm × 35m

ONLY £13·15

SPECIAL COMPLETE KIT COMPRISING 2 AL50's, 1 SPM80, 1 BMT80 & 1 PA100 ONLY £25·30 FREE p. & p.

All prices quoted in new pence *Giro No. 388-7006*
Please send all orders direct to warehouse and despatch department

BI-PAK

P.O. BOX 6, WARE · HERTS

Postage and packing add 10p. Overseas add extra for airmail
Minimum order 50p. Cash with order please

Guaranteed Satisfaction or Money Back

UNISOUND FOR THE NEW SOUN

AT **£26·12** INC. VAT

It's the RT-VC system that screws together to save you pounds! Unisound comprises two superb speakers and an amplifier/record deck plinth—all beautifully finished in simulated teak. The stereo amplifier (4 watts per channel into 8 ohms) is based on the famous Mullard Unilex system brought up-to-date by RTVC using integrated circuits. Turntable is the proven Garrard 2025TC complete with stereo cartridge and tinted acrylic cover. Speakers are big EMI Twin-cone units all ready for mounting in their elegant cabinets, which simply need screwing and glueing together. Easy step-by-step instructions. **£26·12 complete plus £1·40 packing + £1·40 post.** Diamond Stylus £1·37 extra. Stereo headphones with adaptor £4·40 extra. Send for leaflet.

AN RTVC EXCLUSIVE DESIGN

UNISOUND MODULES ONLY £7·64 + 55p. p. & p.
For the man who wants to design his own stereo—here's your chance to start, with Unisound—pre-amp, power amplifier and control panel. No soldering—just simply screw together. 4 watts per channel into 8 ohms. Inputs: 120mV (for ceramic cartridge). The heart of Unisound is high efficiency I.C. monolithic power chips which ensure very low distortion over the audio spectrum.

VISCOUNT III—Now 20 w

If you can sol on printed circuit boa you can build this push-butt car radio kit. It's simple—j follow the step-by-step instructio

THE TOURIST PUSH-BUTTON CAR RADIO KIT

AN INCREDIBLE BUY

ONLY FROM RTVC

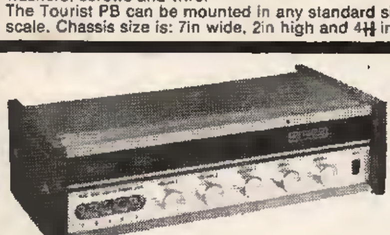
£6·60

The Tourist PB is suitable for 12 volt working on both negative and positive earth vehicles. It covers the full medium and long wave bands. It is permeability tuned and sturdily constructed. Output is a full 2·5 watts into an 8 ohms speaker. But the Tourist PB will operate into any loudspeaker from 8 to 15 ohms.
Apart from the output stage, which is an integrated circuit, the only other electronic components that need soldering are some capacitors, resistors, etc. The kit includes a pre-built RF tuner unit, and fully modulised IF stages which are pre-aligned before despatch. As well as electronic components this kit also contains 2 diamond-spun aluminium knobs, elegant matching front panel, dial, washers, screws and wire.
The Tourist PB can be mounted in any standard size dash panel and it has an illuminated tuning scale. Chassis size is: 7in wide, 2in high and 4 11/16 in deep.

* Circuit diagram and comprehensive instructions 55p free with parts.
* Fully retractable and lockable car aerial £1 post paid.

CAR RADIO KIT £6·60 p. and p. 55p.
Speaker with baffle and fixing strips £1 27p p. & p., post free if bought with the Send stamped addressed envelope leaflet.

RELIANT MkIV

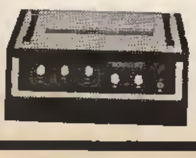


*5 Electrically Mixed inputs. *3 Individual Mixing controls. *Separate bass and treble contro common to all 5 inputs. *Mixer employing F.E.T. (Field Effect Transistors). *Solid State Circuitr *Attractive Styling. INPUTS 1. Crystal Mic or Guitar 9mV. 2. Moving coil Mic. or Guitar 8m Inputs. 3, 4 & 5 are suitable for a wide range of medium output equipment (Gram. Tuner, Monitor, Organ, etc.) All 250mV sensitivity. Output 20 watts into 8 ohms (suitable for 15 ohms). Size approx. 12½ × 6 × 3½ ins.

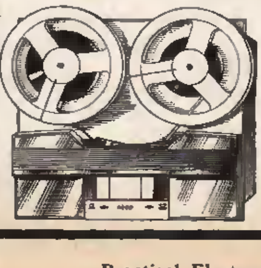
£13·50 p. & p. 60p

SOUND 50

45 WATT MONO AMPLIFIER. Ideal for Disco. Output Power: 45 watts R.M.S. (Sine Wave) Frequency Response 3dB points 30Hz and 18KHz. Total Distortion: less than 2% at rated output. Signal to noise ratio: better than 60dB. Bass Control Range: 13dB at 60Hz. Treble Control Range: 12dB at 10KHz. Inputs: 4 inputs at 5mV into 470K. Each pair of inputs controlled by separate volume control. 2 inputs at 200mV into 470K. Size: 19½ × 10½ × 8ins. Amplifier £31·35 plus £1·65 p. and p.



£31·35 (Inc. VAT)



PE TAPE LINK CONSTRUCTORS

Suitable 3 speed deck, less heads. Ca up to 7ins. spools. 2 AC mains. Unused store soiled hence warranty. £1 p. & p. **£4·**

TE-20D RF SIGNAL GENERATOR

Accurate wide range signal generator covering 120 kHz-500 MHz on 6 bands. Directly calibrated. Variable R.F. attenuator audio output. Xtal socket for calibration. 220/240V a.c. Brand new with instructions. **£15.** Carr. 37p. Size 140mm × 215mm × 170mm.

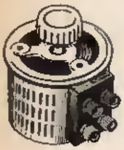
TE22 SINE SQUARE WAVE AUDIO GENERATORS

Sine: 20c/s to 200 kc/s on 4 bands. Square: 20c/s to 30 kc/s. Output impedance 5,000 ohms. 200/250V a.c. Supplied brand new and guaranteed with instruction manual and leads. **£17·50.** Carr. 37½p.

"YAMABISHI" VARIABLE VOLTAGE TRANSFORMERS

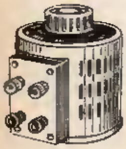
Excellent quality at low cost. All models—Input 230v. 50/60 c/s. Variable output 0-260v.

MODEL S-260 GENERAL PURPOSE BENCH MOUNTING



1 amp.	£7·00
2·5 amp.	£8·05
5 amp.	£11·75
8 amp.	£15·90
10 amp.	£22·50
12 amp.	£23·60
20 amp.	£49·00
25 amp.	£58·00
40 amp.	£82·50

MODEL S-260B



Panel mounting

1 amp	£7·00
2·5 amp	£8·05

Carriage and Packing Extra

AUTO TRANSFORMERS

0/115/230V. Step up or step down. Fully shrouded.

80W	£2·10	P. & P. 18p
150W	£2·70	P. & P. 18p
300W	£3·60	P. & P. 23p
500W	£5·25	P. & P. 33p
1000W	£7·50	P. & P. 38p
1500W	£10·20	P. & P. 43p
2250W	£17·25	P. & P. 50p
5000W	£35·00	P. & P. £1

MCA.220 AUTOMATIC VOLTAGE STABILISER

Input 88–125V a.c. or 176–250V a.c. Output 120V a.c. or 240V a.c. 200VA rating. **£11·97.** Post 50p.

PS.200 REGULATED P.S.U.

Solid state. Variable output 5–20V d.c. up to 2 amp. Independent meters to monitor voltage and current. Output 220/240V. a.c. Size 7¼in. × 5⅛in. × 3¾in. **£19·95.** Post 25p.

PS.1000B REGULATED POWER SUPPLY

Solid state. Output 6, 9 or 12V d.c. up to 3 amps. Meter to monitor current. Input 220/240V a.c. Size 4in. × 3½in. × 6¾in. **£11·97.** Post 25p.

230V/240V SMITHS SYNCHRONOUS GEARED MOTORS

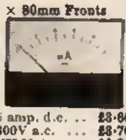
Built in gearbox. All brand new and boxed. 30 RPH CW; 2 RPH CW; 20 RPH CW; 2 RPH ACW; 30 RRH CW. **50p each,** Post 12p.

SEW CLEAR PLASTIC PANEL METERS

USED EXTENSIVELY BY INDUSTRY, GOVT. DEPTS., EDUCATIONAL AUTHORITIES, ETC.

Over 200 ranges in stock—other ranges to order. Quantity discounts available. Send for fully illustrated brochure.

TYPE SW.100 100mm × 80mm Fronts



50µA	£4·15
50-0-50µA	£3·95
100µA	£3·95
100-0-100µA	£3·90
500µA	£3·70
1mA	£3·60
20V d.c.	£3·60
50V d.c.	£3·60
300V d.c.	£3·60
1 amp. d.c.	£3·60
5 amp. d.c.	£3·60
300V a.c.	£3·70
VU Meter	£4·30

Type SD.830 82·5mm × 110mm Fronts

50µA	£3·40
50-0-50µA	£3·40
100µA	£3·35
100-0-100µA	£3·35
200µA	£3·30
500µA	£3·15
1mA	£3·10
5mA	£3·10
10mA	£3·10
50mA	£3·10
100mA	£3·10
500mA	£3·10
1 amp.	£3·10
5 amp.	£3·10
10 amp.	£3·10
5V d.c.	£3·10
10V d.c.	£3·10
20V d.c.	£3·10
50V d.c.	£3·10
300V d.c.	£3·10
15V a.c.	£3·30
300V a.c.	£3·30
VU Meter	£3·50

Type SD.640 63·5mm × 85mm Fronts

50µA	£3·05
50-0-50µA	£3·05
100µA	£3·00
100-0-100µA	£3·00
200µA	£3·00
500µA	£2·95
1mA	£2·90
5mA	£2·90
10mA	£2·90
50mA	£2·90
100mA	£2·90
500mA	£2·90
1 amp.	£2·90
5 amp.	£2·90
10 amp.	£2·90
5V d.c.	£2·90
20V d.c.	£2·90
50V d.c.	£2·90
300V d.c.	£2·90
15V a.c.	£3·00
300V a.c.	£3·00
VU Meter	£3·15

Type SD.460 46mm × 59·5mm Fronts

50µA	£2·80
50-0-50µA	£2·80
100µA	£2·75
100-0-100µA	£2·75
200µA	£2·70
500µA	£2·65
1mA	£2·60
5mA	£2·60
10mA	£2·60
50mA	£2·60
100mA	£2·60
500mA	£2·60
1 amp.	£2·60
5 amp.	£2·60
10 amp.	£2·60
5V d.c.	£2·60
10V d.c.	£2·60
20V d.c.	£2·60
50V d.c.	£2·60
300V d.c.	£2·60
15V a.c.	£2·70
300V a.c.	£2·70
VU Meter	£2·90

"SEW" EDGEWISE METERS

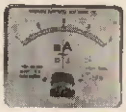
Type PE.70. 3 17/32in. × 1 15/32in. × 2½in. deep.

50µA	£3·75
50-0-50µA	£3·60
100µA	£3·60
100-0-100µA	£3·50
200µA	£3·40
500µA	£3·20
1mA	£3·20
300V a.c.	£3·25
VU Meter	£3·85

*MOVING IRON— ALL OTHERS MOVING COIL

Please add postage

Type MR.85P. 4¼in. × 4¼in. Fronts



50µA	£3·95
50-0-50µA	£3·40
100µA	£3·40
100-0-100µA	£3·30
200µA	£3·30
500µA	£3·20
500-0-500µA	£3·10
1mA	£3·10
1-0-1mA	£3·10
5mA	£3·10
10mA	£3·10
50mA	£3·10
100mA	£3·10
500mA	£3·10
1 amp.	£3·10
5 amp.	£3·10
15 amp.	£3·10
30 amp.	£3·20
20V d.c.	£3·10
50V d.c.	£3·10
150V d.c.	£3·10
300V d.c.	£3·10
15V a.c.	£3·10
300V a.c.	£3·10
S Meter 1mA	£3·15
VU Meter	£3·95
1 amp. a.c.*	£3·10
5 amp. a.c.*	£3·10
10 amp. a.c.*	£3·10
20 amp. a.c.*	£3·10
30 amp. a.c.*	£3·10

Type MR.52P. 2½in. square Fronts.

50µA	£3·50
50-0-50µA	£3·05
100µA	£3·00
100-0-100µA	£2·95
500µA	£2·65
1mA	£2·50
5mA	£2·50
10mA	£2·50
50mA	£2·50
100mA	£2·50
500mA	£2·50
1 amp.	£2·50
5 amp.	£2·50
10V d.c.	£2·50
20V d.c.	£2·50
50V d.c.	£2·50
300V d.c.	£2·50
15V a.c.	£2·60
300V a.c.	£2·60
S Meter 1mA	£2·60
VU Meter	£3·60
1 amp. a.c.*	£2·50
5 amp. a.c.*	£2·50
10 amp. a.c.*	£2·50
20 amp. a.c.*	£2·50
30 amp. a.c.*	£2·50

Type MR.65P. 3½in. × 3¼in. Fronts

50µA	£3·70
50-0-50µA	£3·15
100µA	£3·15
100-0-100µA	£3·10
200µA	£3·05
500µA	£2·75
500-0500µA	£2·60
1mA	£2·60
5mA	£2·60
10mA	£2·60
50mA	£2·60
100mA	£2·60
500mA	£2·60
1 amp.	£2·60
5 amp.	£2·60
10 amp.	£2·60
13 amp.	£2·60
20 amp.	£2·60
30 amp.	£2·80
50 amp.	£2·90
5V d.c.	£2·60
10V d.c.	£2·60
20V d.c.	£2·60
50V d.c.	£2·60
150V d.c.	£2·60
300V d.c.	£2·60
15V a.c.	£2·80
50V a.c.	£2·80
150V a.c.	£2·80
300V a.c.	£2·80
500V a.c.	£2·80
S Meter 1mA	£2·85
VU Meter	£3·70
50mA a.c.*	£2·60
100mA a.c.*	£2·60
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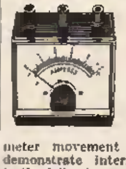
"SEW" EDUCATIONAL METERS



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10V d.c.	£4·85
20V d.c.	£4·84
50V d.c.	£4·85
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Dual range	
500mA/5A d.c.	£5·10
5V/50V d.c.	£5·10

Type MR.38P. 1 21/32in. square Fronts.

50µA	£2·55
50-0-50µA	£2·50
100µA	£2·45
100-0-100µA	£2·40
200µA	£2·25
500µA	£2·25
500-0-500µA	£2·25
1mA	£2·25
1-0-1mA	£2·25
2mA	£2·25
5mA	£2·25
10mA	£2·25
20mA	£2·25
50mA	£2·25
100mA	£2·25
150mA	£2·25
200mA	£2·25
300mA	£2·25
500mA	£2·25
750mA	£2·25
1 amp.	£2·25
2 amp.	£2·25
5 amp.	£2·25
10 amp.	£2·25
3V d.c.	£2·25
10V d.c.	£2·25
15V d.c.	£2·25
20V d.c.	£2·25
50V d.c.	£2·25
100V d.c.	£2·25
150V d.c.	£2·25
300V d.c.	£2·25
500V d.c.	£2·25
750V d.c.	£2·25
15V a.c.	£2·35
50V a.c.	£2·30
150V a.c.	£2·30
300V a.c.	£2·30
500V a.c.	£2·30
S Meter 1mA.	£2·30
VU Meter	£2·65

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100µA	£2·60
100-0-100µA	£2·50
200µA	£2·50
500µA	£2·45
500-0-500µA	£2·40
1mA	£2·40
5mA	£2·40
10mA	£2·40
50mA	£2·40
100mA	£2·40
500mA	£2·40
1 amp.	£2·40
5 amp.	£2·40
10V d.c.	£2·40
20V d.c.	£2·40
50V d.c.	£2·40
300V d.c.	£2·40
15V d.c.	£2·40
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VU Meter	£2·70
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50-0-50µA	£3·05
100µA	£3·00
100-0-100µA	£3·00
500µA	£2·70
500-0-500µA	£2·70
1mA	£2·60
1-0-1mA	£2·60
5mA	£2·60
10mA	£2·60
5mA	£2·60
50mA	£2·60
100mA	£2·60
500mA	£2·60
1 amp.	£2·60
5 amp.	£2·60
15 amp.	£2·60
30 amp.	£2·60
50 amp.	£2·60
5V d.c.	£2·60
10V d.c.	£2·60
20V d.c.	£2·60
50V d.c.	£2·60
150V d.c.	£2·60
300V d.c.	£2·60
30V a.c.*	£2·65
50V a.c.*	£2·65
150V a.c.*	£2·65
300V a.c.*	£2·65
500mA a.c.*	£2·60
1 amp. a.c.*	£2·60
5 amp. a.c.*	£2·60
10 amp. a.c.*	£2·60
20 amp. a.c.*	£2·60
30 amp. a.c.*	£2·60
50 amp. a.c.*	£2·60
VU Meter	£3·65
50mV d.c.	£2·90
100mV d.c.	£2·90

Type S-80 80mm square Fronts

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50-0-50µA	£3·40
100µA	£3·40
100-0-100µA	£3·30
500µA	£3·05
1mA	£3·00
20V d.c.	£3·00
50V d.c.	£3·00
300V d.c.	£3·00
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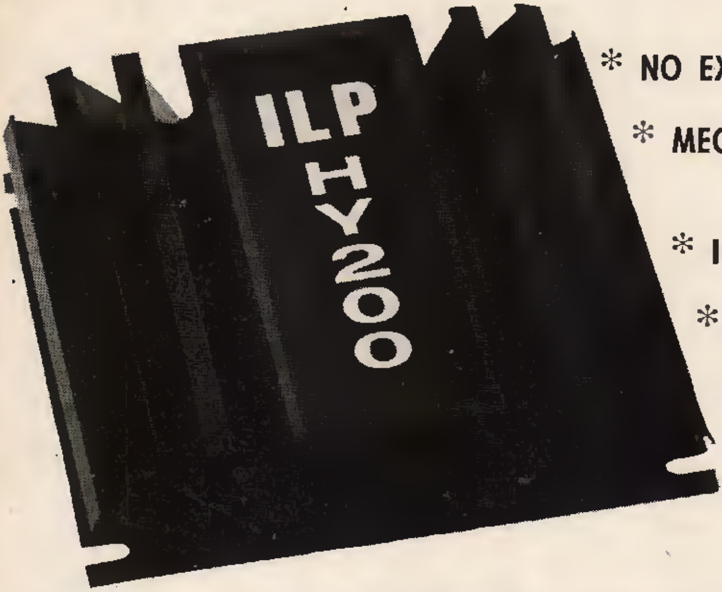

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PE

ANOTHER SENSE

THIS month we break new ground in applied electronics. Most of the characteristic human senses can be simulated in some fashion by electronic means, but smell and taste are much more difficult for non-biological systems to imitate. Only just recently has it become possible to simulate in some degree the sense of smell without complex and costly chemical devices. This is due to a newly developed semiconductor transducer which responds to the presence of molecules carried in the air.

This particular kind of transducer is a valuable and timely addition to the field of instrumentation and control. Its appearance is especially relevant in these days of public consciousness about the environment and concern for a curb on all objectionable and harmful pollution of the atmosphere. Electronics is now equipped to wage an increasingly effective part in the battle of the environment.

Considering the actual trandsucer itself: now that it has been realised, the gas and vapour detector seems quite simple and rudimentary in its practical form. This apparent simplicity (a common enough outward characteristic of many solid state devices) should not give cause to underestimate the technical achievement it represents. Although the powers of discrimination between different vapours and odours are limited, this transducer is obviously but the first in a series of devices of ever increasing sensitivity and selectivity that will appear in due course. In a wider context the emergence of such a device must be recognised as but one reward from a continuing process of exploration into semiconductor materials which has followed in the wake of the original transistor breakthrough of 25 years ago. This research, conducted on a world wide basis, frequently gives birth to new devices and these largely constitute the power and strength behind electronics, particularly when they enable this technology to penetrate and influence other fields.

With the creation of a kind of electronic nose, interest is likely to be directed towards a simulation of the human taste buds. This, we are given to understand, is a rather more formidable problem. But problems involving electronics usually do find their solution, as suggested in the previous paragraph.

Finally, a slight digression in order to discuss a (not too serious) question of terminology. There are some who might question the propriety of applying biological descriptions to inanimate devices or equipments. True, we have the outstanding example of the poor old computer which has long suffered from the over-generous honour accorded it by the popular title "electronic brain". We could be strictly objective and refer to this month's feature project as simply a gas and vapour detector. However, "electronic nose" seems a rather apt and certainly more colourful description for this unusual innovation in the home constructor field. Its applications are serious enough, however, as will soon be appreciated.—F.E.B.

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DETECTS
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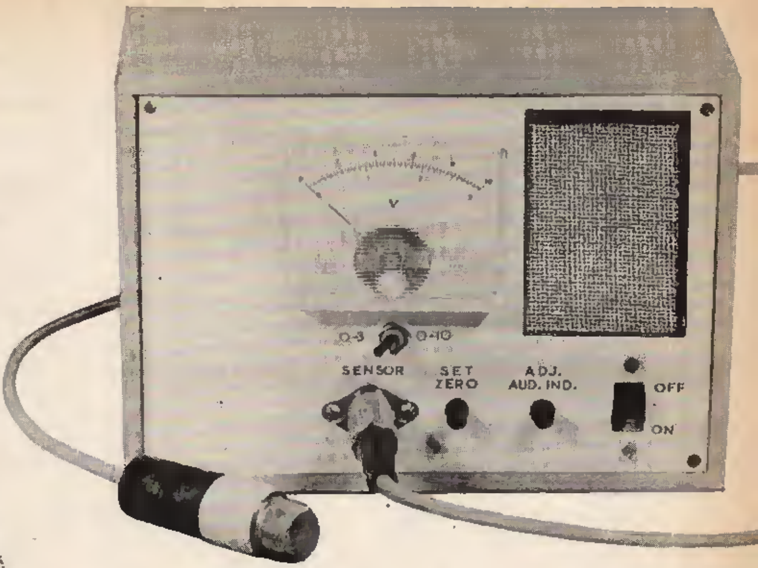
ELECTRONIC NOSE

BY D.BOLLEN



THIS battery operated instrument is designed around a new type of semiconductor sensor which responds to certain gases, vapours, and smoke particles. The sensor cannot distinguish between different smells but it does allow an assessment to be made of the relative concentration of a contaminant in air. Applications include breathalyser, fuel vapour and firedamp detector, air pollution meter, paint dryness indicator, and gas leak locator.

The electronic nose has a meter readout scaled in arbitrary units of 0–3 and 0–10, as well as an audible indicator giving a note of rising pitch proportional to gas or smoke intake. As a rough indication of sensitivity, a measurable response is obtained from 1 cubic millimetre of alcohol evaporated in a volume of air the size of a tea-chest, this is approximately 10,000 times less than the concentration needed to form an explosive mixture.

SEMICONDUCTOR GAS SENSOR (SGS)

The gas sensor consists of two heating filaments embedded in an *n*-type semiconductor chip, see Fig. 1. Only one filament is used for heating the chip, the other merely serving as an ohmic contact. Gas or smoke impurities reduce the intrinsic resistance of the chip, as measured between the two heating filaments, and chip heat determines the rate at which an impurity is absorbed and deabsorbed.

The Japanese manufacturers of the gas sensing device used in this article are not very informative on the working principle involved, but an educated guess is that the semiconductor chip undergoes temporary doping in the presence of air impurities, and this lowers intrinsic resistance in the same way as it does with other types of semiconductor. Heat is required to convect the impurity through the porous structure of the chip, and for deabsorption when the source of contamination is removed.

Heater requirements are around 1·2V maximum at 750 milliamps, and the device runs warm to the touch.

The chip is non-polarised and will conduct in either direction. Chip resistance is in the range 10 to 50 kilohms in clean air, falling to less than 1 kilohm in the presence of moderate concentrations of gases such as hydrogen, carbon monoxide, methane, propane, coal gas, and the vapours from alcohol, petrol, acetone, etc. A whiff of tobacco smoke is also sufficient to cause a similar resistance change.

BASIC CIRCUIT

Fig. 2 shows the basic circuit of the electronic nose, where the voltage across the SGS chip is compared with a fixed voltage at the junction of R1 and R2. In the absence of an air contaminant, VR1 is adjusted so that both voltages are equal and the meter reads zero.

When gas or smoke is detected, the chip resistance decreases and "pulls down" the voltage at the junction of H2 and VR1 slider, thus causing the voltmeter to display a reading. Tests indicate that the resulting meter reading is linearly related to contaminant concentration.

With its balanced configuration, the Fig. 2 circuit is insensitive to small changes in the voltage of battery B2; when the reference voltage drops, so does the voltage across the chip, by a corresponding amount.

RESPONSE TIME

The response of the Fig. 2 circuit, to the sudden application and removal of a "smell", is shown by the graph of Fig. 3. Absorption time is about two seconds and complete deabsorption takes about 80 seconds. However, when the instrument is employed merely for tracing the source of a contaminant, and not for measurements, there is no need to wait for complete deabsorption.

COMPLETE CIRCUIT

In the complete circuit of the nose, Fig. 4, a reference voltage is provided, as before, by R1 and R2, and VR1 adjusts meter zero. The sensor is contained in a small probe and leads connecting to the measuring circuit *via* plug and socket PL1 and SK1.

A 100μA meter movement, with two switch selected series resistors R3 and R4, is used as a voltmeter in Fig. 4. Because the voltmeter places a significant load on the circuit, particularly when switched to the 0–3 range, the values of R3 and R4 are compensated to give a true relationship between ranges. In the 0–10 S1 position, meter full scale is represented by 4V.

Voltage controlled oscillator TR1 and TR2 gives an audible indication of changes in SGS resistance. VR2 sets the oscillator frequency to zero when the meter reading is zero. When SGS resistance decreases, the voltage across VR2 slider and the positive supply rail increases, thus applying a bias current to TR1 base. C1 charges up via TR1 and R5 at a rate dependent on the TR1 bias current.

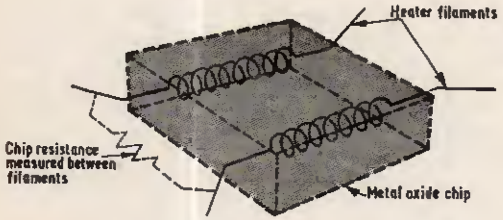


Fig. 1. Construction of the semiconductor gas sensor

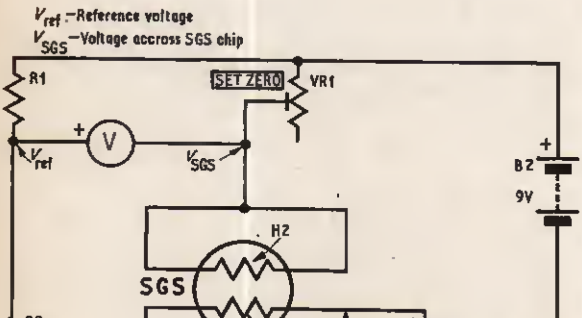


Fig. 2. Basic circuit of the electronic nose

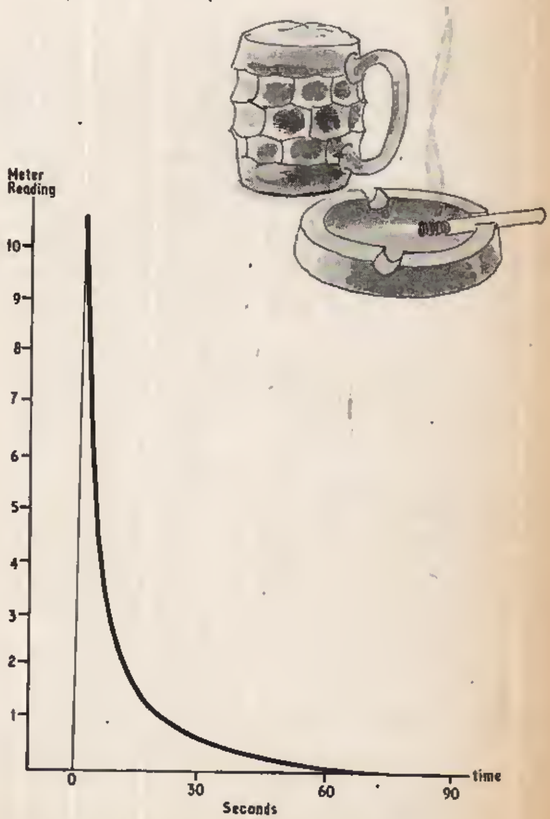


Fig. 3. Gas sensor response time graph

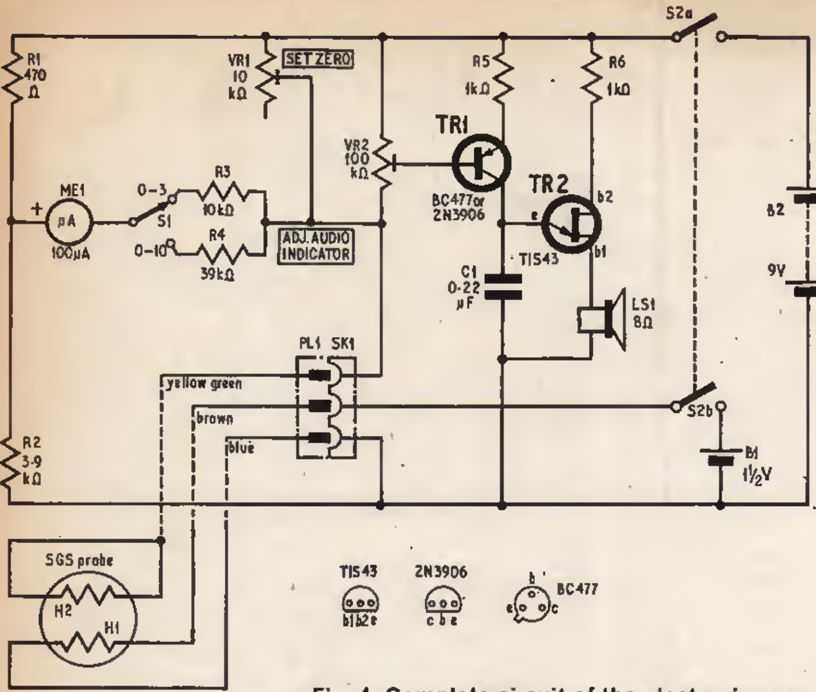
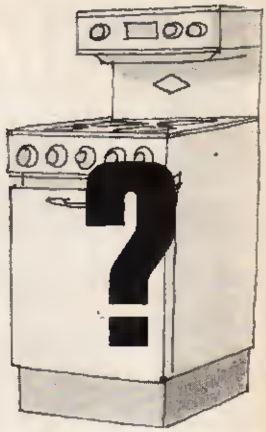


Fig. 4. Complete circuit of the electronic nose



At the threshold voltage of the unijunction transistor TR2, C1 is rapidly discharged through the loudspeaker LS1 to give an audible "click". For a small decrease in chip resistance, the audible indicator clicks like a Geiger counter, but if the chip resistance continues to decrease the clicks will run together to form a note of rising pitch which is related to the meter reading.

Battery B1 in Fig. 4 is a U14 gas lighter cell of nominal 1·5V. When loaded by the SGS heater, the internal resistance of the cell, plus the small resistance presented by interconnecting wiring, will give a voltage drop of around 0·3V, thus only 1·2V is finally applied to heater H1.

A reduction of heater voltage as B1 ages will increase absorption and deabsorption times, but will not materially affect calibration accuracy. Life of a U14 will be approximately 1 week when the instrument is used for two to three hours per day.

CIRCUIT BOARD CONSTRUCTION

Transistors, fixed resistors, and capacitor C1 are mounted on a 1·9in by 1·5in piece of 0·1in matrix plain circuit board, see Fig. 5. Insert terminal pins in the positions shown, so that they project from the underside of the board, then component leads can be pushed through and soldered to the pins, or other component leads. The unused portion of the circuit board is used for mounting purposes.

FRONT PANEL CONSTRUCTION

Front panel layout is shown in Fig. 6, and the photographs, but this will depend to some extent on the size of meter used.

Position the loudspeaker in the top left-hand corner at the back of the panel and draw round it with a pencil. Find the best position for ME1, to clear LS1 and B1, and mark this out. Next draw in hole centres for the controls, leaving a clear space above VR1 and VR2 for a short section cut from a plastic clip of the type used to hang posters, this makes an ideal circuit board mount.

Drill and cut all holes, including a loudspeaker aperture shaped to suit the space available, and apply lettering to the front of the panel. If VR1 and VR2 are miniature printed circuit mounting knob pre-sets, these can be glued to the front panel, along with the circuit board mounting clip, loudspeaker gauze, and loudspeaker. It is best to employ a semi-flexible glue as this will allow components to be prised off for replacement.

BOX AND BATTERY MOUNT

The U14 cell for B1 is held by a spring steel clip which is bolted to the back of the box and serves as the negative connection. A strip of brass makes contact with the positive battery pole. If the box is made of metal, the brass strip should, of course, be insulated from the box. A simple metal clip serves to hold B2 in position.

PROBE DETAILS

Details of the sensor probe are given in Fig. 7. The probe lead should not be more than 1 metre long, and all solder connections should be really secure, to minimise heater voltage drop. Try to avoid contaminating the SGS gauze with any material which might influence chip resistance, such as glue or paint. H1 and H2 heater pins are interchangeable.

ADJUSTMENT AND TESTING

Set VR1 and VR2 to the mid-position, S1 to the 0–10 range, and switch on. The meter pointer should

COMPONENTS . . .

Resistors
R1 470Ω
R2 3·9kΩ
R3 10kΩ 2% metal oxide
R4 39kΩ 2% metal oxide
R5 1kΩ
R6 1kΩ
All 10% ½W except where stated

Potentiometers
VR1 10kΩ } miniature knob presets
VR2 100kΩ }

Capacitor
C1 0·22μF

Transistors
TR1 BC477 *or* 2N3906
TR2 TIS43

Sensor
SGS1 Semiconductor gas sensor (available from Trampus Electronix, P.O. Box 29, Bracknell, Berks.)

Meter
ME1 100μA f.s.d.

Batteries
B1 U14 1·5V gaslighter
B2 PP6 9V

Loudspeaker
LS1 2¼in dia, 8Ω

Switches
S1 Miniature single pole toggle
S2 D.P.D.T. slide

Plug and Socket
PL1 3-way DIN
SK1 3-way DIN

Miscellaneous
Plain 0·1in matrix board 1·9in × 1·5in. Terminal pins. 2A 3-core mains cable, 1 metre. Connecting wire.

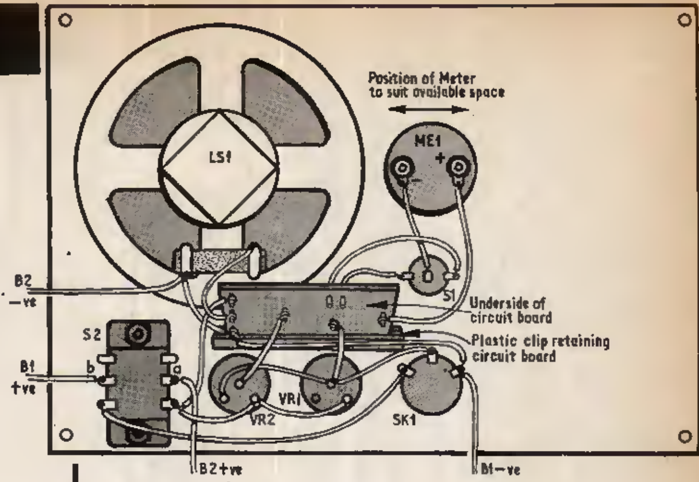


Fig. 6. Front panel interwiring details

touch the zero stop and then rise quickly to beyond full scale, accompanied by a note of rising pitch from the loudspeaker. After about a minute, the meter reading and audio note will begin to decline as the SGS decontaminates. Because absorption takes place when the SGS is not in use, and reaches a high level, five minutes should be allowed for initial warm up and complete deabsorption when the instrument is first switched on.

Now trim VR1 for a reading of 0·2 on the 0–3 range and adjust VR2 for a series of slowly repeated clicks from the loudspeaker, these should cease when the meter is zeroed.

After the initial warm up period the meter zero reading should remain reasonably stable, but remember that the SGS can detect slight traces of smoke and other contaminants in an ordinary room so some fluctuation just above zero will occur. In the event of erratic meter readings, the wiring between B1 and H1 should be suspected.

Out of doors, and in strong draughts, the meter reading may drop below zero due to cooling of the semiconductor chip, this effect can be minimised by enclosing the probe in a simple windshield.

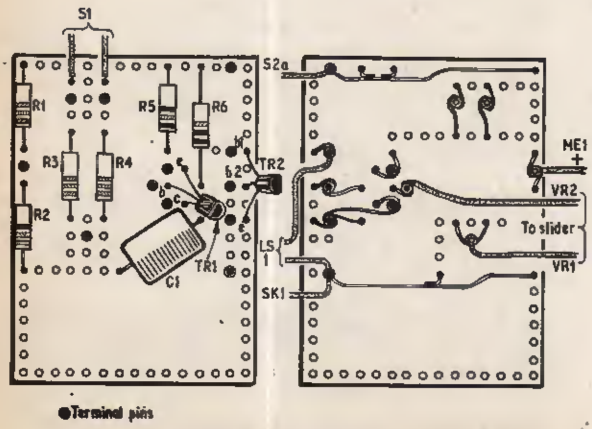


Fig. 5. Layout of the components on the perforated board

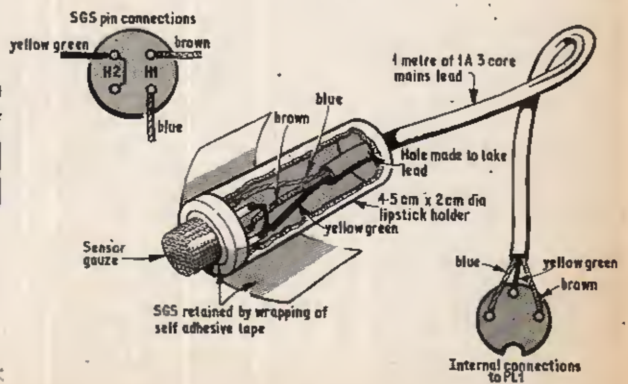
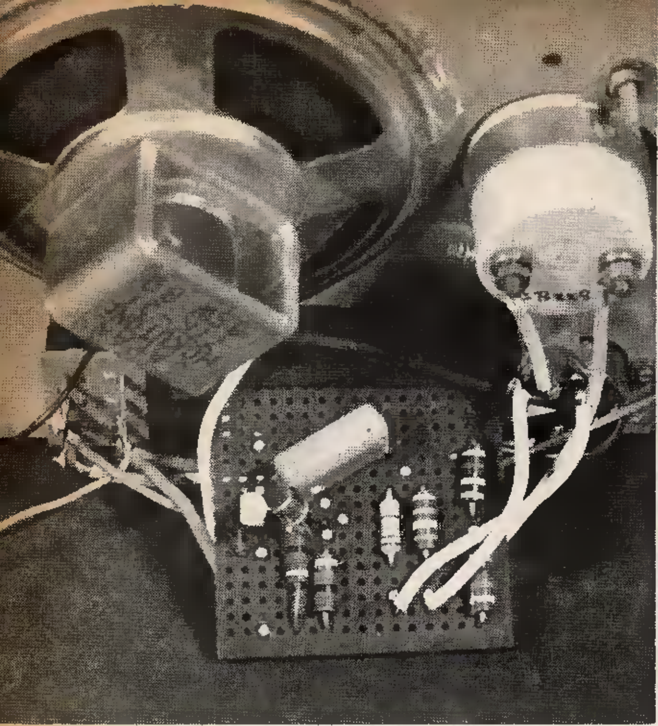


Fig. 7. Details of the sensor probe



Photograph of the rear of the front panel showing Veroboard and meter connections

To test the nose, move the probe near to an open bottle of methylated spirits or blow smoke at the sensor gauze.

APPLICATIONS

If the probe is gently breathed upon one or two hours after drinking a pint of beer, this should be sufficient to cause a reading of 10. The nose can therefore act as an ultra-sensitive breathalyser. Similarly, it may be possible to assess the alcoholic content of drinks by placing the sensor at a fixed distance from a sample of given volume and temperature.

Minor gas leaks from cigarette lighters, camping stoves, and domestic cookers are readily detected, with the aid of the audible indicator, as are fumes from storage batteries and many volatile chemicals. The electronic nose is particularly useful for detecting odourless gases.

When placed near the exhaust of an internal combustion engine, the SGS will respond to carbon monoxide, as well as oil fumes and unburnt fuel, so the reading obtained can be taken as a general measure of engine tune and condition. However, for really accurate results, the exhaust gases should be captured in a bottle or can, the contents of which are "sniffed" in a draught free environment.

For air pollution measurements, the instrument should first be zeroed in a clean air zone, preferably out in the country, and then be taken to the area to be tested. Alternatively, comparative readings can be taken in a city environment by adjusting the meter to read 1 unit instead of zero. A high reading does not necessarily suggest serious pollution as this could be caused by a wide range of harmless volatiles, such as perfumes and deodorants! ★

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BY FRANK W. HYDE

OUTER HEBRIDES ACTIVITY

In aerospace activities the more glamorous and spectacular events command most attention. The fact is that other very important projects are proceeding which seldom appear in the news. One is the work that goes on at South Uist in the outer Hebrides.

In one day during April this year seven British *Petrel* rockets were launched. This is the first time that more than three launches a day have been made. Each rocket carried a payload constructed at the Science Research Council's Radio and Space Research Station at Slough.

The object of the launchings was to study the ionisation of the atmosphere above 60km (40 miles) altitude. The experimental data gained will demonstrate the development of the D-region of the ionosphere through a day which will assist the checking of the theoretical work in progress at the research station.

Each payload carried a number of experiments dealing with:—

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   These frequencies are transmitted from the ground to the rocket.

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3. Measurement of the intensity of the solar ultraviolet radiation at 1216Å (the Lyman alpha region) and the concentration of molecular oxygen as a result of the atmospheric absorption of this frequency of radiation.

4. The measurement of X-rays from the Sun in the range 2–8 Ångstrom units.

5. A new experiment which was developed in collaboration with the Max Planck institute at Lindau, West Germany and the University College of Wales at Aberystwyth, to measure the concentration of atomic oxygen in the ionosphere by the manner in which corrosion takes place of thin silver film.

6. The housekeeping functions of the vehicle, that is, the attitude of the rocket to the Sun, the slant range of the rocket from the launching site, the instrumentation of temperature etc.

EXERCISE ACHIEVED

The rockets all reached altitudes of some 140km (90 miles) and measurements were transmitted by each rocket to the ground station on South Uist and recorded on tape.

The data shows that the objects of the exercise have been achieved although some problems were met, such as postponements due to gale force winds and spectacular, though from the project point of view unwanted, aurora displays. The performance of this rocket, which is 7½ inches in diameter and nine feet long, has shown that it can be safely launched in near gale force winds.

The project scientist Dr P. H. G. Dickinson of RSRS has praised the support he has received from the U.K. Atomic Energy Authority and from the Army which was responsible for the safety of the range and the surveillance radar on St Kilda. The *Skylark* rocket was designed and made by Bristol Aerojet.

ARGENTINA AND THE SKYLARK

Two test firings have been carried out by a British team for the Argentine government. This is an attempt to use *Skylark* as an Earth resources rocket with the aim at finding a cheaper method of carrying out such surveys.

A combined team from the British Aircraft Corporation and the Royal Aircraft Establishment, Farnborough, launched the rockets from a transportable launcher to a height in excess of 240km. The payloads consisted of four cameras with different lenses and different films. The descent of the payload was by parachute.

Recovery was very rapid as helicopters were used.

Some 640 photographs were obtained taking in a large part of Argentina. The pictures will be analysed by teams from Reading University and the Instituto Nacional de Technologia Agropechuaria of Argentina.

The valuation made will be in terms of land use and crop inventory.

SOVIET SATELLITES

The Soviet Union launched more than three times the number of *Cosmos* photo-reconnaissance satellites than the United States during 1972. In spite of this only 25 per cent more time was logged by the U.S.S.R. amounting to 366 days, compared with 295 days for the United States, which used only eight satellites.

It would appear that there was some acceleration of effort after the international agreement was signed. Eighty per cent of the satellites were of an advanced design with the provision of a rocket that can be vernier controlled which makes it possible to direct the satellite over a specific target.

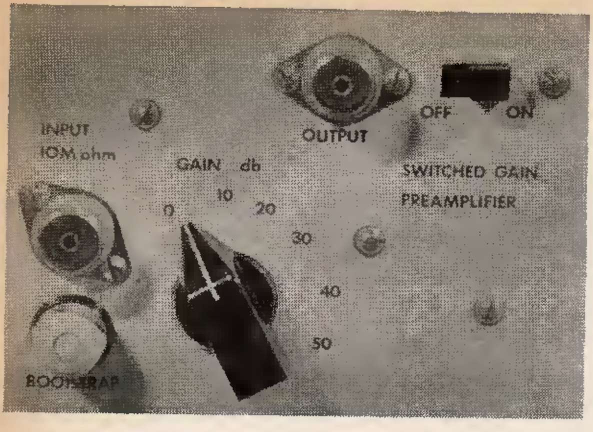
The cameras used are probably of high resolution and narrow angle to get greater detail.

The satellites are not just used for mapping strategical situated industrial plants. There is a more practical use for them. Two of the satellites were launched at 81 degree orbits and used to check ice packs and sea lanes. Another satellite enabled information about the conditions to be applied to the sea routes with the result that a flotilla of ice breakers and cargo vessels were able to make a safe trip from the Yenisei river to Murmansk. The U.S.S.R. attribute the success to the availability of accurate information from the satellites.

PIONEER

The second Jupiter probe, *Pioneer G*, is now on its way. It will take over from *Pioneer 10* if that vehicle should have difficulty when in the vicinity of Jupiter.

The conditions there could be such that high level radiation could damage the spacecraft. If however, the fly-by is successful the second vehicle will have a slightly different programme. *Pioneer G* or *Pioneer 11* as it will be known will approach within 27,000 miles of the giant planet.



Switched Gain Preamplifier

By D. Crocker

THE amplifier to be described was designed to serve as a general purpose unit for a wide range of applications. It may be used, for example, between a signal source and a power amplifier to increase sensitivity, as an a.c. coupled oscilloscope preamplifier, a monitor amplifier to feed a crystal earpiece directly, or as an impedance matching device for coupling a crystal or ceramic pickup or a crystal microphone to an amplifier having a low input impedance.

In order to make the amplifier as versatile as possible, it was decided that a variable gain of up to 50dB was required together with a wide band width and high input and low output impedances. It should also have a low power consumption so that it may be run from batteries, making it self contained.

CIRCUIT DESCRIPTION

The complete circuit is shown in Fig. 1. In order to obtain a high input resistance, use of a field effect transistor is made in the first stage. Unlike a bipolar (conventional) transistor, that is a voltage operated device drawing very little current from the input signal. The current flowing between the source and drain terminals is varied by the voltage between the gate (the third terminal) and the source.

This varying current is fed to the base of a *p-n-p* transistor, TR2, comprising the second stage.

Since it is desirable to apply negative feedback to the source of TR1 in order to accurately determine the gain and widen the frequency response, the open loop gain (i.e. the gain before feedback is applied) should be above 3,000 for a closed loop gain of 50dB. Although the phase shift between TR1 source and TR2 collector is the required 180 degrees (TR2 having provided this), the gain provided would be much less than 1,000 if TR2 was given a simple resistor as a collector load. Another common emitter stage cannot be used as it would provide an extra 180 degree phase shift, making the feedback positive; an emitter follower, TR3, has therefore been used.

As this can provide no voltage gain by itself, R9, the collector load of TR2, has been bootstrapped by C4. This makes R9 appear to be in parallel with TR3 emitter-base junction, and since the effective resistance of this is lower than R9, most of TR2 collector signal current flows through TR3, giving rise to an amplified collector/emitter current in TR3 which flows through R12, developing an output voltage across it.

SPECIFICATION

Gain
Switched gains of 0, 10, 20, 30, 40, and 50dB
Bandwidth
Low frequency: —3dB at 10Hz
High frequency: —3dB at:
200kHz (50dB gain)
500kHz (40dB gain)
800kHz (30dB gain)
>800kHz (0, 10 or 20dB gain)
Maximum output
12V p-p (no load)
7V p-p (10kΩ load)
1·5V p-p (1kΩ load)
Slewing rate
Approximately 10V/μS minimum
Noise
Referred to input: approx. 150μV p-p (input open)
approx. 25μV p-p (input shorted)
Supply current
Approximately 1·2mA
Input resistance
12MΩ with S3 out.

The overall effect of the emitter follower TR3 and bootstrapped resistor R9 is to make the collector load resistance of TR2 very high, so that TR2 gives a high voltage gain.

FEEDBACK

Negative feedback is applied from the output to TR1 source through R11. As well as enabling the gain to be varied, this stabilises d.c. conditions throughout the amplifier and reduces its output impedance. When S1 is set for unity gain (0dB), full negative feedback is applied; for higher gains resistors R4 to R8 are switched in to reduce the amount of feedback.

For an amplifier of this sort, the gain is given by the formula

$$G = \frac{A(Rs + Rf)}{Rf + Rs.A} \qquad \text{if } A \gg 1$$

or

$$G = 1 + \frac{Rf}{Rs} \qquad \text{if } A \gg G$$

In this circuit A, the open loop gain, is between 3,000 and 7,000 depending on the load. Rf is R11 of Fig. 1 and Rs is the resistor switched in by S1. This resistor is connected in series with C3 in order not to disturb the d.c. conditions.

The current consumption of the amplifier has been reduced to about 1·2mA by giving R12 the rather high value of 10kΩ. This limits the maximum output available when a low impedance is used to the figures given in the specification. Whilst this has proved to be satisfactory, any constructor requiring a higher output current capability can decrease the value of R12 (but not below about 2kΩ) at the expense of reduced battery life.

an open loop gain of over 6,000, so that over 67dB of feedback is applied when the amplifier is set for unity gain, this form of instability has not occurred in the prototype.

CONSTRUCTION

In order to avoid hum pick-up at the high impedance input, the amplifier is constructed in an aluminium box which provides screening. Most of the circuitry is constructed on a piece of 0·1in matrix Veroboard measuring 25·4mm × 50·8mm.

Before mounting the components, breaks are made in the copper strips as shown in Fig. 2 and terminal pins are inserted from the copper side of the board. These should then be soldered in place and tinned.

The pins in row 7 support the screens; these are made from 2 pieces cut from tin measuring about 9mm × 33mm and 17mm × 33mm. They are flattened, cleaned, and one side of each is coated with solder. After placing small pieces of p.v.c. insulating tape between the 5 terminal pins over rows B, D and F, the

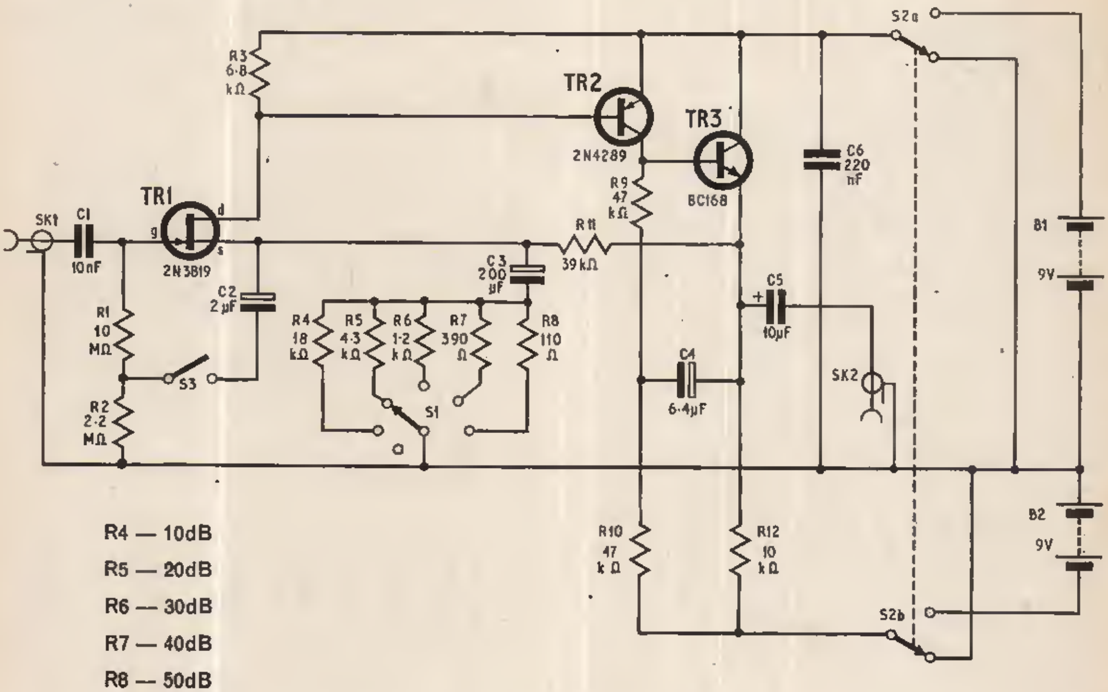


Fig. 1. Circuit diagram of preamplifier.

Since the output offset voltage may be positive or negative, the output capacitor C5 is a tantalum type; these can withstand small reverse voltages.

STABILITY

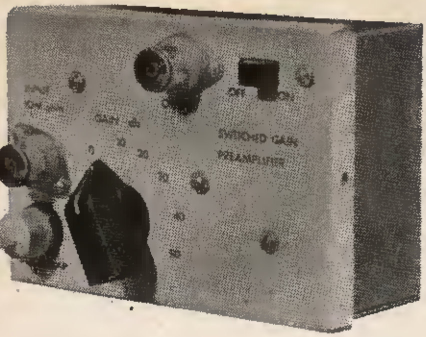
There are two ways in which an amplifier of this sort might be unstable. First, since the amplifier has a high, non-inverting gain and a high input impedance, feedback from the output to the input can easily occur causing oscillation. This is prevented by placing an earthed metal screen on the circuit board and using co-axial input and output connectors.

Secondly, due to extra phase shift in the amplifier, the feedback through R11 could become positive at high frequencies. In spite of the fact that the amplifier has

screens are soldered in place on the terminal pins in the position shown in Fig. 2. The smaller piece of tin is fitted on the copper side of the board. The components may then be wired in the positions shown in Fig. 3. Component wires should be sleeved where appropriate. An aluminium box measuring 4in × 2¾in × 1½in with lid is required. The lid is drilled to accommodate the switches and sockets and these fitted.

MOUNTING THE BOARD

In order to mount the circuit board, one face of a ⅜in 6 B.A. tapped hexagonal pillar is tinned and soldered to the screen on the copper side of the board, placing it approximately below hole F8 (see Fig. 2), without allowing the screen to part from the pins. The pillar



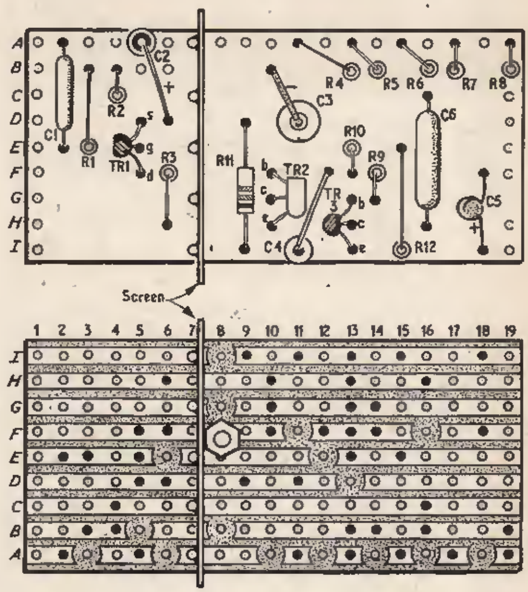


Fig. 2. Component assembly and wiring details.

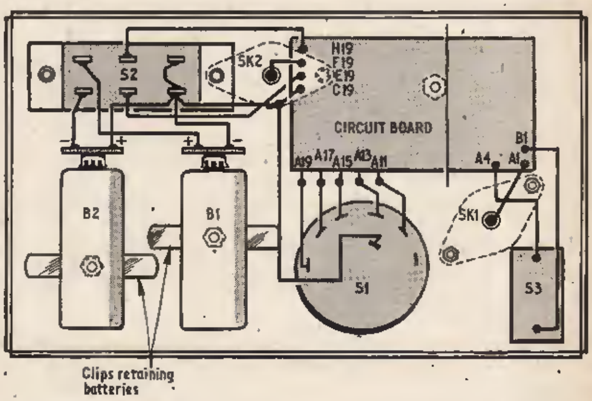


Fig. 3. Total component assembly within the aluminium box.

COMPONENTS . . .

Resistors

R1 10MΩ
R2 2·2MΩ
R3 6·8kΩ
R4 18kΩ
R5 4·3kΩ
R6 1·2kΩ
R7 390Ω
R8 110Ω
R9 47kΩ
R10 47kΩ
R11 39kΩ
R12 10kΩ
All ¼W 5% carbon

Capacitors

C1 0·01μF miniature polyester
C2 2μF 16V miniature electrolytic
C3 200μF 6·4V miniature electrolytic
C4 6·4μF 25V miniature electrolytic
C5 10μF 25V tantalum bead electrolytic
C6 0·22μF miniature polyester

Transistors

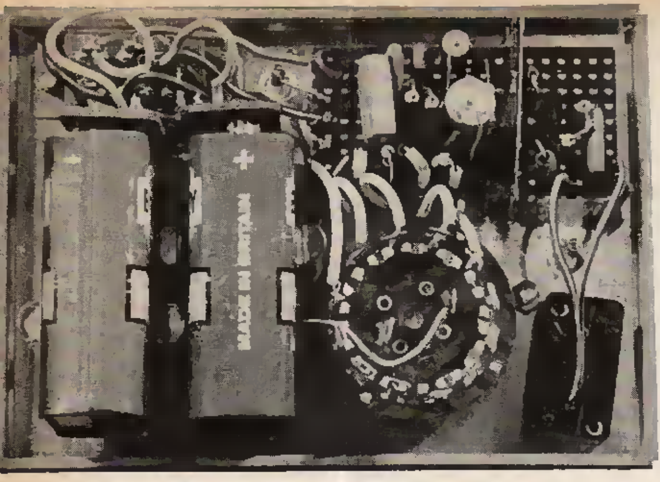
TR1 2N3819
TR2 2N4289
TR3 BC168B or BC169

Switches

S1 2 pole 6 way miniature wavechange switch (only 1 pole used)
S2 d.p.d.t. slider switch
S3 s.p.s.t. push on/push off switch (see text)

Miscellaneous

SK1, SK2 Surface mounting co-axial sockets (2 off). B1, B2 9V PP3 batteries (2 off). Aluminium box 4in × 2¾in × 1½in with lid
0·1in matrix Veroboard 2in × 1in. Veropins for 0·1in matrix Veroboard (12). 6BA bolts (½in), nuts and washers ⅜in or ½in. Terry clips (2) PP3 battery connectors (2)



Rear view of the preamplifier front panel showing layout of components and position of circuit board

should not touch the board itself. It is then necessary to see if the board can be screwed into place by a 6 B.A. bolt passing through the appropriate hole in the lid into the pillar; check that the box will still fit inside the lid, and if necessary desolder and re-position the pillar. This pillar also earths the case.

Once the circuit board has been mounted the components may be wired up as in Fig. 3.

TESTING

When the wiring has been completed and checked the batteries may be inserted. If a milliammeter is available, it may be connected in series with B1. When the circuit is switched on it should read about 1mA (ensure that S3 is out when measuring this). The amplifier can be tested using a signal generator or other signal source and an oscilloscope, power amplifier or crystal earpiece.

USING THE AMPLIFIER

This preamplifier has many uses in the workshop. As an audio preamplifier when a power amplifier has insufficient sensitivity or an input impedance too low for the signal source, as an audio signal tracer (using a crystal earpiece or a small power amplifier), as an i.f. signal tracer (using a detector diode at the output) or as a general purpose oscilloscope pre-amplifier.

In normal use a screened input lead should be used to prevent feedback or hum pick-up, this is not always necessary when the amplifier is fed from a low impedance source.

It should be noted that a very low frequency damped oscillation occurs for several seconds after S3 is closed. Closing S3 gives the amplifier a very high input resistance due to the bootstrapping effect on R1; this may be several hundred megohms when a low gain is being used. However, since the 12 megohm input impedance obtained when S3 is out is usually quite sufficient, some constructors may prefer to omit this facility.

Due to the low current drain the batteries should give several months of operation. The use of silicon planar transistors should make this unit very reliable. ★

BOOK REVIEWS

HANDBOOK OF I.C. CIRCUIT PROJECTS

By Jim Ashe
Published by Tab Books
224 pages, 5½in × 8½in. Price $4·95 paperback, $7·95 hardbound

Apart from the very obvious disadvantage over American sourcing and prices, this book forms a useful addition to the shelves where one is comparatively new to work with integrated circuits.

Indeed, the fast reducing prices of i.c.s makes some sort of volume of this type almost mandatory for the experimenter.

The current book deals with the subject from start to finish taking the reader through the basics of i.c.s and their handling and then gently introduces him to various projects. These range from audio equipment through various "novelty" items such as touch-plates to instrumentation and security devices.

Readers of all conversions are catered for from the scientist to the Ham and indeed the author has taken the precaution of supplying a good deal of additional data on specific components, the sources of these and of data and so on. It is unfortunate that much of the source data is not valid here but most readers will be able to find products in the columns of Practical Electronics.

R.D.R.

UNDERSTANDING ELECTRONIC CIRCUITS

By Ian R. Sinclair
Published by Fountain Press M.A.P. Book Division
205 pages, 8½in × 5½in. Price £3·50

Like Ian Sinclair's earlier book "Understanding Electronic Components", this volume is directed to the reader with some basic understanding of electronics, certainly to the extent of the properties of electronic components and the elementary laws of electrical circuits.

The author has directed his attention to the enthusiast who wishes to extend his understanding of the subject as well as to the undergraduate who wishes a wider understanding of electronics in an overall sense.

It should perhaps be emphasised that this volume does not set out to tell the reader how to construct something so much as how many of the circuits he will meet in electronics actually operate.

R.D.R.

POINTS ARISING

PUSHBUTTON VARICAP STEREO TUNER
(May 1973)

Some constructors have experienced oscillation of the voltage regulator i.c. This may be cured by placing a 0·1μF capacitor in parallel with C13. Also some constructors have reported hum picked up by the tuner. This may be cured by increasing C1 from 0·1μF to 1·5μF or 2μF.

NEW DEVICES ...APPLICATIONS

A Schmitt Trigger With Variable Hysteresis

As materials are evolved so new devices appear on the market at prices the experimenter can afford. In addition, existing devices come under scrutiny and are adapted to more and more applications.

In this section we present a selection of both new devices and applications, with news of applications developed for existing devices.

Generally only basic circuit details will be given sufficient for the experimenter to create his own equipment.

THE Schmitt trigger is a two-state device which changes state each time a given input voltage is exceeded. It is one of the most widely used building blocks in electronics today, serving as a pulse shaper, voltage level monitor and voltage controlled switch.

All Schmitt triggers exhibit hysteresis, that is the input voltage at which they trigger is higher than the voltage below which they return to their initial state after being triggered. A typical hysteresis curve is shown in solid lines in Fig. 1 (b).

The application of currently available logic circuitry to form Schmitt triggers has been investigated and one useful solution has been developed by Jim Halligan of Motorola. Using CMOS gates he has created a trigger which exhibits variable hysteresis. That is, in the curve of Fig. 1 (b) the voltage at which the trigger returns to the untriggered state can be varied.

First of all, the CMOS gate as a trigger. Fig. 1 (a) shows a Motorola MC14023 triple, three input, NAND gate from the CMOS family.

The voltage measurement function of the trigger is performed by gate *A*, the point at which triggering occurs being determined by the threshold voltage of this gate.

The regenerative switching function in which the trigger returns from the triggered to the untriggered state is provided by gates *B* and *C* which are cross-connected to form a simple bistable.

The threshold depends on the number of gate inputs which are driven, for example with a power supply V_{DD} at 15 volts if two inputs of a three-input gate are held high the threshold of the third gate is about 5 volts. With all three inputs driven in parallel the threshold is 8·5 volts.

Thus in Fig. 1 (a) gate *A* has a threshold of 8·5 volts and *B* a threshold of 5 volts when the output of gate *C* is high.

In addition, with V_{in} at 0 volts the outputs of gates *A* and *B* will be high and, due to bistable action, output of *C* will be low.

Increasing the value of V_{in} will have no direct effect on gate *B* as all its inputs must go high if it is to change state. The truth table in Table 1 shows the various operations of the gates.

When V_{in} reaches 8·5 volts the output of gate *A* will go low as all its inputs are driven in parallel. Thus the input of gate *C* is 11 from gate *B* and 0 from gate *A*. So the output of gate *C* goes high.

As a result gate *B* is presented with a 1 (the V_{in} above 8·5 volts) and 11 from gate *C*. Thus its output goes low.

Hysteresis is created because the gate *B* now has two inputs high from gate *C* and one which is driven by V_{in}. The threshold becomes 5 volts.

As V_{in} falls below 8·5 volts gate *A* output goes high but from Table 1 it can be seen that there will be no change elsewhere following this.

But, as the value of V_{in} falls below 5 volts the outputs of gate *B* goes high and that of *C* falls. Thus the circuit resumes its quiescent untriggered state. The transfer characteristics are shown in Fig. 1 (b) and the output waveform at 1 (c).

VARIATION OF TRIGGER

If one of the inputs of gate *A* is connected to V_{DD} the upper threshold is reduced as shown in dashed in Fig. 1 (b) to 7·5 volts.

The circuit of Fig. 1 (d) uses an MC14011 quad two-input CMOS gate to give true variation of the hysteresis. The value of the potentiometer is not too critical and allows the hysteresis to be set anywhere between 0 and 50 per cent V_{DD} by adjustment of the upper level.

A small value of potentiometer will increase current consumption and a larger one will cause the sensitivity of adjustment to suffer.

Prices of the components are:—14011, £0·52, 14023, £0·52, one off from distributors.

Table 1: NAND Gate Truth Table

Input	Output
000	1
001	1
010	1
011	1
100	1
101	1
110	1
111	0

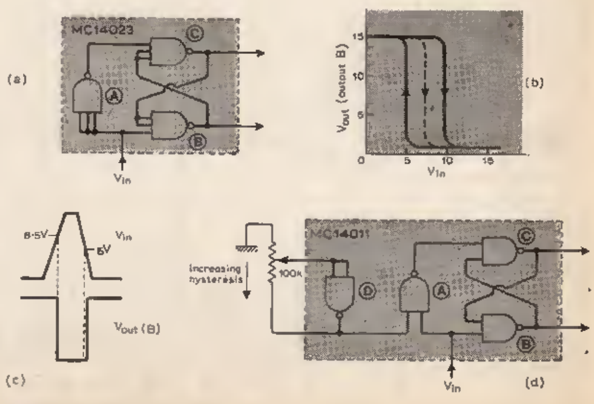


Fig. 1.

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AURORA
Multichannel Sound Controlled Light (PE Apr./Aug. 71). S/c's (excl. SCRs), Rs, Cs, Pots, Cores—8 ch. **£17·75**; 4 ch. **£10·15**. Reg. PSU **£3·65**. PCB—4 ch. control (4¾in × 10¾in) Mk. 2—also holds rotary or slider pots **£2·35**. PCB (4¾in × 5in) Mk. 2—for PSU, Sync Gen. 8 cores, 8 SCRs, **£1·35**. SCRs—1A, **50p**, 3A, **55p**.

HI-FI TAPE LINK
(PE Mar./Apr. 73). S/c's, i.c.'s, Rs, Cs, Relay and pc-base, Pot Cores and pc-bases, Sw's, Pots, Panel Lamp—Mono, **£11·80**; Stereo, **£18·70**. PSU, **£2·50**. PCB—Main Assy. (3¾in × 9in) (Stereo) also holds relay and cores, **£1·85**. PCB—Sub-Assy. (2½in × 6½in) (Stereo) holds Sw-assoc. Rs, Cs, Presets and mounts on Sw's, **80p**.

A.F. SIGNAL GENERATOR
(PE Nov. 72). S/c's, Rs, Cs, Pots, Sw's, PCB (2½in × 4in) also holds Sw's, **£3·15**.

AUDIO MIXER
(PE Jan. 72). Rs, Cs, Pots, PCB (1¾in × 2in) (i.c. excl.), **£1·55**.

DOOR BELL YODELLER
(PE Apr. 71). S/c's, Rs, Cs, Pots, PCB (3in × 3¾in), **£5·10**. T/fmr **£1·30**. L/spkr **£1·30**.

BIOLOGICAL AMPLIFIER
(PE Jan./Feb. 73). P/A Set—S/c's, i.c.'s, Rs, Cs, Pots, PCB (1½in × 3¾in), **£3·70**. O/P Stages (S/c's, Rs, Cs, Pots and Sw's as reqd.). Alphaphone **60p**, Cardiophone **75p**, Freq. Meter **£1·90**, Vis-Feedback **60p**. Audio Amp PC7 avail. to order **£4·75**.

ELECTRONIC PIANO
(PE Sep. 72/Jan. 73)—Details in lists

GEMINI STEREO AMPLIFIER
(PE Nov. 70/Mar. 71) Stereo Sets and PCBs. Pre-amp—S/c's **£1·85**. Rs, Cs, Pots, Maka-Sw's—with ¼W MO Rs, **£11·60**—with ½W CF Rs, **£9·35**—with ¼W CF Rs, **£8·90**. PCB (3½in × 10¾in) for sets with MO and ¼W Rs, also holds rotary or slider pots and Maka-Sw's, **£2·10**. Main Amp—Rs, Cs, Pots, **£5·40**. PCB (3½in × 5in), **£1·40**. PSU—Rs, Cs, Pot, **£3·70**. PCB (2in × 4in), **75p**.

LOGICAL RADIO CONTROL
(PE Apr./Jun. 72)—Details in lists

MODEL SERVO CONTROL
(PE Feb./Mar. 72)—Details in lists

GEMINI STEREO TUNER
(PE Apr./Jun. 72). Rs, Cs, Pot, **£3·80**. PCB as publ., **£1·80**.

MICROPHONE MIXER
(PE Apr. 69). S/c's, Rs, Cs, Pots, **£2·90**. PCB (3¾in × 4½in) also holds 6 rotary or 4 slider pots, **£1·20**.

8 WATT AMPLIFIER
(PW Nov./Dec. 72). Pre-amp—S/c's, Rs, Cs, Pots, Sw—Mono, **£2·50**; Stereo, **£5·20**. PCB (3½in × 7½in) (Stereo) also holds rotary or slider pots and Sw, **£1·50**. Main Amp—S/c's, Rs, Cs, Pot—Mono, **£3·90**; Stereo, **£7·70**. PCB (2½in × 3in) Mono), **60p**.

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REVERBERATION UNIT
(PW Nov./Dec. 72). S/c's, Rs, Cs, Slider Pots, T/fmr, **£6·80**. PCB (2in × 11½in) also holds sliders, **£1·20**. 9in Spring Unit avail. to order, **£3·75**.

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(PW Sept. 70). Incl. Mic P/A, 2-Guitar P/A, Trem and Tone Controls, Master Volume. S/c's, Rs, Cs, LDR, Rotary Pots, Lamp, Coupling T/fmr, **£7·75**. PSU, **£2·80**. PCB (3½in × 10¾in) Mk. 2, also holds 7 rotary or slider pots, **£2·30**.

ULTRASONIC TRANSMITTER-RECEIVER
(PE May 72). S/c's, Rs, Cs, Pot, Relay, Dual PCB (2in × 5½in), **£3·90**. T/ducers avail. to order, **£7·30** per pair.

ALSO
PCBs as published (while stocks last) for:
DIGICAL PSU (PE Aug. 72), **60p**
OSCILLOSCOPE P/A (PE Aug. 72), **40p**
SCORPIO (PE Nov./Dec. 71), **70p**
TRIFFID (PE Feb. 73), **60p**

AND
DIGITRONIC (PW Mar. 73). Read-out PCB (1½in × 3½in), **60p**.

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U.K. Orders only—add 10% to total cost of order.

TAPE NOISE LIMITER
(PE Feb. 72). S/c's, Rs, Cs, Pot, PCB (1½in × 3in), **£2·20**. Reg. PSU and PCB (1½in × 2½in), **£3·20**.

VERSATILE LIGHT EFFECTS UNIT
Single Channel Sound Controlled Light with built-in variable strobe. (PE June 72). S/c's, Rs, Cs, Pots, T/fmrs, Keyswitch, **£8·85**. PCB (3½in × 7½in) Mk. 2, also holds pots, Sw, T/T7 T/fmr, **£1·50**. SCRs—1A, **50p**, 3A, **55p**.

PHOTOPRINT PROCESS CONTROL
(PE Jan./Feb. 72). Finds exposures, controls timing, stabs. mains voltage. S/c's, SCR, LDR, Rs, Cs, Pots, Relay, Keyswitch, T/fmr, **£7·60**. PCB (3½in × 5½in) also holds pots, Sw, relay, **£1·20**.

SOUND SYNTHESISER
(PE Current Series)
Details of PCBs and Components in list. Free mailing list service available for further information about PCBs and Sets for this project.

LIST
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INGENUITY UNLIMITED

A selection of readers' suggested circuits. It should be emphasised that these designs have not been proven by us. They will at any rate stimulate further thought.
This is YOUR page and any idea published will be awarded payment according to its merits.

TAPE MOTOR CONTROLLER

The mechanical governor provided on a recently acquired portable tape recorder motor posed problems of electrical noise and mechanical wear. Thus it was decided to replace it with an electronic system to control motor speed both within a given speed setting as did the original governor and from speed to speed as is often achieved using different sized pulleys.

The circuit of the system is shown in Fig. 1 where current supply to the motor is controlled by TR3, itself controlled by the base voltage of TR1. A basic d.c. bias is applied to the base of TR1 from the Zener circuit and chain, R1, VR1/VR2. This sets the main motor speed.

Regulation of the speed about the selected value is supplied by detecting motor shaft speed using a pick-up coil and magnet assembly as shown in Fig. 2. The coil provides an a.c. voltage to D2 which thus gives a d.c. bias at the base of TR1. As the voltage fed back depends on the rotational speed of the motor speed control over a wide range is possible.

Under normal operating conditions the voltage from emitter follower TR1 appearing across R2 is about 2V. An increase in speed raises this value making D3 conduct through R3 and TR2 conducts heavily. This cuts the bias on TR3 to slow the motor.

Similarly, a decrease in motor speed reverses the process.

Supply voltages from 8 to 15V are acceptable and in addition to exhibiting good quick-start properties, the equipment provides almost twice motor voltage on full stall condition.

Colin Anderson,
Wanganui, New Zealand

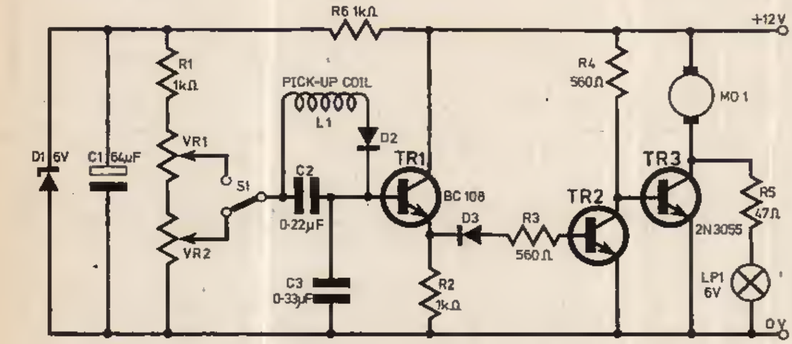


Fig. 1. **Circuit diagram for the tape motor controller**

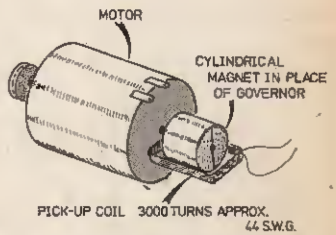


Fig. 2. Pick-up coil and magnet arrangement

I.C. LAMP FLASHER

The DTL integrated circuit type 9944 is a cheap dual buffer amplifier in one dual-in-line package and can be used to make a reliable, economical lamp flasher.

In the circuit, diagram Fig 1, the two amplifiers are cross-connected with capacitors C1 and C2, the values of which determine the frequency. The circuit becomes a multivibrator with the lamp LP1 in one collector.

Numbers in the circuit are the i.c. pin numbers. If C1 and C2 are 100µF (over 8V rating), a flashing rate of 30 per minute is obtained. Any 6V low current bulb may be used or the circuit could be used to operate a relay.

The Mullard equivalent i.c. is the DTL FCH 121, but the pin numbering is different. On this device, pins 1 and 8 are 6 and 8. Cross-connect pins 8 with 13 and pins 1 with 6, using the capacitors C1 and C2. Also pin 7 is +6V and pin 14 is ground (neg).

A. M. May,
Weybridge.

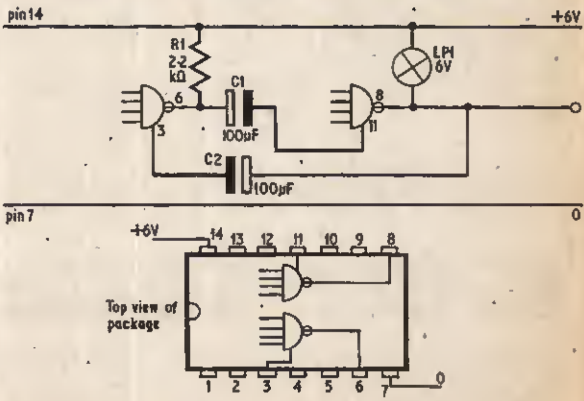


Fig. 1. Circuit diagram and i.c. connections for the simple flasher

WINDSCREEN WIPER CONTROL

THIS device, which can only be used with those windscreen wiper motors having a self-parking system since the system serves to turn-off the thyristor, can provide sweep delays of from 2 to 35 seconds.

The circuit is very simple, see Fig. 1, and uses few components. The original was constructed in a 35mm film can with switch S1 mounted on the variable resistor VR1. The control transistor is a UT46 or equivalent (2N2646) and the thyristor uses the can as a heatsink.

If the vehicle is negative earth with the windscreen wiper motor switched in the earth lead then the can may be earthed and only two leads are needed. One for positive supply and one for the positive supply to the wiper motor. As the thyristor is in parallel with the wiper motor polarity must be observed with care or triggering will not occur.

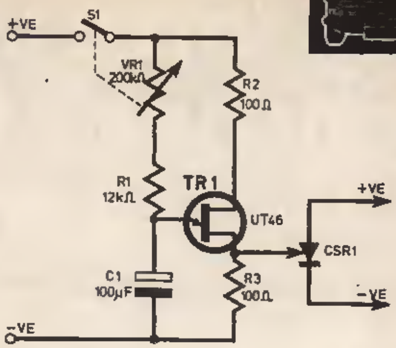


Fig. 1. Windscreen wiper delay circuit

The thyristor should be a high p.i.v. version, in the original a 7A 50V p.i.v. type was used.

C. M. Calver,
Melton Mowbray

ENGINE TEMPERATURE CONTROLLER

The circuit of Fig. 1 includes a stabiliser section, TR1, R1, R3, C1 and D1. This supplies power for the remainder which is basically a Wheatstone bridge circuit in which the thermistor TH1 forms one arm.

Balance of the bridge determines when the transistor TR2 cuts off. The vehicle fan is switched by RLA1.

For operation the normal "Temperature High" warning indicator is replaced with a thermistor. In practice the circuit is fail safe in that if TR2 goes open circuit for any reason then the fan is automatically switched on.

When the engine is cool the thermistor has a high resistance which puts TR2 in the ON condition. As temperature increases and resistance decreases the bias voltage across the transistor decreases until TR1 cuts OFF. The level of cut-off is determined by VR1. The value of R3 is determined by measuring the bridge circuit resistance and making R3 equal it. R1 may need adjusting if R3 is high.

Manual over-ride and a form of test facility may be provided by replacing the link by a switch.

If required a temperature indicator can be added as shown in Fig. 2. The voltmeter must have a high resistance with respect to R2. The 6 volt Zener is used to hold the zero down by 6 volts. In practice the "normal" temperature will probably show as about 1 volt.

R. K. Todd,
Albrighton

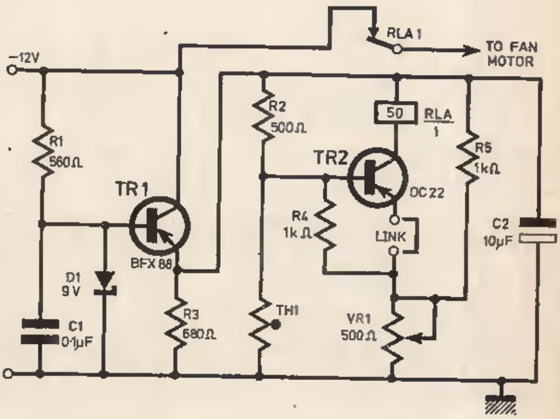


Fig. 1. Circuit for the temperature controller

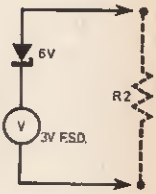


Fig. 2. Adding a temperature gauge

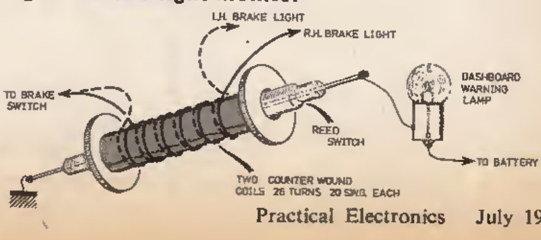
BRAKE LIGHT MONITOR

INDICATION of the state of the brake lights on a vehicle may be obtained without inserting extra lamp bulbs in the brake light circuit by using a reed switch actuated by a specially wound double coil to actuate a panel indicator lamp.

The circuit shown in Fig. 1 indicates the simplicity of the idea. Two coils serve to actuate the one reed but they are counter-wound so that as long as the pair of brake lights operate the reed remains quiescent. If one or other bulb fails then the reed is operated to give an indication at the dash board.

S. W. F. Morum
Chislehurst

Fig. 1. Brake light monitor



25 YEARS OF SEMICONDUCTORS

PART 1 TRANSISTORS AND SMALL-SIGNAL DIODES

By M. J. Rose (MULLARD LTD.)

THE FIRST transistor emerged from Bell Telephone Laboratories twenty-five years ago. Since then, the whole electronics industry has been transformed. Perhaps the most important change the transistor brought about was the introduction of new technologies of manufacture.

It is from the development of these technologies that the many types of present-day semiconductor device have come. These two articles present an overall, and necessarily brief, survey of these devices.

THE FIRST TRANSISTORS

In 1948 John Bardeen and Walter Brattain of Bell Telephone Laboratories invented the point-contact transistor.

The point-contact transistor had two fine wires placed close together on a semiconductor wafer. It was shown that not only was the current flowing between one of the wires and the semiconductor wafer affected by the current between the other wire and the wafer, but under certain conditions amplification could be obtained.

Perhaps the most important result of the point-contact transistor was that it provided experimental verification of the previous theoretical work. It paved the way for the junction transistor, a much more practicable device, invented by William Shockley also of Bell Telephone Laboratories in 1950.

JUNCTION TRANSISTOR

The junction transistor is essentially a sandwich of *p*-type and *n*-type semiconductor material containing two *pn* junctions. The first transistors were literally sandwiches, being made by the alloy-junction method.

A simplified cross-section of an alloy-junction transistor is shown in Fig. 1. This method of manufacture is still used for some audio-frequency transistors today.

Restrictions in minimum base width achievable with this technology gave the early alloy-junction transistors a cut-off frequency of approximately 1MHz, although refinements of the manufacturing technique raised this to approximately 5MHz.

ALLOY-DIFFUSED AND MESA TRANSISTORS

Other types of transistor were developed during the 1950's to overcome the limitations of the alloy-junction type. One of these types was the alloy-diffused transistor. The base layer of the alloy-diffused transistor was very thin, giving a cut-off frequency of approximately 800MHz.

Another type of transistor was the mesa transistor, originally developed to improve the switching characteristics. Its construction is shown in Fig. 2. The mesa transistor could operate with switching waveforms with rise times in the region of 1μs.

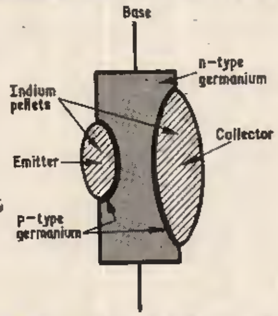
The technique of mesa etching is still used today in some types of transistor.

PLANAR TRANSISTORS

The introduction of the planar transistor in 1960 marked several important changes in transistor manufacture. Silicon rather than germanium was used as the semiconductor material with considerable advantages. Silicon transistors will withstand higher junction temperatures than germanium ones, and have higher voltage ratings and lower leakage currents.

Diffusion from vapour into clearly-defined areas of the silicon wafer enabled close control to be exercised, and the diffusion areas could be constructed by photographic techniques. For the first time in transistor manufacture, true mass-production techniques could be applied, with a consequent drop in price.

In the manufacture of silicon transistors an oxide layer is grown over a wafer of *n*-type silicon. Windows can be cut in this oxide by etching in areas defined by exposure through a mask, and *p*-type silicon formed by a boron diffusion. A second oxide layer is formed, selectively etched, and *n*-type silicon formed by a phosphorus diffusion. In this way a transistor is built up, as shown in Fig. 3.



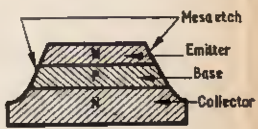


Fig. 1. Simplified cross-section of an alloy-junction transistor (left)

Fig. 2. Cross-section of mesa transistor (right)

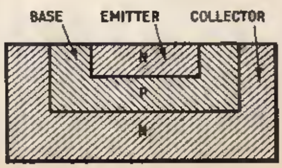


Fig. 3. Cross-section of planar transistor

Because the area of diffusion defined by a mask is the same for each transistor, the whole of a silicon wafer can be exposed at the same time. Thus up to 10,000 transistors can be manufactured on a silicon wafer 5cm in diameter in one manufacturing sequence.

Planar transistors can operate at frequencies up to the microwave region, well above 1GHz.

PLANAR EPITAXIAL TRANSISTORS

A development of the planar transistor that improves the performance is the planar epitaxial transistor. In this type, the transistor is formed in an epitaxial layer which is simply a layer of silicon with a near-perfect crystal structure. The silicon wafer on which the layer is grown forms a substrate as shown in Fig. 4.

By forming the epitaxial layer of high resistivity material but making the collector in the layer very thin, a transistor with high breakdown voltage and high collector current can be obtained.

FIELD-EFFECT TRANSISTORS

The transistors described so far are bipolar types, the current being conducted by two types of carriers (electrons and holes). The field-effect transistor (f.e.t.) is a unipolar transistor, the current being conducted by one type of carrier only.

A current-carrying channel of *n*-type silicon is surrounded by the *p*-type gate, as shown in Fig. 5. When a positive voltage is applied between drain and source, a current flows through the channel. A depletion layer is formed at the *p-n* junction of the gate and channel, and by applying a negative bias between the gate and source the depletion layer moves into the channel to restrict the area available for current flow. As the bias increases, a value is reached, the pinch-off voltage, at which no current flows. Thus the current through the f.e.t. can be controlled by the gate voltage, as in a triode valve.

The f.e.t. described is a junction f.e.t. or j.f.e.t. Another type can be constructed, the insulated-gate f.e.t., MOSFET or MOST. The initials MOS strictly speaking stand for Metal Oxide Semiconductor.

MOS refers to the construction of the transistor formed, a metal gate (aluminium or polysilicon) insulated from the silicon substrate by a layer of silicon oxide, as shown in Fig. 6.

By applying a voltage of the correct polarity to the gate, a current-carrying channel can be formed between the source and the drain, and when a voltage is applied across the source and the drain, a current flows.

The current-carrying channel in a *p*-type substrate is an *n*-type inversion layer. Similarly, a *p*-channel is formed in an *n*-type substrate. In addition, the *p*-channel and *n*-channels MOSTs can be enhancement or depletion types. Enhancement MOSTs are normally off, and require a gate voltage greater than the threshold voltage before conduction can occur. Depletion MOSTs are normally on, and require a pinch-off voltage on the gate to stop conduction.

Thus the circuit designer has four types of MOST to choose from for his application. All types of f.e.t. have very high input impedances, and so form a useful complement to bipolar transistors.

UNIJUNCTION TRANSISTOR

A unijunction transistor consists of a bar-shaped silicon slice with contacts either end and a *p-n* junction (the emitter) at some point along the length, see Fig. 7. It is therefore a three-terminal device but with only one junction.

With no emitter current flowing, the bar acts as a simple voltage divider with a fraction of the interbase voltage providing a reverse bias across the emitter junction. As the emitter voltage is increased, no appreciable current flows until the emitter voltage is greater than the reverse bias when there is a sudden increase in current. The unijunction transistor can therefore be used as a voltage-triggered device, in oscillators and sensors.

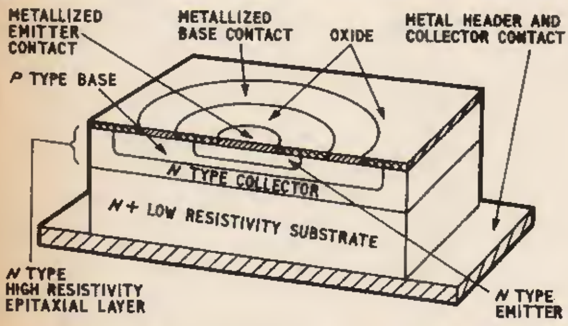


Fig. 4. Cross-section of planar epitaxial transistor

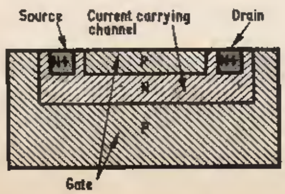


Fig. 5. Structure of junction FET

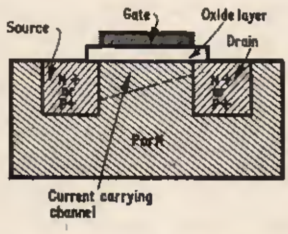


Fig. 6. Structure of MOSFET

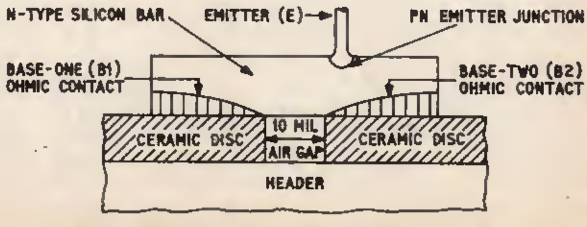


Fig. 7. Cross-section of a typical unijunction transistor

HIGHER POWER, HIGHER FREQUENCY

The development of the planar technology during the 1960's enabled the operating frequency of small-signal transistors to be raised so that by the end of the decade transistors with cut-off frequencies of 6GHz and capable of switching waveforms with rise times of 1ns were available.

Germanium power transistors could handle about 10W with a suitable heatsink. This power level was increased with the introduction of silicon power transistors. Today, silicon power transistors for low-frequency operation are manufactured by the single-diffused method, or, where high voltages are to be encountered (1kV or more), by the triple-diffused method. Powers of up to 150W typically can be handled.

The planar epitaxial technology enabled the operating frequency of power transistors to be raised considerably. More complex base-emitter configurations were developed to take operation high into the radio frequencies. A typical configuration is the interdigital one where fingers of the emitter layer interleave fingers of the base layer. Typical performance figures of present-day r.f. power transistors are 100W at 50MHz and 10W at 2GHz.

OTHER TYPES OF TRANSISTOR

The mexa transistor has an epitaxial base layer. The lightly-doped base is grown on a heavily-doped collector, the emitter layer diffused, and the complete structure mesa etched. The resulting transistor is rugged and has a low collector resistance.

Hometaxial transistors are made by simultaneously diffusing impurities on both sides of a homogeneous base layer, followed by a mesa etch of the emitter. Because of the homogeneous base, the risk of hot spots is reduced, and the transistor has good second-breakdown properties. The wide base width also gives good voltage breakdown properties.

Triple-diffused transistors are also manufactured in this way; the base and emitter are diffused on one side of the collector wafer as usual, but a third diffusion is used to form another collector layer. The technique can be used on planar or non-planar devices, and gives an improved value of collector saturation voltage.

SMALL-SIGNAL DIODES

The modern point-contact diode uses a germanium wafer to which a fine wire contact is welded. Because the current rating is very low (only a few milliamps) these diodes are only used for applications where junction diodes cannot be used efficiently, for example, as detector and mixer diodes at microwave frequencies.

Besides the low current rating, germanium point-contact diodes have a low inverse voltage and a high reverse current. These disadvantages were overcome by the introduction of the silicon junction diode in the mid-1950s. The junctions were made first by alloying with aluminium pellets, and later by diffusion. With the introduction of the planar technology, planar epitaxial diodes became available.

The limit of operating speed is set by the lifetime of the minority carriers formed by the reverse voltage. Gold doping reduces the lifetime of minority carriers in silicon, and by using silicon diodes with small junction areas and gold doping, recovery times of less than 5ns are obtained, making the diodes suitable for use in high speed computers.

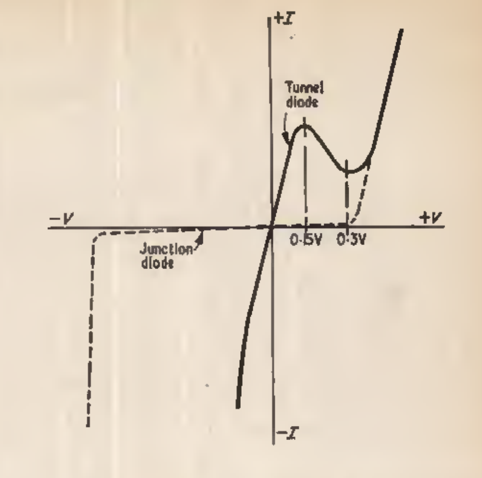


Fig. 8. Voltage/current characteristic of tunnel diode compared with junction diode

Faster switching diodes can be made by using gallium arsenide instead of silicon as the semiconductor material.

"ZENER" DIODES

As the reverse voltage across a junction diode is increased, a point is reached where the small leakage currently suddenly increases. This "breakdown" may be caused by electrons breaking from their bonds (the Zener effect), or more usually by avalanche breakdown.

In this type of breakdown, the electron minority carriers gain sufficient velocity to dislodge other electrons which in turn are accelerated sufficiently to dislodge further electrons. There is therefore a sudden build-up of current, and this may destroy the diode.

If the breakdown can be controlled, however, a useful range of devices, generally called (incorrectly) Zener diodes but more accurately voltage regulator diodes, is obtained. The value of breakdown voltage is determined by the doping level of the impurities in the diode.

Voltage regulator diodes are incorporated into supply lines to provide a simple method of stabilisation. Special types with very low temperature coefficients are called voltage reference diodes, and provide a simple form of voltage standard. If the voltage regulator diode is made rugged enough to withstand the dissipation, then it can be used to suppress voltage transient surges. Such range suppression diodes can withstand surges as high as 10kV provided the duration is only a few microseconds.

TUNNEL DIODES AND VARACTOR DIODES

Two types of diode use the properties of *pn* junctions to give special characteristics. The tunnel diode uses a normal *pn* junction in which both regions are heavily doped. With a reverse bias such a large number of electrons are present at the junction that some "tunnel" their way across the junction. Similarly, with a small forward bias below that required for conduction in a normal diode, tunnelling occurs. The forward tunnel current reaches a peak at approximately 0·15V, then decreases until normal forward conduction occurs at approximately 0·3V.

The V/I characteristic of a tunnel diode is shown by the full line in Fig. 8 with, for comparison, the characteristic of a normal diode in broken lines. The negative resistance part of the tunnel diode characteristic can be used in oscillators.

The varactor diode uses the capacitance of a reverse-biased *pn* junction. The reverse bias causes a depletion layer between the *p* and *n* regions, the width of the layer being proportional to the voltage. The junction area is made large to exploit this effect and to provide a reasonable change in capacitance with voltage.

Varactor diodes can be used as tuning elements to replace such devices as the parallel-plate tuning capacitor. They also have application as frequency multipliers. A string of varactor diodes and tuned circuits can be used to generate power efficiently at microwave frequencies from a lower-frequency source.

MICROWAVE DIODES

Some types of diode have properties that make them especially useful at microwave frequencies. Such types are the backward diode, PIN diode, Schottky barrier diode, and Gunn diode.

The backward diode, as the name implies, is a reverse-biased junction diode but one in which the breakdown voltage occurs very near the zero voltage point. Thus the resistance with reverse bias is lower than the forward resistance. Backward diodes can therefore be used as microwave detectors.

The PIN diode is also a *pn* junction but with a layer of intrinsic silicon between the *p* and *n* regions. With a forward bias, the PIN diode presents a low resistance because the bias injects carriers into the intrinsic region. With a reverse bias, however, the resistance remains very high. The PIN diode can therefore be used as a detector and also as a switch.

The Schottky barrier diode uses a metal-semiconductor junction as the rectifying element. Like the point-contact diode, the Schottky diode has the advantage of not suffering from minority carrier storage effects that limit the performance of junction diodes. Thus Schottky diodes can be used for higher-frequency applications, and also for very fast switching.

GUNN DIODE

The Gunn diode is not, strictly, a diode at all as it does not contain a rectifying element. It is formed by a thin layer of *n*-type gallium arsenide grown on a gallium arsenide substrate. The substrate forms the "anode" of the Gunn diode, while a "cathode" contact is formed on the face of the *n*-type layer.

When a low d.c. voltage is applied across the diode, high field regions called domains are formed at the cathode and rapidly cross to the anode. Current pulses are superimposed on the steady current through the diode, the frequency of the pulses depending on the transit time and therefore the thickness of the layer. For a thickness of 10μm, the frequency is 10GHz.

The Gunn diode can be mounted in a tuned cavity to form a simple microwave oscillator with advantages in space and cost over such devices as klystrons. Maximum output powers up to 3W can be obtained from Gunn diode oscillators.

The second article will describe power devices, photo devices, and integrated circuits.

PHYSICS EXHIBITION

It is interesting to see that, in the issue in which PRACTICAL ELECTRONICS publishes an article on an "Electronic Nose", we are also able to describe an electronic alcohol meter which will probably replace the so-called Breathalyser in drinking-and-driving cases and prove useful in many fields of research.

BREATHALYSER?

The Alcolmeter, as the latter is called, is an electronic instrument capable of indicating the presence and concentration of certain chemicals in air. It was on show at the Physics Exhibition, Earls Court, in April together with several other interesting items which show the steady movement of electronics into the important field of measurement and control.

The Alcolmeter uses a "fuel cell" developed to detect only alcohol unlike the one used in the P.E. Electronic Nose, which is capable of much wider application. In operation the Alcolmeter cell gives an output in millivolts dependent on the alcohol content of air drawn into a cell chamber by a small single-stroke pump. This is amplified and applied to a meter calibrated in milligrams of alcohol per 100 millilitre of blood. It is understood that accuracy is up to the requirements for normal police operation here so we can perhaps expect to see the instrument in use on the roads soon.

Of course, such an instrument has many applications in research and, using somewhat different cells, can be made to detect other types of chemical.

Light detection in the operation of power stations was well in hand on the CEGB stands with a demonstration of the Nordust smoke monitor, used to identify the presence of dust in smokestack gases. This instrument uses light scattered back to a photocell from dust particles in the airstream. Here electronics not only makes the operation possible in terms of sensitivity, as the amount of light available is very small, but also in terms of removal of anomalies due to cell variables by using balanced input operational amplifiers.

LOOKING AT FIRE

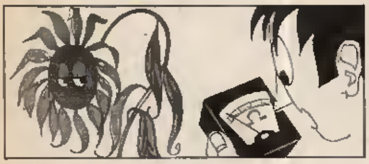
Similarly, it is only because electronic techniques such as correlation between two signals exists that the CEGB have been able to develop a flame monitor capable of identifying one flame in a furnace using perhaps 20 burners. This is effected by looking at the flame in question from two different directions, correlating the outputs of the viewing cells and indicating the amount of correlation present. Where there is a high percentage, say 80 or more, the flame is alight. Under any other conditions the amount of correlation is much lower. Such equipment can be used to initiate some form of "flame-out" warning.

On the signal generation front it looks as if there are some interesting developments afoot. The Royal Radar Establishment at Malvern have developed some devices called Surface Acoustic Wave Oscillators using an excess gain amplifier and a SAW delay line.

As both devices are very small and can be made using photoetching techniques, samples have been prepared capable of oscillation up to 490MHz as a fundamental frequency and mounted in a single TO8 can. It is envisaged that frequencies up to 1GHz are well within the bounds of possibility with this device. But first of all some problems over temperature variations have to be overcome.

Gerry Brown . . .

ON THE FRINGE



OHM NURSERIES

Gardening is not one of my personal predilections, although there are times when the subject manages to stir a glimmer of interest in me, as when, a few months ago, someone employed electronic means to accelerate crop-shedding (which you will, no doubt, recall) in orchards. Then there's the subject, requiring a lot more scrutiny (and perhaps something to which we shall return) called "Electrology" claiming an ability to reproduce whole outlines of leaves by previous photography of incomplete or damaged specimens!

However, the subject taking interest with a number of nurserymen in Canada right now is the result of some researches recently conducted by Professor D. S. Fenson and Dr G. Craig for their department of agriculture. Apparently, too much guesswork is associated with assessing the right time to lift plants for storage during the winter, following a hardening-off period in the autumn.

Measurement of the plants (in this case the strawberry) resistance, electrical that is, they have established a direct correlation with the fittest time to dig 'em up. This resistance changes (they don't say how) with the sudden drop in temperature immediately preceeding the winter, thus permitting early removal of the less hardy plants before frost damage can occur.—Do I hear an "ohm groan" from the non-gardeners?

GETTING THROUGH

Would you believe, communication-without-wires (apart from jungle drums, semaphore, and heliographs) was "old hat" before either Marconi, or, that great Russian, Popof, "invented" radio? Actually, it was about 1866; even prior to the invention of the electric lamp, that a dentist, one Mahlon Loomis, demonstarted a workable electric wire-less set-up over a distance exceeding 14 miles. Just how this worked is not terribly clear, but in essence it consisted of a pair of kites, one at each station, carrying some several hundred feet of wire "line". This, at the "transmitter" was grounded to earth, while at the "receiver" it was terminated to earth via a sensitive galvanometer.

The principle of operation seems to have been one which relied upon charged air currents and, presumably, a stiff breeze to boot. But credit where it is due, he *did* manage in some way (by, probably, making and breaking the transmitter earth connection) to interfere with the static charge in the vicinity of the wire and so influence the overall electrical equilibrium; sufficient, certainly, to be detected well over ten miles away.

Obviously, there must have been both considerable delays, and uncertainty about the reception (particularly for changes in wind direction and speed) but his idea at the time carried enough conviction for two fair sized companies to be formed; unfortunately, poor old Loomis died without ever fully realising his ambitions and with him too did the "atmospheric communicator".

RADIO VACUUM

You might be interested to hear that even today people are experimenting with methods foreign to normal transmission techniques to overcome the many disadvantages, to name poor penetration of the walls of buildings as a typical one. Just the other day I learnt that Dr Richard Arnold of Argonne National Laboratories in Illinois managed to achieve success with the transmission of a pulse-coded signal along a muon beam of all things! Since muons are atomic particles, detection consisted of a scintilation counter arrangement.

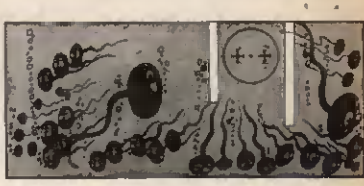
If this were not enough, my colleague, inspired by all this chat about particulate transmitters, assures me that once he has overcome the teething troubles with the bag size of the laboratory vacuum cleaner, he is entirely convinced that we will be able to announce the birth of the worlds first dust'n'soot scatter propagation system; what do you think?

NASTY TASTE?

Apart from the ferry, Gosport now seems to be in the position to capture our hearts with yet another singularly cunning piece of wizardry; a firm there has brought into being an electronic (more accurately, ionic) water de-bugging device.

Designed to clip into the supply pipe, it works on the principle that bacteria have a common dislike for silver ions, and comprises simply a pair of electrodes which cause ions to go into solution and rapidly interact with the bugs, "doing them in" very quickly. One of these units can comfortably handle as much as 250 litres of brackish aqua in a little over a minute or so.

Good news for campers, but what happens once it's in the gut, I wonder? Perhaps the stomach's hydrochloric acid converts it to the chloride which ought to be very harmful, except to your pocket; have you seen the price of silver recently?



QUESTION OF FITNESS

Probably because I'm a bit of an "odd-ball" anyway, the Editor and I sometimes have difficulty agreeing about the relevance of subject matter in this column to the field of electronics; and, since this magazine is one which sets out to deal fairly exclusively with the subject, it isn't unreasonable that he should expect there to be some link. But there's the problem. Just what is some link? And by exclusively, do we really mean restrictive?

Each time you buy your copy of P.E. have you ever wondered whether, sooner or later, the "crunch" might come when there will be literally nothing left to invent? Of course, there are the good old standbys like electronic doorbells, burglar alarms, and so forth, plus even more sophisticated ways of doing these same things in miniature. But what then?

In this inventing lark, for whatever the outlet, it seriously looks as if, to survive, we must look upon our particular subject in a less exclusive way. Indeed, to innovate in the real sense of the word must require us to never completely exclude any other discipline, just in case it turns out to be vital!

Once we (and, certainly, industry) accept this maxim, my prediction is that it will only be a matter of time before technology sees the "birth" of Interfacing Engineers capable of performing a sort of inter-disciplinary integration. Henceforth, instead of knowing an awful lot about a little, they will be in the unique position to discover myriads of, previously unheard of, applications from the suddenly limitless number of available permutations.

Let's drink to the daring, the real innovators, and to the possession of minds that never permit us the hollow excuse to be bored stiff!

PE Sound Synthesiser 6

TONE CONTROL & EXPERIMENTAL SOUND STUDIO

By G.D. Shaw

This month the Tone Control module will be described together with some notes on the setting up of an experimental sound studio.

HUTCHINSON TONE CONTROL

The tone control circuit used in the Synthesiser is based upon the design by P. B. Hutchinson which appeared in *Wireless World* (November 1970) and which, in turn, was inspired by R. Ambler's design for a "Tone Balance Control" which was published in the March 1970 issue of the same journal. A number of minor changes have been made to the original circuit in order to make it fully compatible with the circuitry in the Synthesiser but the frequency selective network, suggested by Hutchinson have been retained.

The type of tone control usually adopted for the majority of domestic equipments is that in which the greatest effect occurs at the extreme ends of the audio frequency spectrum while the mid-band frequencies remain relatively unchanged. The Baxandall and Siemens designs provide just such a characteristic. In recent years however there has been a tendency towards extending the scope of the tone controls in domestic equipment.

For purely domestic purposes there is no doubt that the ability to manipulate the frequencies over the whole of the audio frequency spectrum can make an enormous difference to the quality and effect of the ensuing sound. The Hutchinson tone control circuit combines many of the advantages of mid-band correction with relatively severe "end of range" effects all of which are extremely useful to the experimenter in sound.

TONE CONTROL RESPONSE CURVES

Fig. 6.1 shows a graphical representation (shown dashed) of the kind of effect obtainable by means of a conventional tone control circuit of the passive kind. Note that there is very little effect on the mid-range frequencies even when the treble and bass controls are adjusted to their maximum value positions.

On the other hand, the designed response of the Hutchinson circuit (shown solid) provides an overlap of bass and treble responses ranging from about 200Hz to 4kHz. The provision of separate boost and cut controls to both the bass and treble ranges therefore means that it is possible to tailor the overall characteristic of the curve to suit many particular applications. It is, for example, possible to build up tonal correction curves to compensate for deficiencies in sound transmission transducers such as pick-ups or loudspeakers.

The basic principle of operation is illustrated graphically in Figs. 6.2 and 6.3. Each potentiometer in the circuit controls the 3dB frequency of a curve having a slope of about 6–7dB/octave, the function of the potentiometers being in accordance with the direction of the slope. In Fig. 6.2 the dashed lines (1) represent the effect on the audio frequencies when all the controls are set flat. Since both the boost and cut selective networks are designed to have a fairly close match a similar result is obtained if all controls are set to their maximum positions.

With all the controls set flat, the effect of advancing any one of them is to bring the related slope further into the audio spectrum. The dotted line (2) shows the result of advancing the treble boost control about halfway. So far, of course, the resultant curve is similar to that obtainable from a conventional tone control circuit but if the treble cut control is now advanced from its flat position the effect is to reduce the

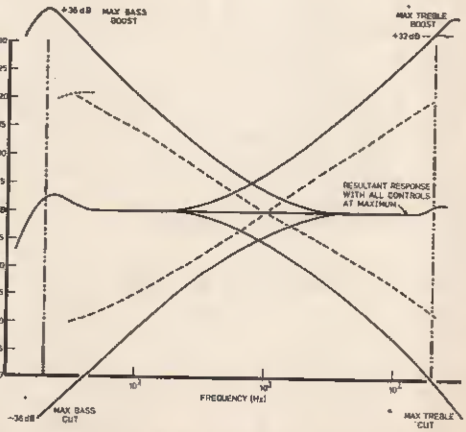


Fig. 6.1. A comparison of characteristic curves obtained from a conventional passive tone control (shown dashed) and those from the Hutchinson circuit (shown solid)

degree of boost to the upper frequencies without affecting the boost applied to the middle frequencies. This is shown as the overall resultant (4) by means of the solid line in Fig. 6.2.

An advantage of this form of control lies in the possibility of combining the effect of boost and cut settings from opposite ends of the spectrum to provide a resultant slope of up to 12–14dB/octave. A typical curve obtainable from such combination is shown in Fig. 6.3.

TONE CONTROL BASICS

The general form of the tone control circuit is shown schematically in Fig. 6.4, from which it will be seen that two frequency selective networks are employed. One lies directly in the signal path to the operational amplifier and acts as the cut network whilst the second lies in the amplifier feedback loop and acts as the boost network.

The design of each network is identical and is shown in Fig. 6.5. C1, R1 and VR1 form a simple first-order high pass filter with a slope of about −6dB/octave. The 3dB frequency is given by 1/CR where C is the value of C1 and R is the value of R1 in series with the value of VR1. With the component values shown the highest 3dB frequency is thus 1·54kHz and the lowest is 28Hz. C2, R2 and VR2 form a simple first-order low pass filter again with a slope of about —6dB/octave. In this case the highest 3dB frequency is 22·6kHz and the lowest is 415Hz.

The same network is able to provide boost characteristics since, in the feedback path of the operational amplifier, it reduces the a.c. feedback thereby increasing the gain of the amplifier.

Depending upon the settings of the potentiometers the input impedance of the frequency selective networks can vary between 470 ohms in parallel with 470 ohms at minimum and 25·5 kilohms in parallel with 25·2 kilohms at maximum. It is thus necessary to provide a driving source having an output impedance of less than 200 ohms.

Similarly, it is necessary to compensate for changes in output impedance of the tone control circuit by driving into a load of 50 kilohms or more.

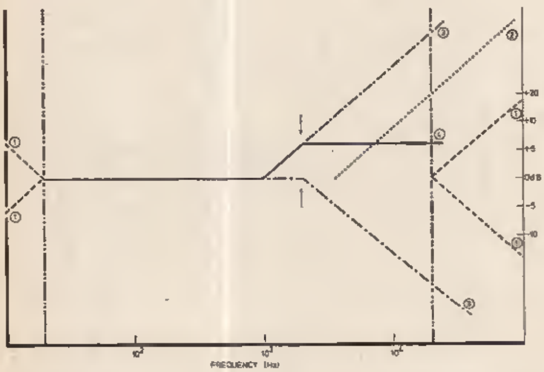


Fig. 6.2. Operation of the Hutchinson Tone Control circuit. Controls set flat ①, treble boost advanced—other controls flat ②, projected treble boost and cut with controls adjusted separately ③, resultant curve resulting from summing the boost and cut curves

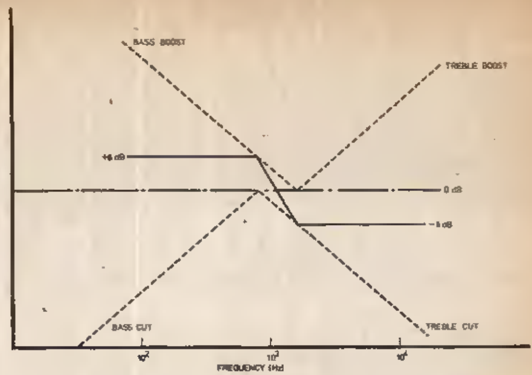


Fig. 6.3. Combining controls to give a 12dB/octave cut-off at mid-band. Dashed curves indicate responses when controls are used separately

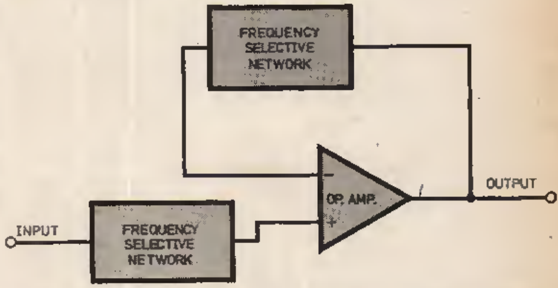


Fig. 6.4. Block diagram of Hutchinson Tone Control

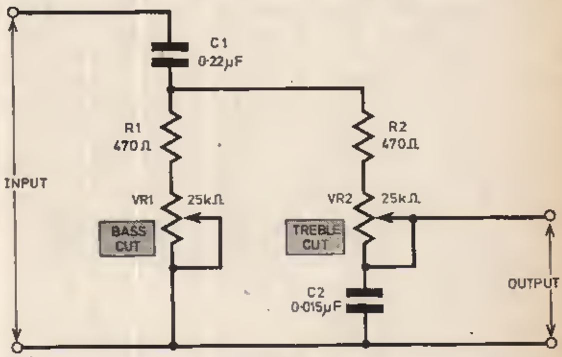


Fig. 6.5. Configuration of high pass and low pass filters used in Hutchinson Tone Control

THE COMPLETE CIRCUIT

The complete circuit of the Tone Control is shown in Fig. 6.6. TR1 is an emitter follower which provides a low impedance drive. R10 and R11 provide d.c. feedback to maintain the output of the amplifier at 0 V. Capacitor C6 decouples audio frequencies from the d.c. feedback loop and R12 provides a limit to this decoupling so that the a.c. closed-loop gain of the amplifier is limited to about +36dB. In the original circuit this was found necessary to avoid resonances at the extreme ends of the audio spectrum under conditions of maximum boost. The resonances were caused by interaction between the boost characteristic and the d.c. feedback loop at the bass end, and the high frequency compensation of the amplifier at the treble end.

TONE CONTROL MODULE

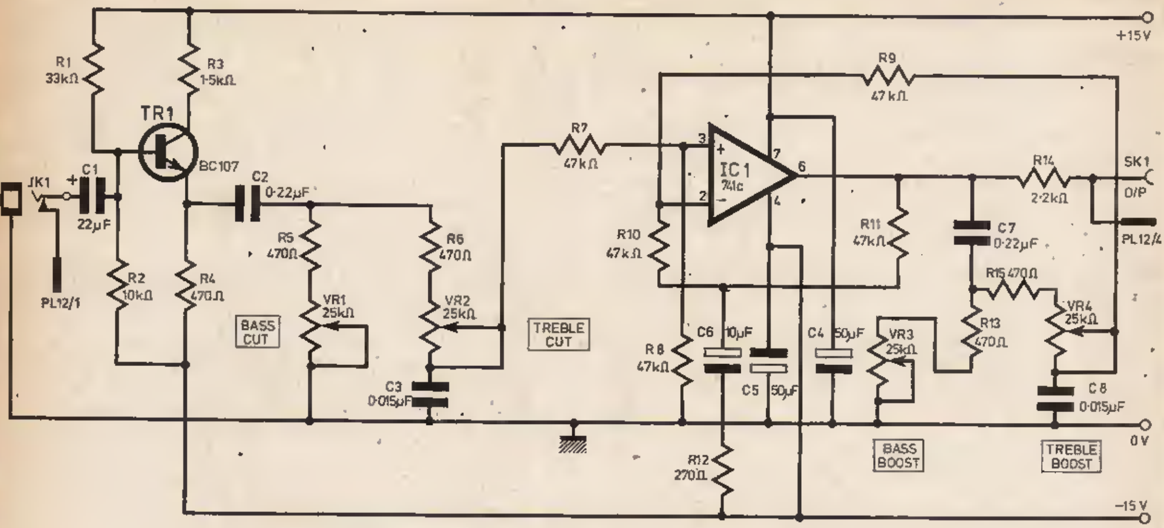


Fig. 6.6. Circuit diagram of the tone control

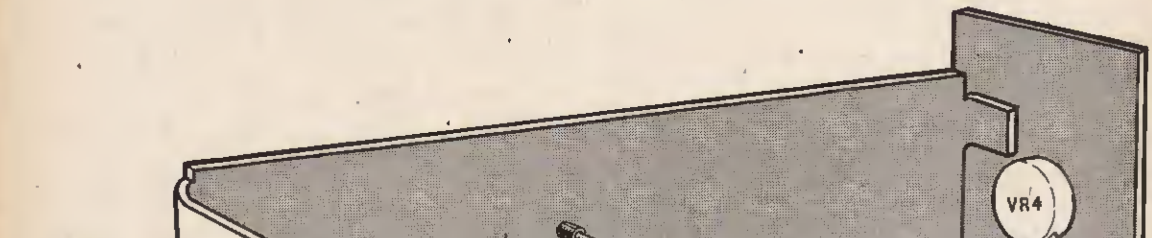


Fig. 6.7. Veroboard component assembly and wiring details for Tone Control module

The original circuit utilised a 709 operational amplifier as the active element and substitution of a 741 has resulted in the virtual elimination of high frequency resonance problems. However there is the possibility that low frequency resonance may remain under conditions of maximum bass boost although this can be tuned out by careful adjustment of the value of R12.

ASSEMBLY

Construction of the module should generally follow the pattern already outlined, that is, assembly and wiring of the front panel components followed by assembly of the module hardware and finally the wiring in of the circuit board.

Layout of the components on the circuit board is not too critical and the recommended circuit board layout is shown in Fig. 6.7.

Some care should be taken in wiring up the potentiometers since it is quite easy to wire these in the wrong way round and this will give rise to some very odd results during testing out the finished module. Fig. 6.7 also shows the component layout and wiring on the front panel and McMurdo plug.

TESTING

Testing the module covers only the establishment of performance characteristics at various points in the audio spectrum and it is recommended that a sine wave oscillator be used for this purpose. Starting with the oscillator at 20Hz the frequency should be advanced in multiples of 20Hz up, to and including 100Hz and thereafter in multiples of 200Hz up to 1,000Hz.

From 1,000Hz the frequency advance should be in steps of 2,000Hz. This procedure will give about 20 points on the graph and should be quite sufficient to establish the circuit characteristics.

COMPONENTS . . .

TONE CONTROL

Resistors

R1	33kΩ	R7–R11	47kΩ (5 off)
R2	10kΩ	R12	270Ω
R3	1·5kΩ	R13	470Ω
R4	470Ω	R14	2·2kΩ
R5–R6	470Ω (2 off)	R15	470Ω

All 2% ½ watt metal oxide

Capacitors

C1	22μF tantalum 16V
C2	0·22μF polyester
C3	0·015μF polystyrene
C4–C5	50μF elect. 25V (2 off)
C6	10μF elect. 25V
C7	0·22μF polyester
C8	0·015μF polystyrene

Integrated Circuit

IC1 741C 8pin d.i.l.

Transistor

TR1 BC107

Potentiometers

VR1–VR4 25kΩ linear min. moulded carbon (4 off)

Miscellaneous

JK1–3·5 mm jack socket, SK1—2 mm miniature socket, 0·1 matrix Veroboard

The measuring procedure should be repeated five times, the first being with all controls set flat and subsequent measurements with each of the individual boost and cut controls set to maximum in turn. If component values have been chosen as specified the resultant graph should bear a very close resemblance to that shown in Fig. 6.1.

There is little to be said concerning the actual usage of the module since, as with all tone control circuits, the position of the various controls will be dictated by a variety of circumstances not least of which is the individual constructor's preference. The little extra trouble involved in the manipulation of four controls is well rewarded by the greater versatility of the system in the provision of exactly the sound required. As a general guide to module usage there are two basic methods of operation.

Tonal correction curves are provided by setting both the boost and cut slopes to the middle of the audio spectrum and then moving one or the other out until the required effect has been achieved.

Simple boost or cut characteristics are obtained by setting all the slopes to the extreme ends of the audio spectrum and then moving the appropriate one in towards the middle until the desired effect is achieved. If only one control is manipulated in this latter case the resultant slope will, of course, be about 6dB/octave.

FORMING A STUDIO

In part four of this series the reader was introduced to the idea that the tape recorder was a very necessary adjunct to the Synthesiser if the full potential of the instrument were to be realised. This idea may be extended by considering the Synthesiser as the central focus around which may be constructed a simple yet versatile sound studio capable of providing a wide range of facilities to the keen experimenter. Thus, in addition to the tape recorder, there are a number of other items of so-called peripheral equipment which may be added to and usefully extend the versatility of the system. Fig. 6.8 illustrates one possible arrangement which utilises a fairly wide range of external apparatus.

In common with the basic concept of modular construction for the Synthesiser, the establishment of a studio may also be considered on the basis of a form of modular growth in which individual pieces of apparatus, including the Synthesiser, are treated as separate modules. In the Synthesiser itself all the modules plug into a bus-bar system which provides power supplies and signal paths for the interconnected, prewired modules. In a similar fashion the studio must have a central signal routing system and this is provided by what is known as the main patch. The power supplies for the studio apparatus are not, however, routed via the main patch, and the provision of a power supply distribution system will be dealt with later in these notes.

THE MAIN PATCH

The main patch in any studio is thus a very important piece of apparatus. Ideally it should provide a rapid means of interconnecting the signal pathways of all the apparatus incorporated in the studio in virtually every possible configuration and do so with a minimum of noise and crosstalk addition.

There are a number of possibilities for the construction of the main patch, the actual method adopted depending largely upon the means and inclination of individual constructors. It is worthwhile stressing,

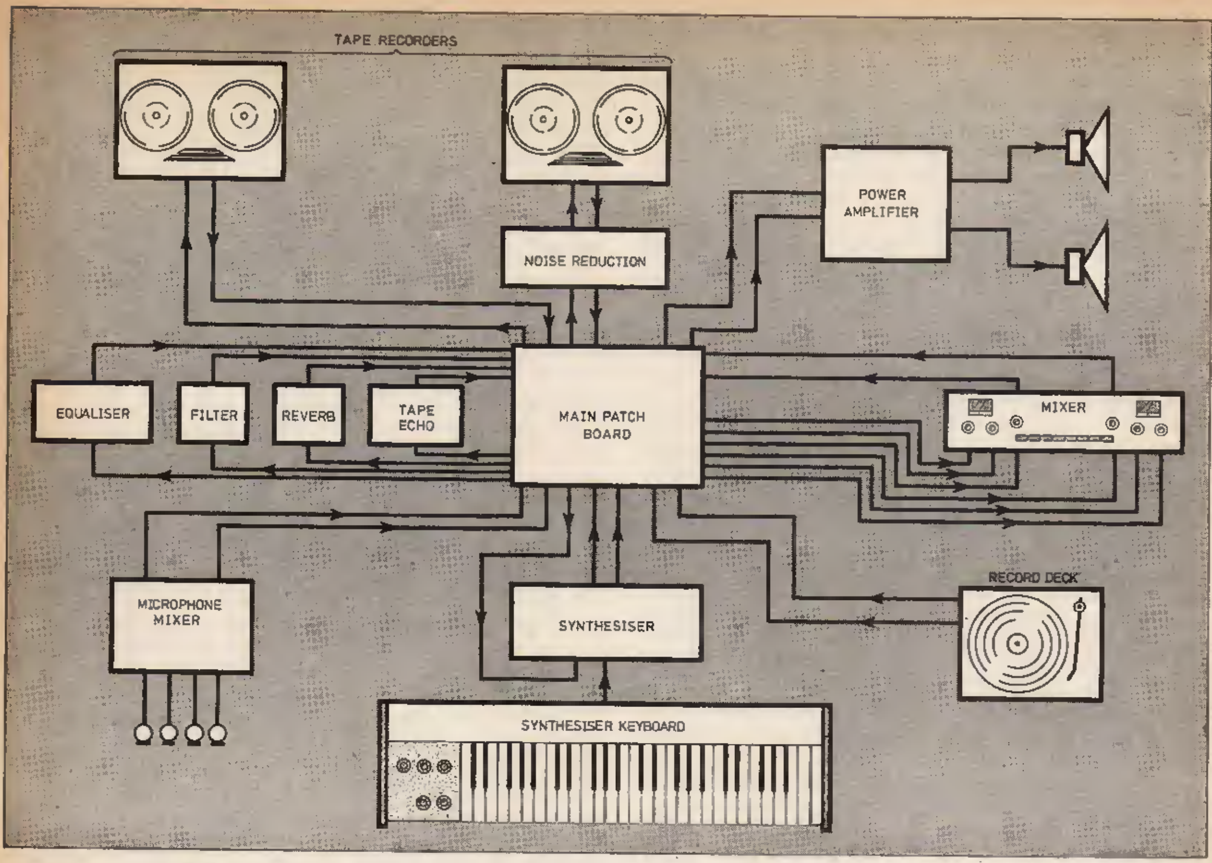


Fig. 6.8. One possible arrangement of apparatus to form an experimental sound studio

however, that a little extra quality in components chosen and effort expended in construction will be amply repaid in terms of reduction in the problems associated with poor contact assemblies.

One method of construction involving very little effort on the part of the constructor lies in the employment of ready-built patching matrices such as those manufactured by Sealectro Ltd. Matrices of a similar type are supplied "built-in" in a number of commercially available synthesisers and have proved to be quite successful in this application. The adoption of a ready-built matrix has the advantage that the patch can be assembled very quickly. In addition, the space taken by the patch is very small indeed although this could perhaps be something of a disadvantage if the screened signal cables for connection to the matrix are of any size at all. Another idea for the construction of a patching system is the use of 3·5mm jack sockets arranged generally as shown in Fig. 6.9. It is important to note that the type of jack sockets employed should be of the open-circuit variety.

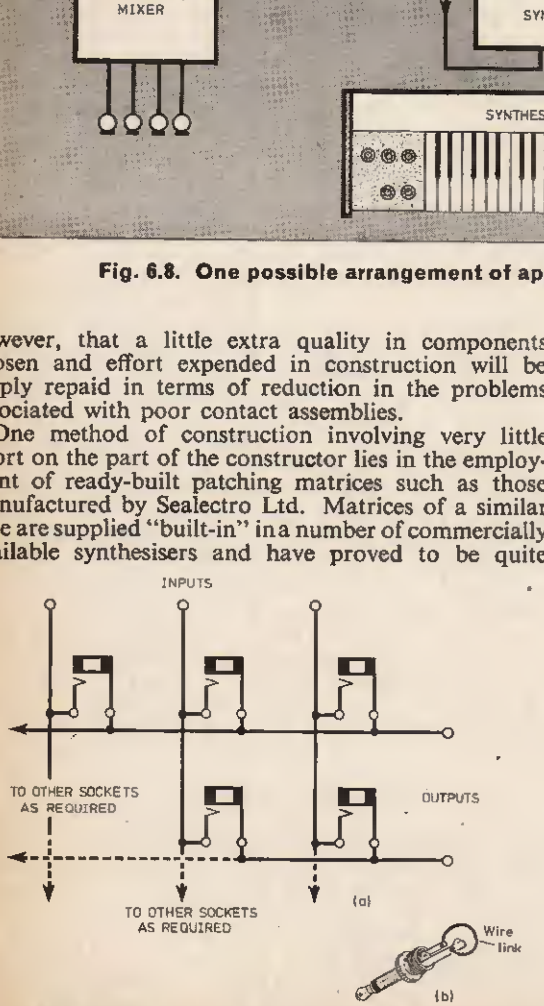


Fig. 6.9. Arrangement of jack sockets to form a patch board

The type of main patch employed in professional circles frequently makes use of a system based upon standard G.P.O. type jacks. Although rather larger than either of the other possibilities mentioned the greater contact area and general robustness of the components involved makes this latter system worthy of consideration if any serious work of high quality is envisaged. In terms of cost the system is not significantly more expensive than those previously mentioned.

OVERCOMING HUM

Perhaps one of the greatest problems associated with the interconnection of a range of apparatus lies in the formation of ground or hum loops within the system. In some circumstances the source of the hum can be quite difficult to trace and it is therefore worthwhile expending a little time in establishing a system which eliminates, from the outset, as many sources of hum as possible.

By far the greatest source of hum lies in the formation of loops through the earthing system of mains powered apparatus. The frequency of the hum can vary between 50Hz and 120Hz depending upon the mains frequency and type of rectification employed. Until quite recently the majority of mains powered apparatus employed the live chassis method of construction in which the signal ground was common with the mains earth. This type of apparatus provides the greatest hazard as far as the formation of hum loops is concerned.

COMMON POINT EARTH

Connection of a number of pieces of mains powered apparatus into the main patch may be accomplished as shown schematically in Fig. 6.10. In this case power supplies are distributed from a panel which has one common earth to the mains. Screened signal cables are used where the screen is disconnected at one end of the cable only. Thus the connections at the main patch are made on high signal levels only while the circuit is completed through the common earth in the power distribution panel.

Although these latter remarks apply particularly to apparatus in which live chassis contruction has been employed, a similar form of interconnection may be employed with apparatus which has a fully floating signal ground, i.e. there is no electrical connection between the signal ground and the mains earth.

In circumstances where *all* the apparatus involved is of this latter form of construction it is necessary to provide a common ground return on all signal lines and this is best done by connecting the screens of all signal cables to a common point at the main patch. This latter point is left floating except in the case where mixed types of apparatus are being used and, in these circumstances, the signal cable screens of apparatus with floating outputs only are commoned at the main patch and this point then returned direct to mains earth.

CHOOSING THE RIGHT CABLE

A second prime source of hum lies in the type of cable used to route signals and its relationship to the impedance of the inputs to which it is connected. It is best to choose a signal cable which is compatible with both low and high signal level inputs and thus one should steer clear of the majority of commercially available so called miniature signal cables which are prewired to a range of plugs and sockets. Unfortunately many of these, whilst perfectly suitable for the transmission of relatively high level signals into high impedance loads, are quite unsuited to low impedance networks due to the relatively high impedance and core/screen capacitance of the cable itself.

A signal cable which should prove suitable for most purposes in the studio will have a nominal impedance of about 50 ohms and a core screen capacitance of not more than 100 picofarads/metre.

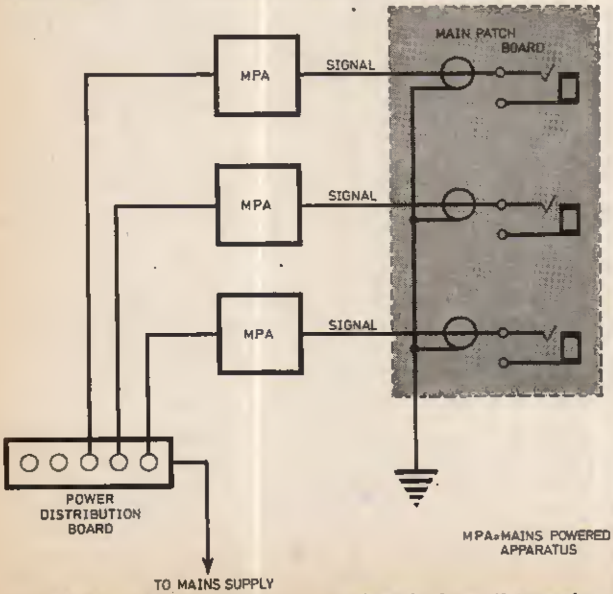


Fig. 6.10. Connections of peripherals into the main patch

CHOICE OF PERIPHERALS

Referring again to Fig. 6.8 the choice of peripherals for the Synthesiser must rest primarily with the individual, the only limiting factor being the compatibility of one unit with another. Although all the equipment shown is available commercially in several different forms a large proportion of it could be constructed at home with the aid of designs published. For example the Synthesiser Reverberation Amplifier (to be published next month) can be employed, without modification, to drive the spring line unit type HR162 available from Henry's Radio Ltd. Commercially available reverberation units include those manufactured by Eagle, Grampian and Sansui ranging in price from about £20 to £70 and offering a variety of facilities.

The choice of mixers is legion and can range from the four channel T.T.C.–B2005 distributed by Adastra at about £4 to the four channel Unimixer by Soundex at prices from about £90. Again, however, the constructor may opt to build his own mixer from a range of published designs.

The choice of filter units is rather more restricted for domestic users but for those with about £200 to spend the Levers-Rich A501 offers full audio spectrum equalisation in seven bands.

THE TAPE RECORDER

As with the case of the mixers, the choice of tape recorder is extremely wide but can be narrowed down by application of a list of specific requirements which are desirable although not absolutely mandatory. In professional circles the production of a Synthesiser recording may entail a mix-down from perhaps as many as twenty-four discrete tracks. In these circumstances the final master tape will have been involved in only one tape to tape transfer and consequently the recorded sound is likely to have suffered only the very slightest loss in quality.

If the amateur attempts to simulate these professional methods (in terms of tracks involved) with the equipment normally available to him there may be as many as fifteen to twenty tape transfers involved in a very complex recording. Thus the quality of sound on the tapes involved in a number of transfers is likely to be much reduced in comparison with the original. This factor alone provides the first and foremost requirement of any tape recorder to be used for creative work and that is quality.

In general terms the purchaser should invest in a machine which offers the best possible specification coupled with a minimum number of features designed to ease the problems entailed in the production of good quality recordings. These may be summarised as follows.

SPECIFICATION AND MACHINES

Three speed machines are preferable with 38cm/sec: 19cm/sec and 9·5cm/sec providing the ideal. Speeds below 9·5cm/sec are unlikely to be very useful. Three or four heads with provision for "on" and "off" tape monitoring. Stereo quarter track machines having sound-with-sound facilities, ideally through the medium of an input mixer, provide the minimum facilities for just about the only form of multitracking available to the average amateur.

There are a number of tape recorders on the market which combine an excellent technical specification with the features listed above. Amongst these are: Akai 1720L and GX220D; Beocord 1600; Ferrograph 702 and 704; Philips N4418 and N4450; Pye 9137; Rovex Series 77 1104; Sony TC630 and TC270; Telefunken M204TS; Uher Royal de Luxe.

As far as sound-with-sound or track transfer is concerned most of the recorders listed employ slightly different methods of providing this facility involving the use of one or more switches and, in some cases, an external signal routing cable. In this respect the Philips N4450 is notable in that, after laying down the first recording, this may then be transferred back and forth between tracks, with or without the addition of further material, by the manipulation of a single switch. This latter recorder also incorporates facilities for the addition of echo/reverberation again at the throw of a switch.

DECK CONVERSION

Recorders offering the facility of more than two tracks, or four tracks if one includes the quadraphonic types that are beginning to make their appearance, would normally be expected to be priced out of the reach of most amateurs. The determined constructor, however, could do worse than consider the conversion of some of the computer decks which become available from time to time. Several of the capstan driven decks now available from about £40 are superbly engineered devices and suitable for conversion. The speed of computer decks is usually quite high but this need not necessarily be a disadvantage since it would be used for record and replay of its own material only.

Heads are available from a number of sources. Gresham, for example, manufacture an eight-track, half-inch head for record/replay purposes at a price of around £70–£80. For the purposes of erasing, economies can be made by stacking a number of stereo erase heads. The electronics for the recorder could be based on the Hi-Fi Tape Link (recently published in this magazine) or, alternatively, on the range of Motorola integrated circuits designed specifically for tape record/replay purposes.

OTHER ADDITIONS

The addition of a Dolby B noise reduction unit should be a prime consideration and for a studio system it is best to choose a discrete unit rather than have the system built-in to a recorder.

Other useful additions to the studio include a separate power amplifier with speakers for monitoring purposes and a suitable turntable unit. These latter items could generally be "borrowed" from the domestic Hi-Fi system as and when required.

Next Month: The Meter Unit; Voltage Controlled Reverberation Amplifier and Ring Modulator.

NEWS BRIEFS

Telephone Scrambler for Commercial Use

For businessmen who require absolute security in their communication, EMI have introduced a new electronic scrambler for use with both private and public telephone networks. Known as the Privateer it is suitable for a wide number of applications in business, commercial and industrial organisations.

Once a telephone call has been set up in the conventional manner the Privateer telephone is brought into operation simply by pressing a separate switch. Subsequent conversation is then electronically scrambled as it is transmitted to the telephone line, and only becomes intelligible when it is unscrambled by matching equipment at the receiving end.

Commercial Radio

Studio automation is expected to be a major feature in many of the radio stations forming Britain's new commercial network which will start broadcasting within the next 12 months. The trend is being set by London's general entertainment channel Capital Radio, which is aiming for equipment which can automatically select and play a high proportion of the station's daily programme output from material stored on magnetic tapes.

Negotiations are going ahead with EMI to supply equipment from their extensive range of Schafer radio automation systems.

Equipped with a solid-state memory, this system is able if required, to provide a full 24 hours of continuous broadcasts—the memory being programmed to select on a time or sequential basis pre-recorded "events", including entertainment, commercials, and station announcements, from its vast repertoire. Using a keyboard, an operator can insert a complete day's programme in the memory, building up the programme on a minute by minute basis if required.

Data Transmission

Many different kinds of information, from heartbeats to motorway hazards, can now be transmitted over Britain's public telephone network in a new communications service introduced by the Post Office on June 1.

During trials, the new Datel 400 service has already been used to send heartbeat readings from a small hospital to a large one a mile away, and information on river pollution has been sent to a Government laboratory. The latest development being studied at the moment is the sending of information on motorway hazards and weather conditions to a central monitoring point.

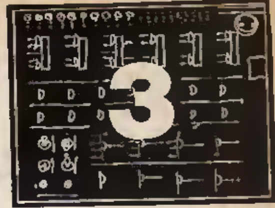
Golden Jubilee

In April the well-known components manufacturers, A. F. Bulgin & Co. Ltd., celebrated their 50th anniversary with an announcement of unbroken profit figures stretching back over the full 50 years to 1923 when Arthur Bulgin started the company on £100 capital.

It is perhaps indicative of the value of "service" that this organisation who hold as their aim to provide customers with a service through a family company, that they have managed to succeed so well in the face of growing and aggressive international competition.

At the celebrations Arthur Bulgin, managing director, presented three new members of the company's 25 Year Club with gold watches including Albert Ridpath, foreman of the injection moulding section, who becomes the 50th member of this club. Quite a record for a company started on £100 and still running as a family concern.

LOGIC TUTOR EXPERIMENTS..



NAND GATES

TO avoid having to make, and use, three different types of circuit (AND, OR and NOT gates) to provide logic functions; the modern logic designer uses exclusively NAND gates. By suitable arrangement of these it is possible to generate any logic function that is desired and this type of gate is to be used throughout this series.

NAND VARIANTS

A NAND gate is made by inverting after an AND; the simplest possible circuit is shown in detail in Fig. 3.1 and depicts a basic form of DTL (Diode Transistor Logic). The DTL used in the Logic Tutor is only a minor variant of this circuit; do not confuse this with the basic TTL (Transistor Transistor Logic) NAND gate—Fig. 3.2—which, although it carries out the same function, has entirely different input gating and output stages.

Though NAND is a compound of AND with NOT it is so commonly used that it is considered to be yet another fundamental gate and as such has a standard symbol of its own (Fig. 3.3.). It is possible to obtain 1, 2, 3, 4 and 6 input NAND gates as standards and certain DTL gates have facility for the number of inputs to be expanded by adding extra diodes at the expander node.

Select a two input NAND on the Logic Tutor and connect the inputs to two logic level switches monitoring the output level on one of the lamps. The output will be the inverse of AND as shown in the truth table ($Q = \overline{A \cdot B}$) which means that the output will always be level 1 until all the inputs are at level 1 and at that condition the output will fall to 0. Verify this for yourself and then do the same with a 4 input gate.

INVERT FROM NAND

We demonstrated INVERT last month, but now look at the truth table and Fig. 3.4 to see how this came about. Consider a gate with inputs A and B shorted together and the shorted node called X. If X is 1 both A and B will be 1—refer to the truth table and see that two ones on the input of a NAND give an output 0. If X is made 0 both A and B will be 0 and this is shown to give an output of 1. Thus whatever X is the output is the opposite—an INVERT or NOT function.

Another way of obtaining INVERT is to make input B permanently a level 1. Whatever A is, the output will be the opposite.

A point worth noting is that in all forms of current sinking logic (DTL and TTL) a floating input to a NAND gate will be presumed (by the gate) to be at level 1 however it is bad practice to leave spare inputs of a gate disconnected as they are liable to pick up stray signals and cause severe logic ambiguities.

AND FROM NAND

If the NAND function is obtained by inverting AND we can get back to AND by inverting again after a NAND gate as shown in Fig. 3.5. The output is $\overline{A \cdot B}$ inverted—the double negate cancels and we are left with simply A·B.

As an exercise try and simulate a six input AND using any of the NAND gates available on the Logic Tutor (expanders are not permitted!). We shall publish an answer next month and at the same time describe De Morgan's Theorem and show how to use this in conjunction with NAND logic to produce OR.

by M. Hughes

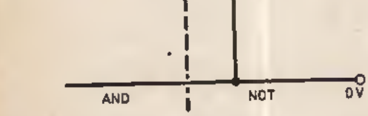


Fig. 3.1. Basic DTL NAND gate

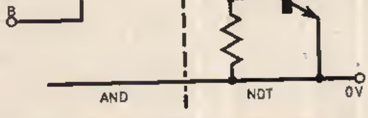


Fig. 3.2. Basic TTL NAND gate

A	B	A·B	$\overline{A \cdot B}$
0	0	0	1
1	0	0	1
0	1	0	1
1	1	1	0

These rows describe the normal inverting function (see text)

If B is permanently '1' the o/p is $\overline{A}$

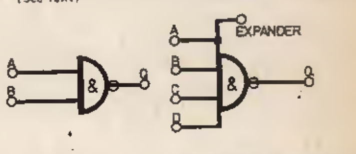


Fig. 3.3. Two forms of NAND gate together with a truth table

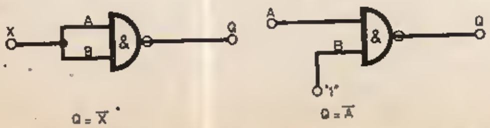


Fig. 3.4. Two ways of getting INVERT from NAND

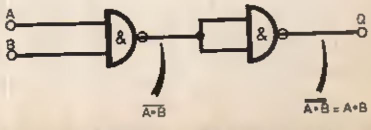
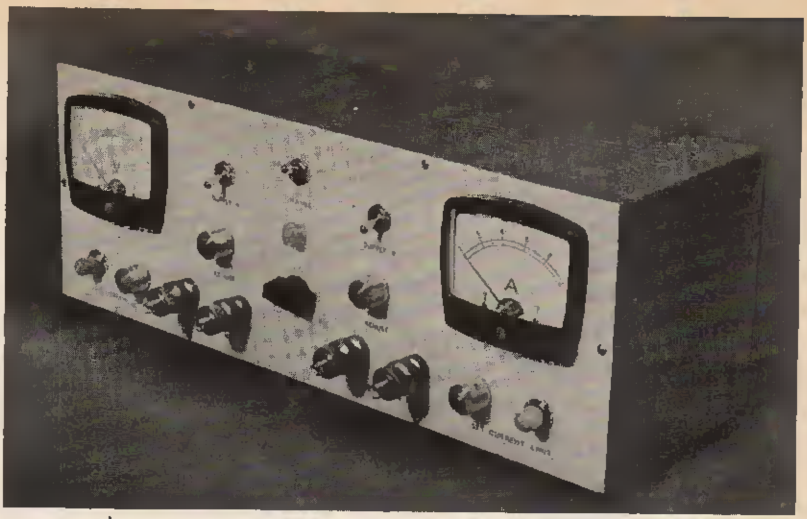


Fig. 3.5. The AND function from NAND gates



TWIN POWER SUPPLY

By G. S. SCHAJER

THE USE of integrated circuits has made it possible to make a high quality regulated supply incorporating a current limit facility using a surprisingly small number of components. Since the supplies are so simple and inexpensive, a twin power supply unit is a practical possibility, and is extremely useful especially in development work.

The current limit facility is one which is not found except in the most expensive power supply units, and it will be found to be extremely useful—sometimes in rather unexpected ways. Apart from its use as an overload protection and as a constant current source, the author has found it to be an excellent way of testing Zener diodes!

The current limit facility is nearly as accurate as the voltage regulator and, if required, the unit may be used as a constant current source.

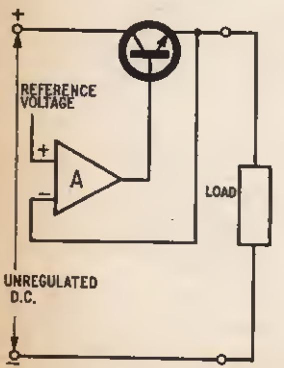


Fig. 1. The basic voltage regulator circuit

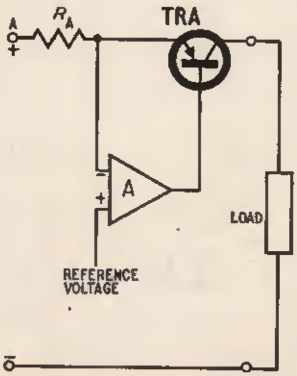


Fig. 2. The basic current limiting circuit

CIRCUIT DESCRIPTION

The integrated circuits used are the 741 operational amplifiers (op amps) which are cheap and readily available. The operational amplifier differs from the ordinary amplifier in as much as that it has two inputs, an inverting one (marked with a minus sign) and a non-inverting one (marked with a plus sign).

If there is a small difference between the voltages applied to these inputs, the output will change according to the magnitude and polarity of the difference. The op amp may therefore be used as a difference amplifier. This is the case in the circuit shown in Fig. 1, which shows a voltage follower circuit.

The output of the op amp is controlling a transistor in the supply rail of an unregulated supply. It is comparing a reference voltage and the output voltage and amplifying the difference. If the output voltage falls, the input to the transistor is increased, tending to restore the output to its original value. Similarly an increase in output will cause less current to the transistor base and thus decrease the output.

Since the op amp has a very high gain, the input need only change by a small amount for it to produce a substantial restorative action. The output thus follows the reference voltage with a high degree of accuracy.

CURRENT LIMITING

Fig. 2 shows a basic current limiting circuit. It functions in exactly the same way as the voltage regulator except that instead of the output voltage, the voltage drop across R_A (and thus the current) is compared with the reference.

The current at which the circuit limits is dependent on the reference voltage and the value of the resistor according to the relationship:

$$\text{Current limit} = \frac{\text{Reference Voltage}}{R_A}$$

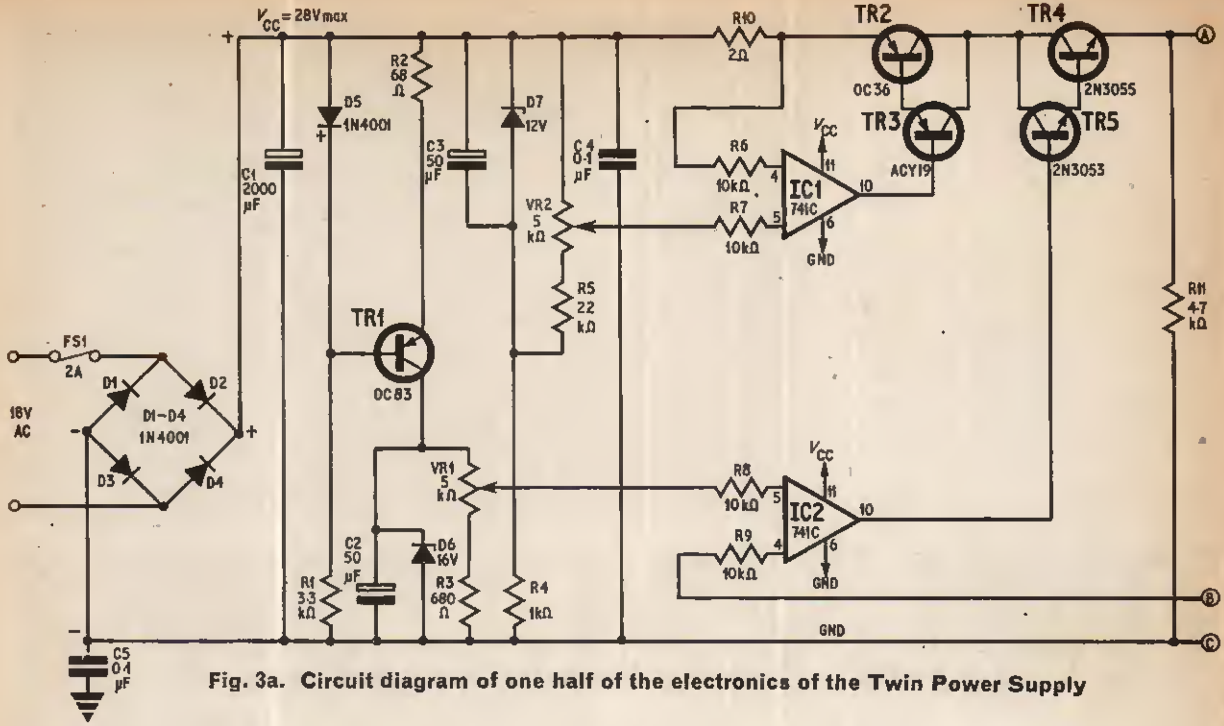


Fig. 3a. Circuit diagram of one half of the electronics of the Twin Power Supply

SPECIFICATION

Two identical supplies with complete isolation	
Fully variable output voltage	2 to 15V
Fully variable current limit	35mA to 1A
Ripple at 15V, 1A	0·4mV
Voltage regulation	0·1%

If the circuit is operated in the region of current limiting it makes a good constant current source. Its accuracy is nearly as good as that of the voltage follower. The slight deterioration is due to the thermal instability of the resistor.

FULL CIRCUIT DIAGRAM

The voltage follower and the current source may be used together as shown in the full circuit diagram, Fig. 3a. The reference voltages are made adjustable so that the output voltage and the current limit may be adjusted.

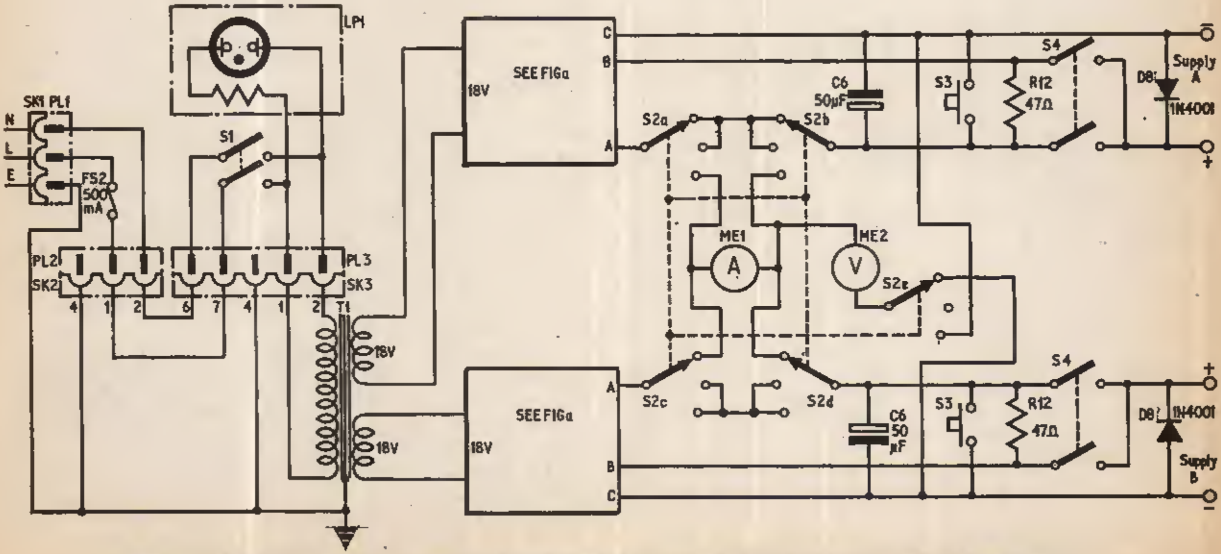


Fig. 3b. Mains input and switching arrangement for the complete Twin Power Supply

COMPONENTS . . .

Resistors

R1	3·3kΩ
R2	68Ω
R3	680Ω
R4	1kΩ
R5	22kΩ
R6–R9	10kΩ (4 off)
R10	2Ω 10W wirewound
R11	4·7kΩ
R12	47Ω

All ±10% ¼W carbon except R10

Potentiometers

VR1	5kΩ linear
VR2	5kΩ linear

Capacitors

C1	2,000μF 50V elect.
C2	50μF 25V elect.
C3	50μF 15V elect.
C4	0·1μF 250V polyester
C5	0·1μF 250V polyester
C6	50μF 25V elect.

Integrated Circuits

IC1, IC2 741C (2 off)

Transistors

TR1	OC83
TR2	OC36
TR3	ACY19
TR4	2N3055
TR5	2N3053

Diodes

D1–4	1N4001 (4 off) *or* 2A bridge rectifier
D5	1N4001
D6	16V 400mW Zener
D7	12V 400mW Zener
D8	1N4001

Switches

S1	D.P.D.T. mains toggle
S2	5 pole 3 way, make before break, rotary wafer
S3	Push to make release to break, pushbutton
S4	D.P.D.T. toggle

All the above components are for one half of the Twin Power Supply except S1 and S2, only one each of these being required

Miscellaneous

T1	Douglas MT127 0–24–30–40–48–60V 2A
ME1	1A f.s.d. 3in meter
ME2	20V f.s.d. 3in meter (or 15V if available)
PL1, SK1	Bulgin P360 mains plug and socket
PL2, SK2	B7G plug and socket
PL3, SK3	B7G plug and socket
LP1	Mains neon with integral resistor
FS1	2A fuse and holder (2 off)
FS2	500mA fuse and holder

Terminals (4 off)

0·15in matrix edge connectors and Veroboard (optional)

Case, plastic feet, paxolin panel, Veroboard, printed circuit board, power transistor insulating set (4 off)

A germanium transistor (TR1) biased by a silicon diode (D5) is used as a constant current source to feed a Zener diode (D6) thus giving a very stable reference voltage. Since the output voltage cannot be taken below 2V a resistor, R3, is connected in series with the potentiometer VR1 to make the minimum reference voltage also 2V.

The current limit reference Zener diode (D7) does not need similar stabilisation as it only operates when the load current is constant and hence the rail voltage is not changing. A maximum of 2V is required for this voltage and this is obtained from a 12V Zener (D7) and a resistor R5 in series with VR2 to produce the required voltage at the potentiometer wiper.

The outputs of the op amps do not run directly to the output transistors but via driver transistors in the super alpha pair configuration. This prevents overloading of the op amp output which can only supply 25mA. The 741 has indefinite short circuit protection which is comforting during testing.

Under extreme conditions one or other of the output transistors is dissipating nearly the full power input of the supply from the transformer, i.e. about 20W. The need for heatsinking is obvious and should be taken into account when deciding the output power required.

OUTPUT VOLTAGE MONITORING

The connection from the inverting input of IC2 is connected directly to S4 (Fig. 3b) so that the voltage drop in meters, switches and wiring does not affect the regulation of the supply. When S4 is closed the input to the op amp is connected to the output terminal and so any voltage drop across the switch due to contact resistance will similarly not affect the regulation.

When the switch is off the supply is disconnected from the output but the high impedance op amp input is still connected to the supply by R12. This enables the supply to operate so that the voltage and current limit may be set when S4 is off. The current limit set switch S3 is independent of S4.

A reverse biased diode D8 is connected across the output terminals to protect the supply from back e.m.f. when disconnecting a reactive load.

Resistor R11 is included so that the supply has a load in the absence of any external load. C6 protects against high frequency oscillation and C5 reduces mains borne interference.

THERMAL EFFECTS

The 2Ω resistor in the current limiting circuit should be a high wattage type to prevent excessive heating which causes resistance variations. A 10W type drifts by about five per cent which is reasonable; a higher wattage should be used for greater stability.

On the prototype the rail voltage off load was 28V. Under no circumstances should this voltage be exceeded by using a higher voltage transformer as this will damage the integrated circuit. On a 1A load the rail voltage drops to 21V.

Meters are provided to measure the voltage and current output of the two supplies. It is possible to switch them from one supply to the other, but without breaking the continuity of either supply, and yet maintaining the isolation between the supplies.

The circuit shows the switching arrangement required. A five pole, three way, make before break switch is used. The centre position is "off". A make-before-break switch is essential, otherwise there will be a break in continuity during switching.

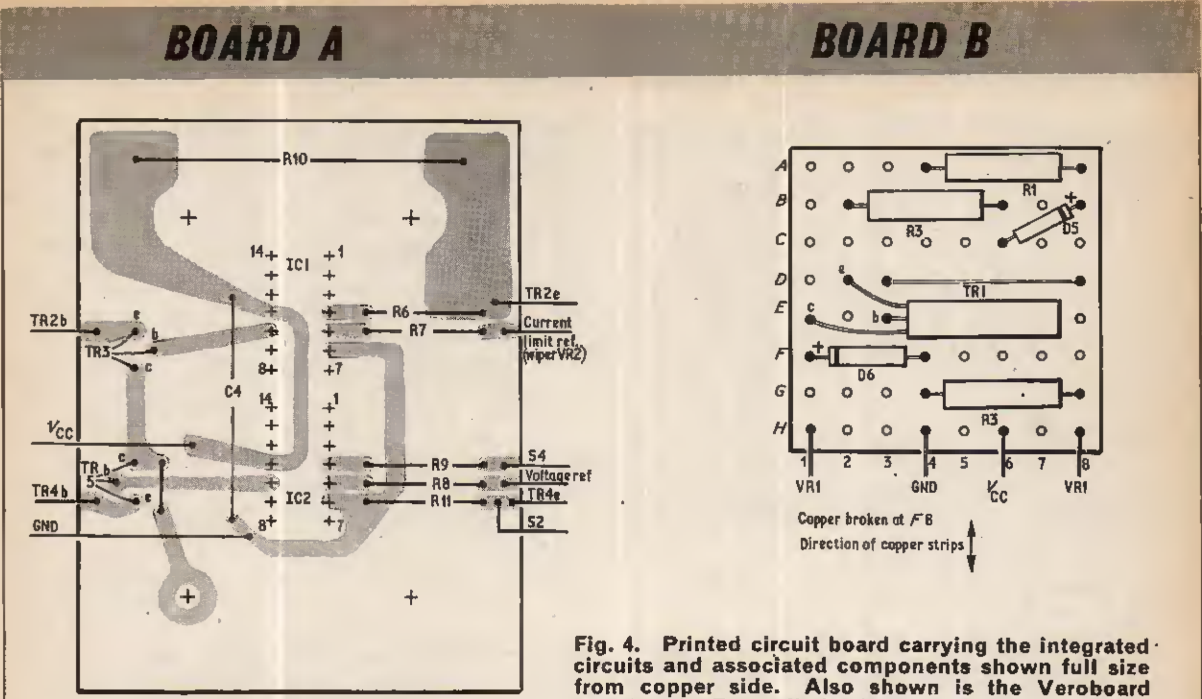


Fig. 4. Printed circuit board carrying the integrated circuits and associated components shown full size from copper side. Also shown is the Veroboard carrying the Zener diode circuit

CONSTRUCTION

The method of construction is a matter of personal choice, dictated to some extent by the materials available. Some thought should be put into planning the layout of the components and a little extra care when making up the unit is well worth the effort.

Some details are given of the construction of the prototype, together with some of the points to remember when building the supply. They are given merely as a guide and need not be adhered to rigidly.

The integrated circuits and associated components are mounted on a printed circuit board which is shown in Fig. 4. The two rows of holes for the i.c.s are easily drilled by clamping a small piece of Veroboard (0·1in matrix) to the printed circuit board and using its holes as a template. Holders for the i.c.s may be used if desired.

The Zener diodes and associated components are mounted on the front panel, attached to the tags of the potentiometers. The stabilisation circuitry for the Zener diode D6 is made on a small piece of Veroboard (0·15in matrix) which is mounted on the back of VR1 by means of its connecting wires. If the potentiometer has a metal case steps should be taken to prevent the Veroboard shorting.

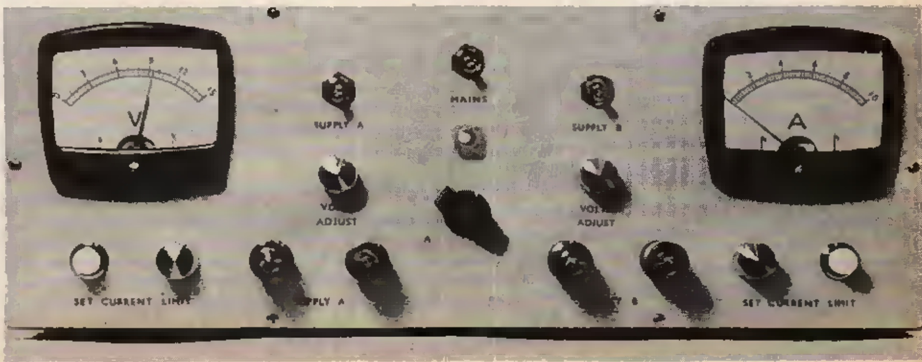
The layout of the front panel is shown in the photograph (Fig. 8). This was made from a piece of white Perspex $\frac{3}{16}$in thick. Detailed drilling details are not given as some of the components will vary according to availability. The meters shown are not generally available but SEW series 65 meters are a suitable type to use.

It is a good idea to connect the spindles of potentiometers VR1 and VR2 to the negative rails of the supplies as this reduces hum pickup. Use thick wire for the current carrying sections of the supply to reduce heating effects.

TRANSFORMER

The power is supplied by a single transformer with two isolated 18V, 2A secondary windings. This is not

Photograph of the completed Twin Power Supply



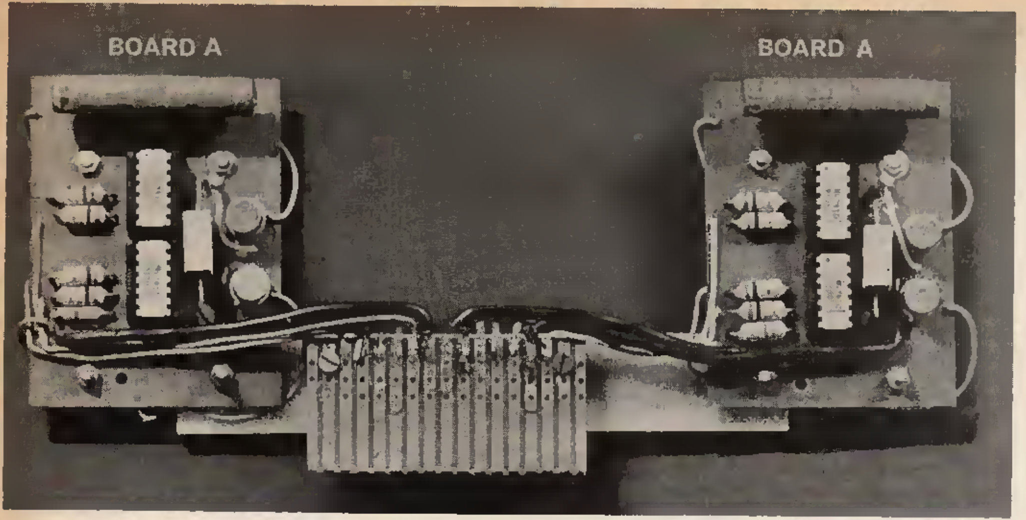


Fig. 5. Layout of the components on the back panel. Details of board A are given in Fig. 4. TR2 and TR4 are mounted under the boards on the panel

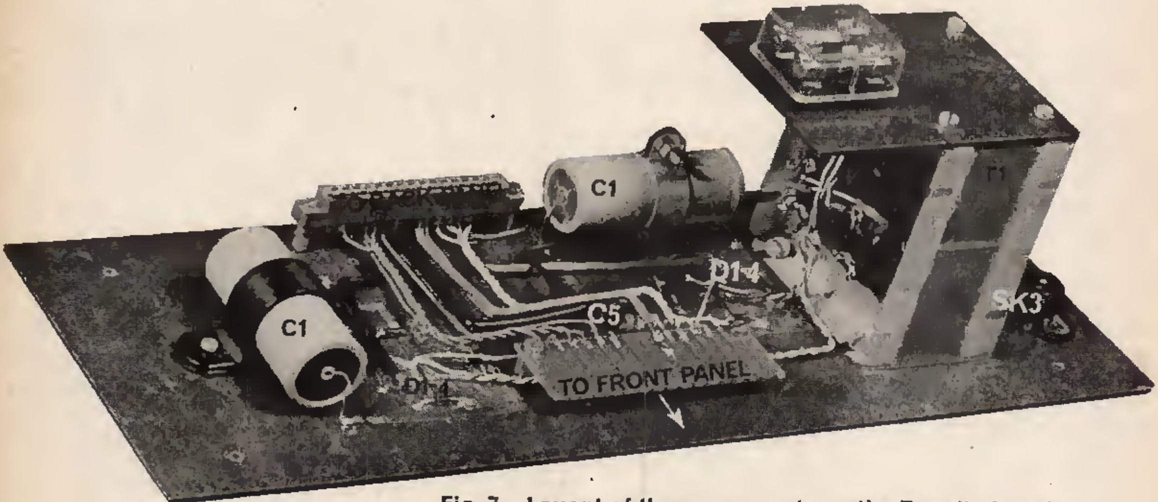


Fig. 7. Layout of the components on the Paxolin board

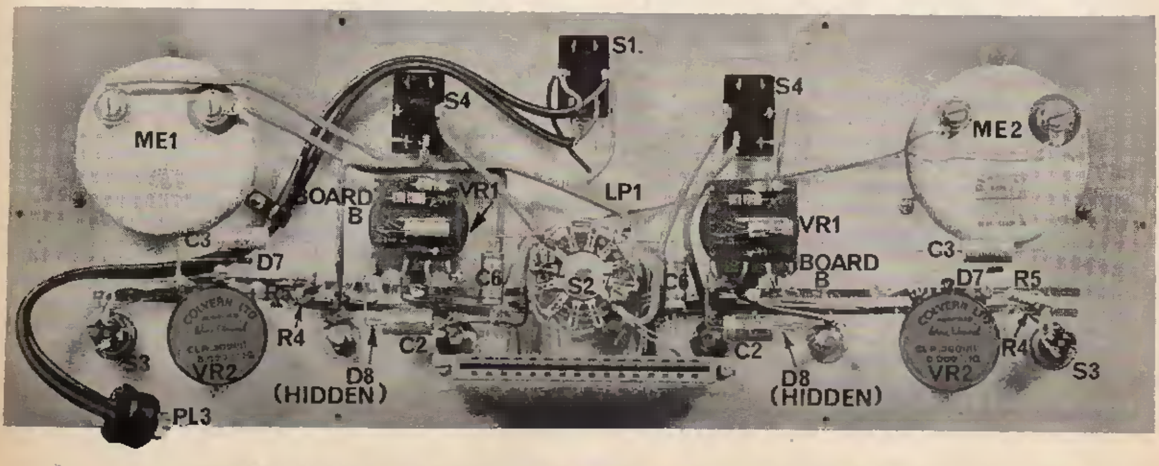


Fig. 8. Layout of the components on the front panel. Board B is shown in Fig. 4

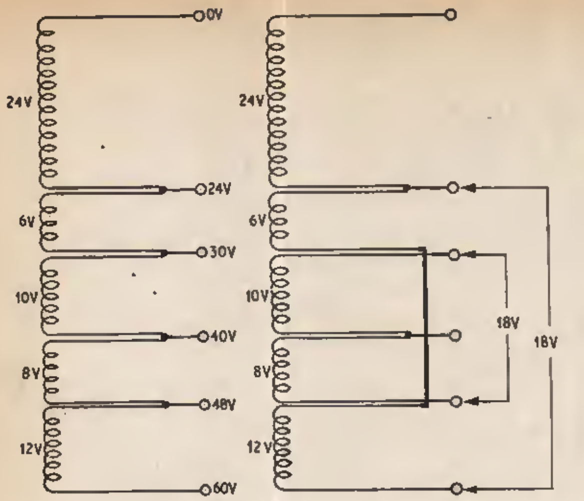


Fig. 6. Diagram showing modification to the Douglas MT127 transformer

available in this form but a simple modification to a Douglas MT127 will give the required result. The MT127 has taps at 0–24–30–40–48–60 volts and these are connected to tags.

The connections to the tags marked 30V and 48V should be carefully unsoldered and the end of the 30V winding should be connected to the beginning of the 48V winding. This is shown diagrammatically in Fig. 6.

One 18V supply is available at the tags of the 30V and 48V and the other at the tags of 24V and 60V. Check that the correct windings are being used with a continuity meter and make sure that there is complete isolation between the two windings. Alternatively two 18V, 2A transformers may be used.

PAXOLIN PANEL

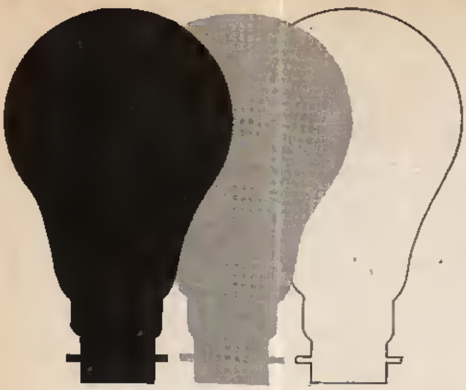
The transformer, rectifiers and capacitors are mounted on a Paxolin panel which fits into the bottom of the case, Fig. 7. Discrete diodes soldered to squares of stick-down copper sheet form the bridge rectifiers but it is probably more convenient to use a ready-made 2A bridge.

The back panel is a piece of 14 s.w.g. aluminium painted matt black and this acts as a heatsink for the four power transistors, Fig. 5. The p.c.b.s carrying the i.c.s are also mounted on this panel. Mica washers to insulate the transistors as well as plastic bushes on the bolts should be used to ensure that the transistors do not make contact with the panel.

On the prototype, both the front and back panels were made removable by using offcuts of Veroboard and edge connectors to form plugs and sockets. The mains input is kept completely separate by using B7G plugs and sockets to make the connections between the front and back panels of the transformer.

TESTING THE SUPPLY

Should the supply not function check the reference voltages as any fault here will be reflected in the output. If they are alright then the fault must lie in the op amps or associated components. ★



LIGHTING CONTROL UNIT

By G. A. Davies

ANYONE who has helped to organise a discotheque group performance or even put lights on a Christmas tree, must have felt the need for a simple flashing light controller. Many circuits, perhaps using a multivibrator, exist. But these are severely limited in their flashing rates if on and off periods are kept approximately equal, and if strobe-like effects and very slow changes are required from the same unit range switching will be needed, leading to expensive and complex wiring and tedious operation.

The circuit described here uses a similar method but a quite different principle to produce a variety of effects all available from settings of a single control. In place of continual OFF/ON switching, gradual changes enhance the effects, which range from a fast strobe to flashes lasting up to and over one minute.

COSTS

The cost of the unit if all parts including case are purchased new will be a little over £2·70. By making the case and shopping around this may be reduced. An experimental set-up may be made from common items in the spares box with the possible exception of the thyristor.

GENERAL

The circuit of Fig. 1 shows a multivibrator, TR1/TR2 actuating a driver circuit TR3 which in turn actuates a thyristor CSR1.

The components of the multivibrator are selected to give a repetition rate of about 50Hz with TR1 in the ON state for about 1ms and TR2 ON for between 10 and 25ms dependent on the setting of VR1.

THE DRIVER CIRCUIT

Output pulses from the multivibrator are fed to the base of TR3 *via* R5 which is large enough to prevent the following circuit from interfering with the multivibrator. Each pulse turns TR3 ON, allowing an amplified pulse of current through the collector into the gate of the thyristor. R6 limits this pulse to about 30mA which should be sufficient to operate most thyristors. If a low current thyristor is to be used some saving in battery drain can be made by increasing the value of R6 to 390Ω.

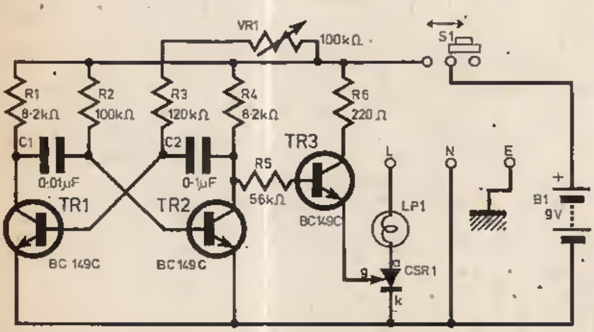


Fig. 1. The circuit diagram of the light controller. TR1/TR2 form a multivibrator driving CSR1 through driver TR3

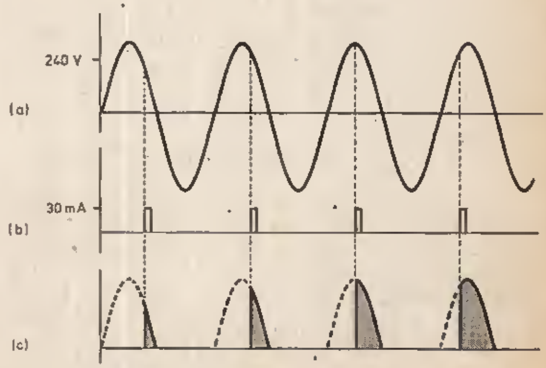
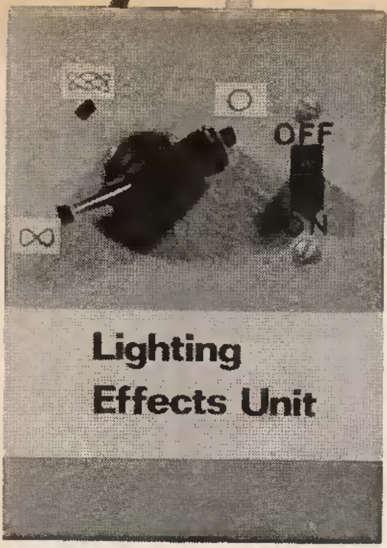


Fig. 2. Graphic representation of the relationship between mains cycles, control pulses and load current, at a given multivibrator frequency



reached when the pulse has finished before the cycle starts. The power then falls to zero until the next pulse arrives at the end of the cycle and power increases slowly again.

If a 100W bulb is used as the load the light will be seen to change intensity as in Fig. 3 (f), the rate of change depending on the frequency difference between the mains and multivibrator pulses. The reversed version, Fig. 3 (g), is obtained by setting the pulse frequency lower than 50Hz.

With large frequency differences a strobe effect is obtained and with careful adjustments an almost constant light output can be set. It must be borne in mind that the maximum light output is only half that given by the bulb connected straight to the mains.

The other effects shown in Fig. 3 can be obtained with the controller remembering that thermal inertia, i.e. the time taken for the lamp filament to heat up and cool down, will slow down some of the faster changes.

CONSTRUCTION

To the inexperienced constructor it is impossible to overstress the need for great care over safety. The whole circuit is connected to the mains, and although the live is isolated through the lamp and is thus proof against short circuits, great care must be taken over insulation. The isolation of the case from the thyristor poses the greatest problem here and the solution depends upon the component chosen.

The prototype was housed in an aluminium box measuring about 4in × 2¾in × 1½in deep and fitted with an overlapping lid held by a self-tapping screw at either end. The switch and the potentiometer are fixed to the lid and the remaining parts are assembled in the box. Firstly the top and bottom should be drilled to accept the components.

A small aluminium clip shown in Fig. 4 is needed to secure the battery with small blocks of polystyrene stuck to the lid and sides to hold it firmly in place. The clip can be fixed with Araldite.

The circuit board and terminal block are secured by ¼in 6 B.A. tapped pillars screwed or Araldited (preferably both, since the screws will have to be very short) to the case. Countersunk screws are used in the prototype, the heads being filled in with Araldite and painted over but this is of course a matter of individual choice.

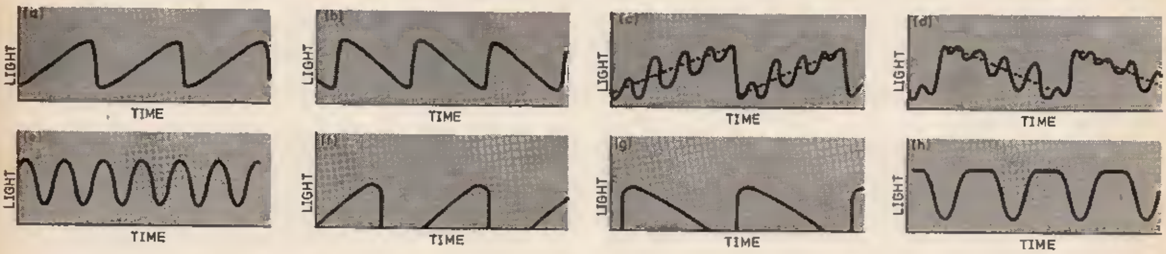


Fig. 3. Variations in light output obtainable with the circuit of Fig. 1

THE THYRISTOR

This semiconductor device can be considered as a combination of a rectifier and a latching relay. It will not under any circumstances (other than breakdown) pass a current from cathode to anode, and also it will not pass a current from anode to cathode unless a sufficiently large current is supplied to the gate. Once triggered in this way, however, the anode current will not stop, even after the gate triggering current has stopped, until the anode voltage is reduced to zero, or changes sign to negative if a.c. is applied.

In this particular application a.c. mains voltage is connected to the anode through the controlled load. When the mains is negative no current can pass due to rectifying action. Thus any current pulses arriving at the gate from TR3 are ignored.

When the mains is positive the thyristor can conduct, but will not do so until a trigger pulse has turned it on.

Fig. 2 (a) shows the mains input voltage. For a given frequency of the multivibrator (b) is the train of current pulses in the gate of the thyristor. All negative half cycles of the a.c. are rectified out and positive half cycles are let through only after an input pulse, so that the voltage supplied to the load looks like Fig. 3 (c).

If the multivibrator is set as shown at a slightly higher frequency than the mains 50Hz, that part of the half cycle allowed through will change. As the drive pulse comes earlier in each cycle, the power in the load slowly rises to a maximum of about half the rated power (all negative half cycles are lost) until a point is

COMPONENT BOARD

Details of this are given in Fig. 4. The six 6 B.A. clearance holes should be drilled carefully first and then the components pushed through and soldered, the transistors being soldered last to avoid overheating.

LIGHTING CONTROL UNIT

COMPONENTS . . .

Resistors
R1 8·2kΩ
R2 100kΩ
R3 120kΩ
R4 8·2kΩ
R5 56kΩ
R6 220Ω
All ¼W 10% carbon

Potentiometer
VR1 100kΩ carbon linear

Capacitors
C1 0·01μF 250V poly.
C2 0·1μF 250V poly.

Thyristor
CSR1 BO226 (see text)

Transistors
TR1, 2, 3 BC149C (or BC169C, BC108C, BC109C)

Miscellaneous
S1 d.p.d.t. slider switch or on/off toggle
B1 9V PP3 or equivalent
2in × 3¾in s.r.b.p. 0·1in matrix, 2A terminal block (5 sections required), 6 ½in 6BA tapped pillars, Case see text, 6BA screws, 18swg aluminium for battery clip and heatsink, grommets, wire, solder, sleeving.

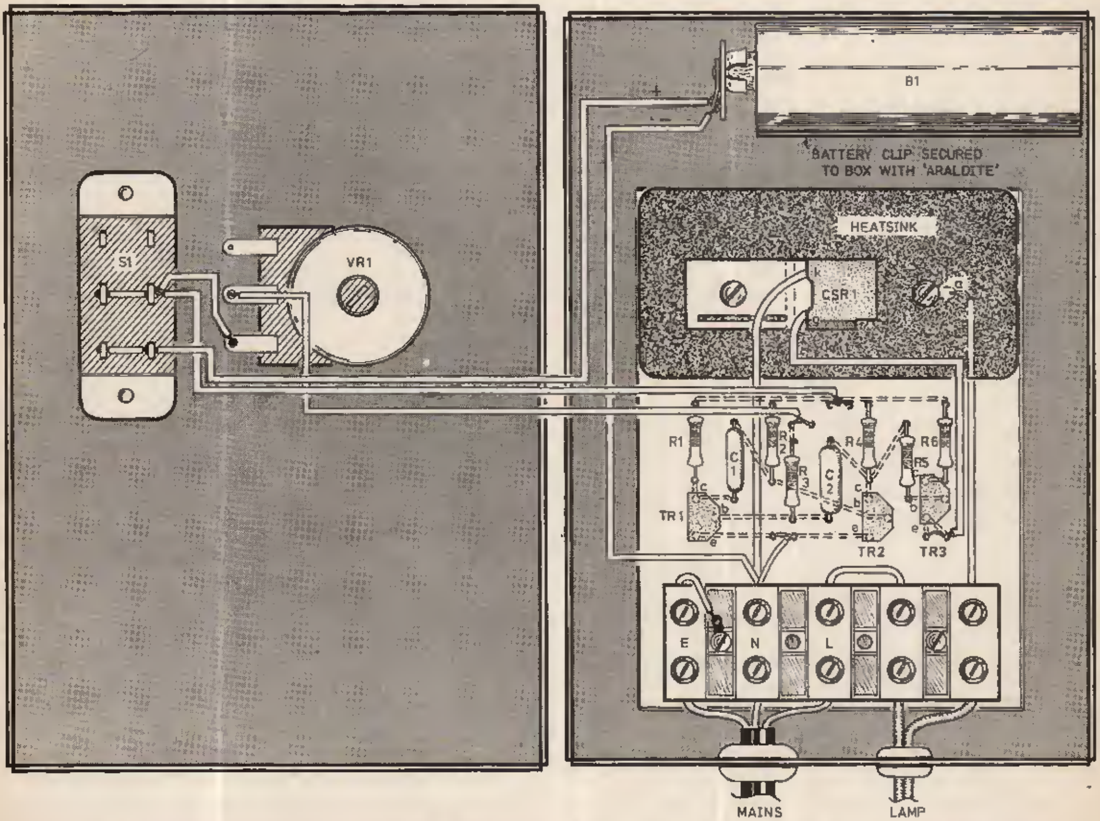


Fig. 4. General layout of the controller showing main wiring board and component positioning. NOTE: Ensure that the heatsink is well isolated from case

Four loops of wire are made on the component side so that connections can be made. Next screw two ½in pillars to the inside holes; the board can then be bolted down onto the pillars.

The heatsink in Fig. 4 is mounted on the board using two further pillars, the thyristor being fixed down under one screw (a smear of silicone grease will be helpful here under the tab to improve heat transfer). The lead from the terminal block can be soldered to, or clamped by the other screw/pillar to act as the anode connection. Make certain the heatsink mounting is insulated from the case.

The wiring can be completed with p.v.c. insulated stranded wire, colours being chosen to suit. Sleeving the thyristor leads is advisable or tape may be used.

COMPONENTS

The components specified in the list are all quite easily obtainable. The transistors can be any of the listed types, BC 149C being most suited to the mode of construction used and also the cheapest.

If surplus transistors are tried TR3 should be selected for low leakage and high gain. The C suffix on the listed types ensures a gain of over 400.

The thyristor will depend on the application; for mains it must be rated at 400V peak forward and reverse voltage, the current will depend upon the power of the lamps used. At 240V a 3A thyristor with a good heatsink will take a total load of 1000W and give 500W of light. A 0·8A version in a TO5 or similar case will overcome the insulation problem and make the unit possibly smaller but will not take more than 250 to 275W load and give 100 to 150 watts of light.

The 2in × 1in panel used cannot be considered a good heatsink and also it is inside a sealed box. In addition large powered bulbs also complicate things because their high thermal inertia causes large surges on switching ON. The unit should be able to take a 500W lamp at all control settings to give 250W of light. With lower powered lamps in parallel it should be possible to go up to 700 to 800W. However, due to the cost of such a setup this has not been tried. A few hundred watts will be found adequate for most purposes but care should be taken to ensure there is no overheating with the components specified.

TESTING

When the wiring is complete and checked, connect the battery in circuit and, using a meter set to a current range, put this across the switch. A current of about 3mA should register, switch the range down if necessary to read this. Rotate VR1 and the current should change slightly.

Following this or, alternatively if no meter is available, connect the mains lead to a plug fitted with a 3A or 5A fuse and the output lead to a lamp of 40 to 100W power. (In the prototype a cable socket was connected so that lamps could be plugged in and removed freely.) Switch the mains on. If nothing happens all is well; now switch on the unit with S1. The bulb should now light and flash in a pattern depending upon the setting of VR1. Explore the range of the potentiometer and see that it is similar to that indicated in Fig. 4. If this is not so, adjustment of R3 may be necessary.

LAMP HOUSING

For lighting effects the lamps will have to be fitted in some way to achieve the desired effect. Coloured pearl bulbs or bulbs fitted in boxes with coloured filters can be used but these give very directed illumination and an improvement is made with more diffuse lighting. Frosted screens can be tried but an excellent result is given by a box with lamps, reflectors and filters placed at the bottom of a wall so that the light is projected up onto the wall. Car headlamp reflectors can also be adapted to produce a focused beam for special effects.

FAULT FINDING

Three conditions will indicate faults in the unit which might occur.

Firstly the lamp may not light. Check the operation of the multivibrator with a high impedance earpiece or an oscilloscope after first unplugging the unit from the mains and putting S1 to ON. With one side of the earpiece connected to battery negative look for a signal at 40 to 100Hz at TR2 collector. If this is present check for the same at the gate of CSR1. If the signal is also present here the thyristor or the mains wiring is at fault. Look for breaks in the relevant part of the circuit or for faulty components.

Secondly if the lamp lights continually at half brilliance then check for a signal at TR2 collector with a voltmeter. If this reads about 1V then check TR3 and its wiring. If it is 2V or more the multivibrator is the cause of the trouble. Check for correct positioning of C1 and C2.

Finally if the lamp lights at its normal full brilliance this indicates a short circuit in the unit. If none can be found then the thyristor may be shorted. Check that the fuse and bulb are not also shorted before replacing.

THE FINISH

Finishing the unit is left entirely to the constructor, the prototype was painted with a silver "hammer" paint and the words "LIGHTING EFFECTS UNIT" painted in black across a white stripe. The "critical settings" of the control were marked approximately with Lissajous figures corresponding to the ratio of the mains and multivibrator frequencies. Any method of calibration will suffice and as long as you can understand it that is all that really matters.

SUPPRESSION

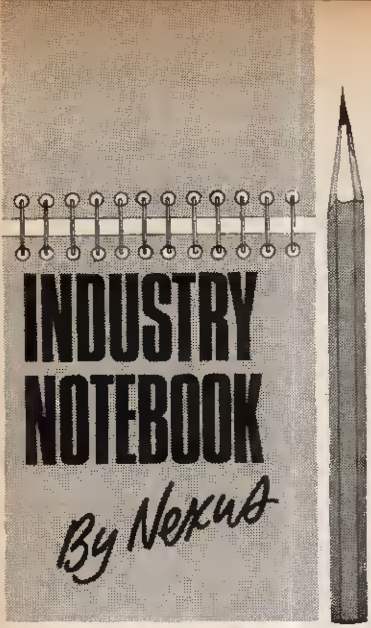
If the unit interferes with radios or TVs on high power operation a suppressor may have to be fitted. This will consist of inductors in series and/or capacitors in parallel with the power lines. This was not included in the prototype because of space consideration and since no interference has arisen anyway.

USE

Every constructor will rapidly become accustomed to the effects produced by the unit and will soon know how to use its effects to the greatest advantage. Positioning and colouring will follow logically to give the best results.

A word of warning, however. The strobe effects produced should not be used as dominant lighting in an otherwise darkened room as it can have a bad effect on the subconscious mind after prolonged exposure. Headaches can also be caused, probably due to the sensation of rapid blinking. If strobes are used make sure that the other lighting is at least equal in strength to the strobed light.

Finally, when fault finding as described earlier make certain the equipment is not connected to the mains. Also earth the case to mains earth. ★



PACE SETTERS

This month I tip two private companies worth watching for future growth. First is Sinclair Radionics currently moving into a strong position with nearly £2 million turnover and a confident forecast of at least £3 million next year. Clive Sinclair at the age of 32 still has the great bulk of his working life ahead of him and now he has the sort of cash flow needed to finance the development of new projects.

The Sinclair "Executive" pocket calculator has proved itself to be the big business breakthrough he had hoped for. It came in a higher price bracket than his previous products and quickly established the volume of production that pushed his company forward, almost overnight, into a new and exciting situation. The "Executive" is now rolling out of final test at the rate of 10,000 per month and 40 per cent of production goes overseas.

Sinclair is investing a lot of his additional turnover in R and D. Expect to see in the next few months or so some new calculators, a range of test instruments to follow up the recently introduced digital multimeter, a pocket-sized TV set, a digital watch and something exciting in digital computers. But he is not going to neglect his army of faithful followers in the audio and hi-fi sector. There will be something new for them too.

Sinclair is clearly widening his market in the consumer sector and starting to move into the professional area, initially through instrumentation. There's nothing that succeeds like success.

My number two tip is Jermyn Manufacturing led by managing director Graham Rattcliff. I last saw him towards the end of April when he was running one of a series of seminars promoting the use of heat pipes, an old idea which has now won a new lease of life as an efficient heat dissipator in modern equipment.

The company's main line is in moulded components and heat pipes are comparatively new. Nonetheless, Rattcliff sees them as an important new line although he confesses that more people want "specials" than from the standard range—always a manufacturer's headache.

I tip both Sinclair Radionics and Jermyn Manufacturing for big growth not only because the products are right but also because both companies are strong on marketing. Sinclair has just established a New York office. Jermyn has sales offices in Munich, Paris and San Francisco.

DISTRIBUTOR NEWS

Component distributors are looking distinctly more cheerful these days now that orders are flowing in faster than supplies rather than the other way round.

Farnell Electronics, among Britain's biggest, has broken through the £1 million pre-tax profit barrier for the first time. Last month SASCO celebrated its 21st Birthday with press advertising wishing founder George ("Stewie") Stewart best wishes.

John Zuber, new chairman and managing director of Guest International has opened a Distribution Division which, if it works as well as his computerised stock control and order system—about the best I've seen—should prosper exceedingly well. And Swift Hardman's new Industrial Electronics and Automation Division, now under the control of ex-TI man Peter Linforth, is aiming at an initial turnover of £1·5 million and was on target when I visited the company a few weeks ago. New franchises include Greenpar (co-axial connectors), Beswick (fuses), and OKI (opto-electronics) bringing the franchise total to 20 in electronics plus 16 in the electro-mechanical sector.

It was rumoured that Motorola Semiconductors might hire or fire one or two distributors this year but the five old faithfuls (Jermyn Distribution, Celdis, Semicomps, A.M. Lock and GDS) all got a nice pat on the back from vice-president Tom Connors at the annual re-appointment ceremony and there were no new appointments.

Leicester-based Atlantic have won a valuable new franchise from National Semiconductors and this should give a big boost to one of our newest distributor companies.

SELLING SERVICES

You don't necessarily have to manufacture or sell goods to make money. Quite a few companies make a good living selling services. Companies like International Aeradio and Cable and Wireless have been doing it for years. A division within Plessey has substantial business on advising and supervising warship re-fits. This outfit works in conjunction with shipyards and although you don't get orders on a daily or even weekly basis, when they come they're big.

Then there is EASAMS which, if my memory serves me correctly, started off in life in 1962 with the name being an acronym for Elliott Automation Space and Military Systems. Since those days there has been some diversification to include consultancy and planning projects in all sorts of fields such as hospitals, transportation and even, recently, an investigation on how best to integrate the coconut industry in Malaya.

FIRST AWARD

EASAMS is the first consultancy firm to win the Queen's Award to Industry for exports with overseas contracts up 300 per cent since 1970. But one of EASAMS toughest jobs must still be the management of the integration of the electronic systems on the European Multi-Role Combat Aircraft (MRCA).

Another unusual Queen's Award winner, again for exports, is four-year-old Racal-Milgo. I write 'unusual' because this company is 50 per cent owned by the Milgo Corporation U.S.A. and I'm wondering (jokingly!) whether Milgo Corp. will be flying the flag and wearing the ties equally with their British partners. Although the equipment comes from the U.S.A. it's the British end of the partnership that provides the international consultancy service, feasibility studies, planning and implementation of some of the most complex data transmission networks in the world today.

Our congratulations go to EASAMS and Racal-Milgo together with English Electric Valve Company who got the only award in the electronics industry for technological innovation, the product being the ceramic hydrogen thyratron.

MOBILE RADIO RATIONALISATION

The long war of attrition in the two-way mobile radio market with lots of little fellows trying to compete with one big one appears to be over following the announcement that Cossor's mobile business has been acquired by Burndept Electronics. This new move follows Burndept's acquisition of the Ultra business in mobile radiotelephones last year, and we must now assume that Burndept will be in a position to seriously start challenging Pye Telecommunications who hold well over 50 per cent of the market.

PATENTS REVIEW...

WATER LEVEL ALARM

BP1 271 654

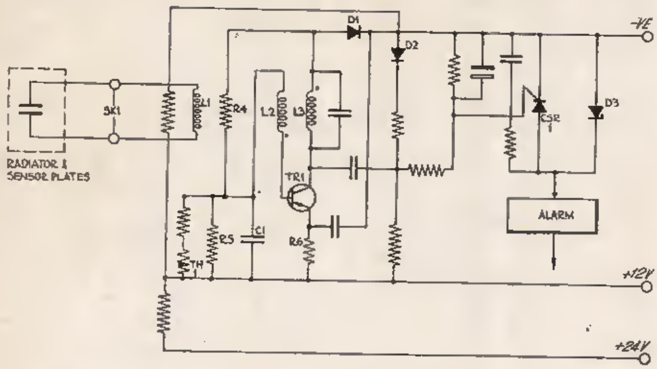


Fig. 1

In BP 1 271 654 Smiths Industries Limited describes circuitry for using an oscillator to sense the loss of cooling water from a car radiator.

A tuned collector oscillator centres round transistor TR1 which has its emitter connected via resistor R6 to a 12 or 24V positive line. The transistor collector connects with the negative line through a transformer winding L3 and diode D1.

The transformer has two further windings L1 and L2, of which winding L2 is connected between the base of TR1 and the junction of R4, R5 and C1. Two electrodes mounted inside the car radiator are connected to L1 through the input socket SK1.

The transformer windings have a turns ratio such that the effective impedance in parallel with L3 is too high to adversely affect oscillation, hence the oscillator will oscillate at audio frequency. But when the radiator water is high enough to short the two electrodes together, the effective impedance in parallel with L3 will drop and so damp down and stop oscillation.

By feeding the oscillator output via a rectification circuit to an alarm system it is possible to sound an alarm or trigger a light when the water level falls and the undamped oscillator starts to produce an audio frequency oscillation.

Various temperature sensitive components, such as a thermistor TH1, provide temperature compensation for the oscillator. This is obviously necessary bearing in mind the high temperature levels encountered in running vehicle engines.

AMPLIFIER PROTECTION

The Marconi Company Limited in BP 1 285 685 has some simple circuitry to offer which, according to some fairly complicated theory, provides protection for transistors against high voltages resulting from generated harmonics.

Fig. 1 shows a well known A-B push-pull wide band amplifier for high frequency working. Transistors TR1 and TR2 are fed by input transformer T1 with a centre-tapped secondary and feed the centre-tapped primary of an output transformer T2. (The circuit is simplified for clarity.)

The amplifier will produce a comparatively high level third harmonic and to eliminate output power at the frequency of this harmonic a filter network (VC1, 2 and L1) is fed via a coaxial cable, the final output being fed to the output terminal. Assuming an applied voltage of 28V, with perfect coupling the voltage on the transistor should never exceed 56 volts. But nothing in this world being perfect, third harmonics produce excessive voltage levels.

The coaxial cable disturbs the ideal phase relationship between the fundamental frequency wave and the third harmonic wave and causes the harmonic to increase the voltage swing in the collector voltage rather than reduce it.

The Marconi invention centres round the provision of a voltage limiting means for modifying the phase of the third harmonic frequency component of the voltage present at the transistor collectors, in relation to the fundamental frequency of the voltage there. But there is no change in amplitude of the fundamental frequency component. Usually a diode clipper is used to limit the voltage wave at the transistor collector so as to produce a flat-topped voltage wave limited to a maximum level such that the fundamental is virtually unaffected by the clipping.

Circuit Fig. 2 shows their novel circuit. This generally resembles the Fig. 1 circuit except that diodes D1 and D2 are used with a d.c. blocking capacitor C1, the diodes receive a d.c. voltage of 60 volts. As a result, the voltage wave form at the collectors of the transistors have a flat top limited to 60 volts.

Although the diodes appear to function as an ordinary amplitude clipper, in fact they operate to clip to a clipping level and merely modify the phase of the third harmonic. Fig. 3a shows the fundamental *Y* and third harmonic *Z* which together make up curve *X* of Fig. 3b. Thus there is no distortion and the clipping is linear.

BP1 285 685

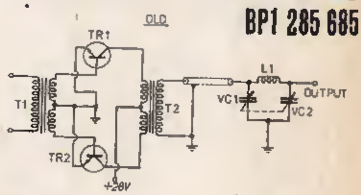


Fig. 1

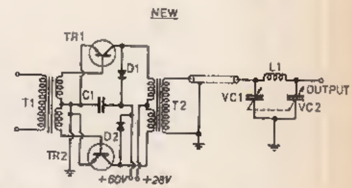


Fig. 2

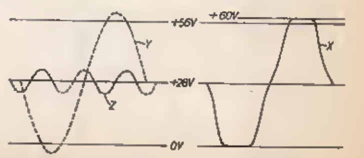


Fig. 3 (a) (b)

TRANNIES

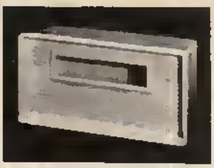
1 DOCKYARD, STATION ROAD, OLD HARLOW, ESSEX
Phone Harlow 37739

P/P 10p. Price list S.A.E. (Saturday callers welcome)

ALL PRICES INCLUDE VAT

£19·50 ELECTRONIC DIGITAL CLOCK

(For complete kit of parts including case.)



This 4 digit 24 hour clock is available to readers at this special price for 1 month only. Parts would normally cost over £25. Kit of parts includes twelve IC's, indicators, and a smart white plastic case.

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SN7403	16p	15p	SN7428	77p	72p	SN7454	16p	15p	SN7492	74p	72p
SN7404	16p	15p	SN7430	16p	15p	SN7460	16p	15p	SN7493	74p	72p
SN7405	16p	15p	SN7432	49p	46p	SN7470	38p	29p	SN7494	85p	72p
SN7406	38p	35p	SN7433	94p	82p	SN7472	33p	29p	SN7495	85p	72p
SN7407	38p	35p	SN7437	72p	68p	SN7473	41p	39p	SN7496	95p	92p
SN7408	20p	18p	SN7438	72p	68p	SN7474	41p	38p	SN74100	1·80p	1·75p
SN7409	20p	18p	SN7440	16p	15p	SN7475	50p	47p	SN74104	1·09p	1·06p
SN7410	17p	15p	SN7441	74p	70p	SN7476	44p	43p	SN74105	1·09p	1·06p
SN7411	27p	25p	SN7442	74p	70p	SN7480	78p	70p	SN74107	44p	42p
SN7412	38p	35p	SN7443	1·43p	1·37p	SN7481	1·32p	1·26p	SN74110	61p	59p
SN7413	32p	29p	SN7444	1·43p	1·37p	SN7482	97p	95p	SN74111	1·37p	1·27p
SN7416	47p	43p	SN7445	2·00p	1·92p	SN7483	1·20p	1·15p	SN74118	1·10p	1·05p
SN7417	47p	43p	SN7446	1·07p	1·02p	SN7484	1·10p	1·05p	SN74119	1·47p	1·37p
SN7420	16p	15p	SN7447	1·10p	1·08p	SN7485	3·96p	3·85p	SN74121	44p	41p
SN7422	55p	50p	SN7448	1·10p	1·03p	SN7486	36p	35p	SN74122	1·54p	1·43p

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307	DIL	69p	748c	DIL	39p
307	TO99	69p	748c	TO99	41p
307	8 PIN DIL	66p	1437	DIL	1·27p
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709c	TO99	31p			

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100µF	6½p
220µF	6½p
330µF	6½p
1000µF	13p
4700µF	29p

6 3 VOLT

33µF	6½p
68µF	6½p
150µF	6½p
470µF	11p
680µF	13p
1500µF	18p
2200µF	18p
3300µF	26p

10 VOLT

22µF	6½p
47µF	6½p
100µF	6½p
220µF	8p
330µF	10p
470µF	10p
1000µF	11p
1500µF	20p
2200µF	24p

16 VOLT

15µF	6½p
33µF	6½p
68µF	6½p
150µF	8p
220µF	9p
680µF	17p
1000µF	17p
1500µF	25p
2000µF	43p

25 VOLT

10µF	6½p
22µF	6½p
47µF	6½p
100µF	8p
150µF	8p
220µF	10p
470µF	13p
680µF	20p
1000µF	22p
2200µF	39p
5000µF	68p

40 VOLT

6·8µF	6½p
15µF	6½p
33µF	6½p

40 VOLT

47µF	6½p
100µF	9p
150µF	10p
220µF	11p
470µF	19p
680µF	25p
1000µF	25p
2200µF	44p

63 VOLT

1µF	6½p
2·2µF	6½p
4·7µF	6½p
6·8µF	6½p
10µF	6½p
22µF	6½p
68µF	10p
100µF	11p
150µF	13p
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330µF	22p
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10 watt 5%
All Voltages
7·5 – 100 Volts
51p each

Transistors

AC107	16p	BC138	36p	BF260	29p	OC44	14p
AC126	14p	BC142	33p	BF329	18p	OC45	14p
AC127	18p	BC143	33p	BF330	18p	OC70	23p
AC128	18p	BC144	30p	BF390	37p	OC71	14p
AC142K	22p	BC145	26p	BFX84	28p	OC72	14p
AC141K	20p	BC147	9p	BFX85	35p	OC81	14p
AC176	16p	BC148	9p	BFX86	22p	OC83	22p
AC187	18p	BC149	9p	BFX87	28p	OC84	28p
AC187K	20p	BC153	16p	BFX88	26p	TIP29A	53p
AC188	18p	BC154	17p	BFY50	21p	TIP30A	64p
AC188K	20p	BC157	13p	BFY51	17p	TIP31A	64p
ACY17	24p	BC158	12p	BFY52	17p	TIP32A	78p
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ACY22	18p	BC177	15p	C426	33p	TIP41A	79p
ACY39	68p	BC179	15p	C428	31p	TIP42A	91p
AD140	40p	BC182L	9p	C450	17p	2N706	13p
AD142	44p	BC183L	9p	MP8111	35p	2N930	23p
AD143	39p	BC184L	9p	MP8112	42p	2N1131	22p
AD149	38p	BC186	33p	MP8113	35p	2N1132	28p
AD160	60p	BC212L	11p	MP8121	33p	2N1613	22p
AD161	29p	BC213L	11p	MP8122	44p	2N1711	26p
AD162	29p	BC214L	11p	MP8123	50p	2N2904	40p
AD M/P	50p	BC258	9p	NKT211	28p	2N2904A	44p
AF114	14p	BC259	9p	NKT212	28p	2N2905	46p
AF115	14p	BC267	14p	NKT214	25p	2N2924	18p
AF116	14p	BC268	15p	NKT217	55p	2N2926	10p
AF117	14p	BC300	40p	NKT261	23p	2N3053	26p
AF118	92p	BC301	32p	NKT271	20p	2N3054	55p
AF124	27p	BC302	30p	NKT274	20p	2N3055	52p
AF139	39p	BC303	50p	NKT275	25p	2N3405	44p
AF239	41p	BC304	40p	NKT403	71p	2N3663	57p
AL100	77p	BCY70	17p	NKT405	83p	2N3702	9p
AL102	86p	BCY71	37p	NKY603F	66p	2N3703	9p
AL103	55p	BCY72	17p	NKT613G	38p	2N3704	9p
ASY26	31p	BD123	66p	NKT674	26p	2N3705	9p
ASY27	40p	BD130	50p	NKT677G	24p	2N3706	9p
AU103	99p	BD131	68p	NKT713	32p	2N3707	9p
AU110	£1·10	BD132	90p	NKT773	27p	2N3708	9p
AU111	77p	BD135	42p	OC19	55p	2N3709	9p
BC107	9p	BD136	50p	OC20	55p	2N3710	9p
BC108	9p	BD141	£1·87	OC23	38p	2N3711	9p
BC109	9p	BD142	50p	OC25	28p	2N3794	17p
BC113	15½p	BF159	33p	OC28	33p	2N3819	28p
BC116	16p	BF173	29p	OC29	33p	40361	50p
BC125	16p	BF177	28p	OC35	38p	40362	50p
BC126	25p	BF178	29p	OC36	38p	40636	50p
BC132	16p	BF179	35p	OC41	14p		
BC134	16p	BF194	15p				
BC135	16p	BF195	17p				
BC137	16p	BF244	27p				

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1N4148	8p
1S44	10p
1N4007	22p
1S113	17p
1S120	17p
1S121	15p
1S130	9p
1S131	11p
1S132	13p
1S920	8p
1S922	9p
1S923	13p
1S940	6p
AA119	11p
AA129	11p
AAZ13	11p
AAZ15	14p
AAZ17	14p
BA100	16p
BA102	25p
BA115	8p
BA144	14p
BA145	22p
BA154	14p
BAX13	14p
BAX16	14p
BAY18	19p
BAY31	9p
BY100	19p
BY126	16p
BY127	19p
BYX10	24p
OA5	18p
OA9	11p
OA10	24p
OA47	9p
OA70	8p
OA73	11p
OA79	8p
OA81	9p
OA85	11p
OA90	8p
OA91	8p
OA95	8p
OA200	11p

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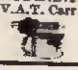

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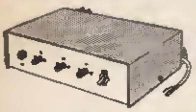

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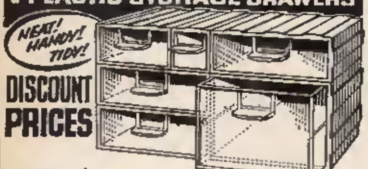

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MARKET PLACE

Items mentioned in this feature are usually available from electronic equipment and component retailers advertising in this magazine. However, where a full address is given, enquiries and orders should then be made direct to the firm concerned.

SLIDE RULE CALCULATOR

Electronic calculators of the pocket variety fall generally into two types. The first is the fairly simple device the operation of which is limited to the more normal mathematical operations, and the price of which is steadily falling to around the £40 mark.

The alternative and much more sophisticated device is capable of carrying out complex maths functions such as rooting or calculating to specific laws. Currently there are only one or two of these latter and their price tends to rest in the £200 region.

Predictably, just as the cost of the smaller version has dropped swiftly over the last two years, the more complex device is now showing reduction tendencies.

Thus **Texas Instruments** have just announced a pocket "slide-rule" type of instrument capable of calculating reciprocals, squares and roots, true credit balance and all the more usual functions.

It will also convert an arithmetic entry to scientific notation when the entry exceeds eight digits.

Capable of handling positive and negative numbers over a 200 decade range, the SR-10 is selling at £87·50.

DIGITAL MULTIMETER

Another contender in the low cost digital multimeter field has just been announced by **Advance.** Called the Alpha, it will retail at £55, a price which makes it a real challenge to the analogue meter as well as other digital multimeters.

The Alpha features a total of 24 ranges enabling it to measure d.c. voltages from 1mV to 1kV, a.c. voltages from 1mV to 500V, d.c. and a.c. current from 0·1μV to 1A and resistance from 0·1Ω to 10MΩ. The reading is given on a three digit l.e.d. display which can be adjusted in brightness to conserve power. Accuracy is claimed to be 0·2% ±1 digit on the 1V d.c. range and 0·5% ±1 digit on other d.c. voltage ranges. Input impedance is a high 10MΩ and the instrument can stand overloads of 350V on the 1V range and 1kV on other voltage ranges.

The unit consumes 90mW to 400mW dependent on the setting of the brightness control. It is normally supplied by a 9V dry battery which will last several months in normal use. There is also an optional mains unit at £7 extra and a rechargeable battery unit at £17 extra.

The circuit uses a simple single ramp analogue-to-digital conversion system and all the digital circuitry is contained in a single m.o.s. l.s.i. integrated circuit, custom-designed by Advance.

The unit is available direct from the maker, Advance Electronics Ltd., Raynham Road, Bishop's Stortford, Hertfordshire.

WORKSHOP

Several items for the workshop seem to be worth further consideration this month.

For the work bench there's a new adjustable vice from **W. Greenwood Electronic.** Called the Oryx, the vice is ideal for holding circuit boards during soldering.

The vice has a rotating base which is also part of a steel ball joint in the bench clamp. This arrangement allows the user to position his workpiece in practically any position and the fibre faced jaws of the vice will hold delicate components without damage

Addresses of nearest stockists and price list can be obtained from W. Greenwood Electronic Ltd., 21, Germain Street, Chesham, Bucks.

With the decrease in size of components, tool manufacturers have had to scale down a great number of their tools to meet the demands of handling these components. With this problem in mind **Tele-Productions** are now marketing a range of Swedish Stirex hand tools.

Available as side cutters, pliers and scissors the tools have been designed for close work and the complete tools measure a maximum length of only 175mm, including handle. A feature of the tools are plastics spring-loaded handles which are available in varying colours. This enables particular tools to be colour coded for easy identification.

Full details of tools available and price lists can be obtained from Tele-Production Tools, 28-B, Hamlet Court Road, Westcliff-on-Sea, Essex.

One of the more unusual items is a set of multi-blade screwdriver packs from **F. Parramore and Sons (1924) Ltd.** For electrical requirements the Multi-3 pack comprising wallet, chuck and three blades is recommended. For general purpose use the Multi-5 pack should be able to tackle most jobs.

Complete with a robust 4-jaw chuck handle the cruciform interchangeable blades are suitable for slotted, Pozidriv and Phillips screws.

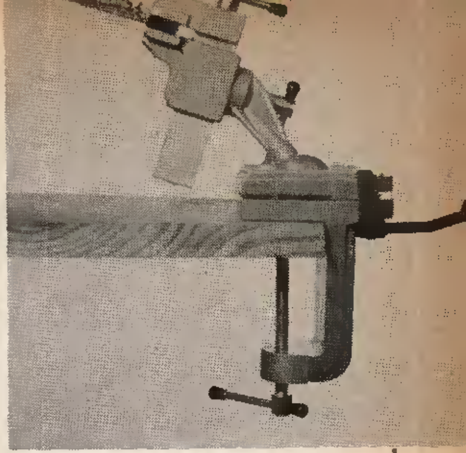
One of the reasons for the shape of the blade is that when dealing with over tight screws extra torque can be applied to the blade with a spanner or a special ratchet, available as an extra.

The price of the Multi packs vary from approximately £2·25 to £3·55 and addresses of nearest stockists can be obtained from F. Parramore & Sons (1924) Ltd., Caledonian Works, Chapeltown, Sheffield.

Finally, to help keep the workshop tools tidy readers may be interested in a new range of "Clipco" nylon general purpose clips from **Herbert Terry & Son Ltd.**

Ideal for holding all kinds of tools, the Clipco is made from unbreakable nylon and having a special toothed stem the clips can be easily fixed (no screws or screwing being required) to walls, tiles, wood and pegboard.

Available from most hardware and do-it-yourself stores the clips are sold in packets containing 8, 9 or 10 clips, dependent on size required, and retail at 21p to 23p per pack. The clips can also be purchased in bulk quantity at £2·18 per 100 direct from Herbert Terry & Son Ltd., Redditch, Worcs.



Oryx adjustable vice from W. Greenwood Electronic

Parramore Paramo screwdriver packs

Alpha digital multimeter from Advance

Readout—

A SELECTION FROM OUR POSTBAG

Correspondents wishing to have a reply must enclose a stamped addressed envelope. We regret we are unable to guarantee a reply on matters not relating to articles published in the magazine. Technical queries cannot be dealt with on the telephone.

Linear or Log Law

Sir—I would like to congratulate your author on the P.E. Sound Synthesiser, on the obviously very impressive results obtained. However, if I might add a few criticisms, I feel that they could prove helpful to your readers, and even Mr Shaw himself. These points are based on a few years' experience in the field of voltage-controlled Synthesiser circuits, and on the successful marketing of such circuits and complete Synthesisers which I have designed.

Firstly, the use of integrated circuits for some applications can be very satisfactory. However, one must remember that one often has to use the most suitable i.c., which is not always (in fact is rarely) exactly made for the job. As a result, one ends up putting the makers' recommended current through the device, say 5 to 10mA, when if one designed a circuit from discrete components one would often find that a few micro-amps is all that is needed for the same job! This means that you can under-run the components at a tiny fraction of the makers' recommended current . . . the life expectancy is thus made infinitely greater.

Secondly, use of most i.c.s involves dual-rail power supply, and also adds dramatically to the overall costs, as i.c.s are going up in price (the Dewtron modules cost, using discrete components, would still be less than £200 for more versatile design than that published, incidentally).

Thirdly, and alas, I feel more importantly, the decision to abandon the use of the proper log-law for the Voltage Controlled Oscillator design. This is really naughty, as it means:

1. No chording facility.
2. No variable keyboard pitch, which is essential if you want the range of use one expects from a synthesiser.
3. Difficulties in tuning the tuning ladder—each note must have its own preset, the adjustment of which will vary vastly from one end of the ladder to the other.
4. Poor frequency stability, because, should voltage or resistance wander, the drift will be concentrated more to one end of the keyboard than the other, due to the non-linearity (or non-log'arity) of the tuning network, whereas, if logarithmic tuning voltage law were used, the variation would be distributed evenly over the whole keyboard, so making it less noticeable, in terms of pitch.
5. Uneven swing in pitch control when driven by a slow-oscillator, unless special (and difficult) compensation is deliberately introduced into the output of the slow oscillator. Imagine a siren that starts climbing in pitch rapidly and then slows down to a slow whine when it reaches the higher frequencies.

Admittedly, the building of a stable, accurate law circuit is difficult, if the effects of temperature are to be minimised, and the circuit shown in the first article is very prone to temperature drift, as matched transistors from a thermal standpoint are virtually impossible to select due to the cycling time involved. None-the-less, circuits are possible (a special unique one is used in the Dewtron-2 module), which will not change even if a hot soldering iron is applied to them! Admittedly, the one in question did take years to perfect, and perhaps Mr Shaw did not have this sort of time at his disposal.

It would be interesting to learn if other readers have further ideas on the above or other points arising from the P.E. Synthesiser design.

B. H. Baily,
Dewtron Design Engineering

Computer Club

Sir—You and your readers may be interested to hear that following my letter in P.E. last year an Amateur Computer Club has been formed.

The club is for those interested in the construction, design or programming of computers as a hobby. At present the main activity of the club is the production of a newsletter which acts as a databus to distribute information on hardware and software techniques of interest to the members.

Any one in joining the club may receive further details from me (SAE appreciated).

M. Lord,
7 Dordells,
Basildon,
Essex

BACK NUMBERS WANTED

Anyone who can supply the undermentioned are asked to communicate directly with the reader.

We regret that back numbers of Practical Electronics can no longer be supplied. We will try to publish announcements of readers' requirements (without a guaranteed date) free of charge.

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January 1968
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Mr. K. S. Reehall, 18, Carey Park, Rednnick Lane, Truro, Cornwall.

February 1972
Mr. P. E. North, 33, Windsor Road, Lowestoft, Suffolk.

December 1971, January 1972
Mr. V. G. Dennison, 24, Ledbury Street, Aspley, Brisbane, Australia, 4034.

November 1965, July 1972
Mr. C. H. M. Limb, 68, Westminster Way, North Hinksey, Oxford.

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Mr. S. Clements, 17, Semple Street, Hamilton, Lanarks, ML3 9JL.

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¼W 2% ELECTROSIL TR5

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½	10%	3·3MΩ–10MΩ	E12	1p	0·8p
¼	2%	10Ω–1MΩ	E24	3·5p	3p
½	10%	1Ω– 3·9Ω	E12	1p	0·8p
⅓	5%	4·7Ω–1MΩ	E12	1p	0·8p
4	10%	1Ω–10Ω	E12	6p	5·5p

Quantity price applies for any selection. Ignore fractions on total order.

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0·5 watt 5% Iskra resistors 5 off each value 4·7Ω to 1MΩ.
E12 pack 325 resistors £2·40. E24 pack 650 resistors £4·70.

POTENTIOMETERS

Carbon track 5kΩ to 2MΩ, log or linear (log ¼W, lin ½W).
Single, 12p. Dual gang (stereo), 40p. Single D.P. switch 24p.

SKELETON PRESET POTENTIOMETERS

Linear: 100, 250, 500Ω and decades to 5MΩ. Horizontal or vertical P.C. mounting (0·1 matrix).
Sub-miniature 0·1W, 5p each. Miniature 0·25W, 6p each.

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AC126	12p	AF126	20p	BD133	75p	OC35	50p	2N3703	12p
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AC128	12p	AF139	32p	BF173	20p	OC44	12p	2N3705	12p
AC131	12p	AF178	32p	BF177	28p	OC45	12p	2N3706	11p
AC132	12p	AF180	40p	BF178	32p	OC70	12p	2N3707	12p
AC176	12p	AF181	40p	BF179	32p	OC71	12p	2N3708	10p
AC187	22p	BC107	9p	BF180	32p	OC72	12p	2N3709	11p
AC188	22p	BC108	9p	BF181	32p	OC81	12p	2N3710	11p
AD140	50p	BC109	9p	BF194	15p	OC82D	12p	2N3711	11p
AD149	45p	BC147	13p	BF195	15p	2N2904	20p	2N4062	12p
AD161	33p	BC148	13p	BF197	15p	2N2926R	9p	40360	35p
AD162	36p	BC149	13p	BF200	32p	2N2926O	9p	40361	35p
AF114	20p	BC157	14p	BFY50	20p	2N2926Y	9p	40362	40p
AF115	20p	BC158	14p	BFY51	20p	2N2926G	10p	40408	40p
AF116	20p	BC159	14p	BFY52	20p			ZTX302	15p
AF117	20p	BC187	22p	BU105	225p	2N3054	58p	ZTX500	15p
AF117	38p	BD131	75p	OC26	45p	2N3055	60p	ZTX502	20p
AF124	22p								

ZENER DIODES

400mW 5% 3·3V to 30V, 12p.

WIRE WOUND POTS, 3W, 10, 25,

50Ω and decades to 100kΩ, 35p.

DIODES

RECTIFIER

BY127	1250V	1A	12p
BZY10	800V	6A	25p
BZY13	200V	6A	20p
IN4001	50V	1A	7p
IN4004	400V	1A	8p
IN4007	1000V	1A	10p

SIGNAL

OA85	7p
OA90	5p
OA91	5p
OA202	7p
IN4148	5p
BA114	8p

BRUSHED ALUMINIUM PANELS

12in × 6in = 25p; 12in × 2½in = 10p; 9in × 2in = 7p

SLIDER POTENTIOMETERS

86mm × 9mm × 16mm, length of track 59mm.
SINGLE 10K, 25K, 100K log. or lin. 40p.
DUAL GANG, 10K + 10K etc. log. or lin. 60p.
KNOB FOR ABOVE 12p.
FRONT PANEL 65p.
18 Gauge panel 12in × 4in with slots cut for use with slider pots. Grey or matt black finish complete with fixings for 4 pots.

THERMISTORS

VA1055S	15p
VA1066S	15p
VA1077	15p
R53	£1·35

THYRISTORS

2N5060 50V 0·8A 30p, 2N5064 200V 0·8A 47p, CRS1/40 400V 1A 25p, 106F 50V 4A 40p, 106D 400V 4A 55p.

MULLARD POLYESTER CAPACITORS C296 SERIES

400V: 0·001µF, 0·0015µF, 0·0022µF, 0·0033µF, 0·0047µF, 2½p. 0·0068µF, 0·01µF, 0·015µF, 0·022µF, 0·033µF, 3p. 0·047µF, 0·068µF, 0·1µF, 4p. 0·15µF, 6p. 0·22µF, 7½p. 0·33µF, 11p. 0·47µF, 13p.
160V: 0·01µF, 0·015µF, 0·022µF, 0·033µF, 0·047µF, 0·068µF, 3p. 0·1µF 3½p. 0·15µF 4½p. 0·22µF, 5p. 0·33µF, 6p. 0·47µF, 7½p. 0·68µF, 11p. 1·0µF, 13p.

MULLARD POLYESTER CAPACITORS C280 SERIES

250V P.C. mounting: 0·01µF, 0·015µF, 0·022µF, 3p. 0·033µF, 0·047µF, 0·068µF, 3½p. 0·1µF, 4p. 0·15µF, 0·22µF, 5p. 0·33µF, 6½p. 0·47µF, 8½p. 0·68µF, 11p. 1·0µF, 13p. 1·5µF, 20p. 2·2µF, 24p.

MYLAR FILM CAPACITORS 100V

0·001µF, 0·002µF, 0·005µF, 0·01µF, 0·02µF, 2½p. 0·04µF, 0·05µF, 0·068µF, 0·1µF, 3½p.

CERAMIC DISC CAPACITORS

100pF to 10,000pF, 2p each.

ELECTROLYTIC CAPACITORS—MULLARD O15/6/7 RANGE REPLACES C426, C457 RANGES.

(µF/v) 1·0/63, 1·5/63, 2·2/63, 3·3/63, 4·7/63, 6·8/40, 10/25, 10/63, 15/16, 15/40, 15/63, 22/10, 22/25, 22/63, 33/6·3, 33/40, 47/4, 47/10, 47/25, 47/40, 47/63, 68/6·3, 68/16, 100/4, 100/10, 100/25, 100/40, 150/6·3, 150/16, 150/25, 220/4, 220/10, 220/16, 330/4, 330/10, 470/6·3, 5p each. 68/63, 150/40, 220/25, 330/16, 470/10, 680/6·3, 1,000/4, 9p. 100/63, 150/63, 220/40, 470/25, 680/16, 1,000/10, 1,500/6·3, 12p. 220/63, 470/40, 680/25, 1,000/16, 1,500/10, 2,200/6·3, 15p. 330/63, 680/40, 1,000/25, 1,500/16, 2,200/10, 3,300/6·3, 4,700/4, 18p.

SOLID TANTALUM BEAD CAPACITORS — 12p

0·1µF	35V	2·2µF	35V	22µF	16V
0·22µF	35V	4·7µF	35V	33µF	10V
0·47µF	35V	6·8µF	25V	47µF	6·3V
1·0µF	35V	10µF	25V	100µF	3V

VEROBOARD

	0·1	0·15
2½ × 3¾	22p	16p
2½ × 5	24p	24p
3¾ × 3¾	24p	24p
3¾ × 5	27p	27p
17 × 2½	75p	57½p
17 × 3¾	100p	78p
17 × 5 (plain)	—	82p
17 × 3¾ (plain)	—	60p
17 × 2½ (plain)	—	42p
2½ × 5 (plain)	—	12p
2½ × 3¾ (plain)	—	11p
Pin insertion tool	52p	52p
Spot face cutter	42p	42p
Pkt. 50 pins	20p	20p

JACK PLUGS AND SOCKETS

Standard screened	18p	2·5mm insulated	8p
Standard insulated	12p	3·5mm insulated	8p
Stereo screened	35p	3·5mm screened	13p
Standard socket	15p	2·5mm socket	8p
Stereo socket	18p	3·5mm socket	8p

D.I.N. PLUGS AND SOCKETS

2 pin, 3 pin, 5 pin 180°, 5 pin 240°, 6 pin
Plug 12p. Socket 8p.
4 way screened cable, 15p/metre.
6 way screened cable 22p/metre.

BATTERY ELIMINATOR — £1·50

9V mains power supply. Same size as PP9 battery.

LARGE (CAN) ELECTROLYTICS

1600µF	64V	74p	2500µF	64V	80p	4500µF	16V	50p
2500µF	40V	74p	2800µF	100V	£2·60	4500µF	25V	£1·68
2500µF	50V	58p	3200µF	16V	50p	5000µF	50V	£1·10

HIGH VOLTAGE TUBULAR CAPACITORS—1,000 VOLT

0·01µF	10p	0·047µF	13p	0·22µF	20p
0·022µF	12p	0·1µF	13p	0·47µF	22p

POLYSTYRENE CAPACITORS 160V 2½%

10pF to 1,000pF E12 Series Values 4p each.

SMOKE AND COMBUSTIBLE GAS DETECTOR—GD1

The GD1 is the world's first semiconductor that can convert a concentration of gas or smoke into an electrical signal. The sensor decreases its electrical resistance when it absorbs deoxidizing or combustible gases such as hydrogen, carbon monoxide, methane, propane, alcohol, North Sea gas, as well as carbon-dust containing air or smoke. This decrease is usually large enough to be utilized without amplification. Full details and circuits are supplied with each detector.
Detector GD1, £2. Kit of parts for detectors including GD1 and P.C. board but excluding case. Mains operated detector £5·20. 12 or 24V battery operated audible alarm £7·30. As above for PP9 battery, £6·40.

PRINTED BOARD MARKER — 97p

Draw the planned circuit onto a copper laminate board with the P.C. Pen, allow to dry, and immerse the board in the etchant. On removal the circuit remains in high relief.

LARGE RANGE ITT/TEXAS IC's NOW IN STOCK

PRICES ARE CALCULATED ON TOTAL NUMBER ORDERED REGARDLESS OF MIX

	1–11 p.	12–24 p	25–99 p	100+ p
7400	18	16	14	13
7401	18	16	14	13
7402	18	16	14	13
7403	18	16	14	13
7404	20	18	16	14
7405	20	18	16	14
7406	50	45	40	35
7407	56	50	44	38
7408	36	30	27	23
7409	36	30	27	33
7410	18	16	14	13
7411	23	21	20	18
7412	36	30	27	23
7413	34	28	26	22
7416	45	43	39	34
7420	18	16	14	13
7421	36	30	27	23
7426	32	29	23	20
7430	20	18	16	14
7432	40	36	32	28
7440	20	18	16	14
7441	80	75	70	65
7442	80	75	70	65
7443	125	120	115	115
7447	175	165	150	120
7448	185	175	170	165
7450	18	16	14	13
7451	18	16	14	13
7453	18	16	14	13
7454	18	16	14	13
7460	18	16	14	13
7470	30	28	25	24
7472	30	28	27	23
7473	40	38	36	30
7474	40	36	32	28
7475	55	52	50	49
7476	40	36	32	30
7480	100	95	90	85
7481	125	115	110	105
7482	100	96	90	85
7483	100	97	95	92
7484	120	115	110	105
7485	250	245	240	230
7486	45	42	37	33
7490	75	67	60	52
7491A	100	92	85	79
7492	75	70	65	60
7493	75	68	60	52
7494	95	90	85	80
7495	105	100	95	90
7496	100	95	90	85
74100	250	240	235	230
74118	100	82	73	64
74121	43	40	38	36
74141	100	95	90	85
74145	150	140	135	130
74150	330	280	250	220
74151	110	100	95	89
74153	120	110	105	95
74154	200	180	170	160
74155	150	120	100	86
74156	130	120	100	96
74180	155	136	112	105
74190	195	190	185	180
74191	195	190	185	180
74192	200	190	180	164
74193	200	180	170	150
74196	200	190	180	170
74197	200	195	180	170

LINEAR IC's

709	14 pin DIL	32p
741	8 pin DIL	34p
741	14 pin DIL	28p
723	14 pin DIL	95p
747	14 pin DIL	85p
748	8 pin DIL	35p
DIL socket,	14 pin and 16 pin	16p

MAINS MOTOR

Precision made—as used in record decks and tape recorders—ideal also for extractor fan, blower, heaters, etc. New and perfect. Snip at 72p. Postage 20p for first one then 10p for each one ordered.

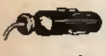
MUSIC ON TAPE

A further buy enables us to offer these at an even lower price—namely 65p each or 5 for £2·50. Send for list of titles. We can't repeat when sold out.

BALANCED ARMATURE UNIT

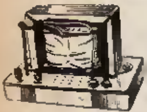
500 ohm, operates as speaker or microphone, so useful in intercom or similar circuits, 87p each, 10 for £8·76.

CAR ELECTRIC PLUG



Fits in place of cigarette lighter. Useful method for making a quick connection into the car electrical system, 38p each or 10 for £3·42.

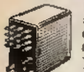
12 VOLT 1½ AMP POWER PACK



This comprises double-wound 230/240V mains transformer with full wave rectifier and 2000 mF smoothing. Price £2·20, plus 20p post & packing.

Heavy Duty Mains Power Pack. Output voltage adjustable from 15-40V in steps—maximum load 250W—that is from 6 amp at 40V to 15amp at 15V. This really is a high power heavy duty unit with dozens of workshop uses. Output voltage adjustment is very quick—simply interchange push on leads. Silicon rectifiers and smoothing by 3,000mF. Price £6·38 plus 65p post.

MAINS RELAY BARGAIN



Special this month are some single, double and treble pole changeover relays. Contacts rated at 15 amps. Operating coil wound for 240V A.C. Good British Make. Unused. Size approx. 1¾" × 1". Open construction.
Single pole 28p each 10 for £2·48.
Treble pole 39p each 10 for £3·57.

MINIATURE WAFER SWITCHES

2 pole, 2 way—4 pole, 2 way—3 pole, 3 way—4 pole, 3 way—2 pole, 4 way—3 pole, 4 way—2 pole 6 way—1 pole, 12 way. All at 28p each.

CONNECTING WIRE

7·0076 Copper conductors. 500 metre drums available in the following colours: Red/Brown, Yellow, Green/Grey, Blue/Green, Red/Orange, Green/White, Grey/White, Blue/Orange, Brown/Red, Brown/White, Red/Grey, Blue/Grey, Blue/Brown. Price £2·20 per drum plus 40p post. State alternative colours. *Ditto*—but with 200 metres. Price £1·38 per drum plus 20p. *Ditto*—but with 100 metres. Price 83p per drum.

DOOR SWITCH

As fitted to refrigerators, etc. Switches off as door closes. White 17p each. Black 15p each.

GOODMANS P.M. SPEAKERS

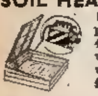
8in × 5in hi flux 15 ohm coil very suitable for use with Mullard Unilex stereo amplifier or with the EP9000 on its own, £1·65 plus 20p post each.

7in × 4in also 15 ohm and suitable for use with the EP9000—not quite such good quality of course. Price £1·05 each.

U.V. LIGHTING

Useful for flaw detection in metals and for looking for water marks, etc., also for fitting over tropical fish tanks—African violets and other indoor plants which must have U.V. for healthy growth. The outfit comprises of a 12in U.V. tube—choke—starter holder and tube ends. Price £2·20 plus 20p post.

SOIL HEATING KIT



Suitable for garden frame or propogating shelf, etc. Comprises 40W mains transformer, heating wire, connection strip and insulated wire with connection diagram. £1·65 plus 20p post.

80 WATT TUBULAR ELEMENTS

Brass encased with beaded flex ends. Standard replacements in most absorbtion type refrigerators but also has dozens of other uses. 28p each or 10 for £1·48.

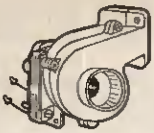
DOUBLE ENDED MAINS MOTOR

This is a very quiet running induction motor, with two special features—one is that it has feet for easy fixing and the other is it has a good length of spindle coming from each end. So it could drive two things at once—or with simple slide attachment could reverse direction. 55p each or 10 for £4·95.

MULLARD AUDIO AMPLIFIERS

All in module form, each ready built complete with heat sinks and connection tags, data supplied.
Model 1153 500mW power output 73p.
Model 1172 750mW power output 84p.
Model EP9000 4 watt power output £1·60.
EP9001 twin channel or stereo pre amp. £1·92.
10% discount if 10 or more ordered.

CENTRIFUGAL BLOWER



Miniature mains driven blower centrifugal type blower unit by Woods. Powerful but specially built for quiet running—driven by cushioned induction motor with specially built low noise bearings. Overall size 4½" × 4¼" × 4". When mounted by flange, air is blown into the equipment but to suck air out, mount it from centre using clamp. Ideal for cooling electrical equipment or fitting into a cooker hood, film drying cabinet or for removing flux smoke when soldering etc. etc. A real bargain at £2·05.

GOOD COMPANION I.C. VERSION

We can now offer these again in I.C. version using Ferranti ZN414 and Mullard AF Module 1172. Cabinet size approx. 11in wide × 8in high × 3in deep. Complete assembly instruction—Excellent tone wood cabinet £5·75 plus 25p post and insurance.

MIGHTY MIDGET

Probably the tiniest possible radio, as described in Practical Wireless, 4 January 73. All electronic parts £2·20 post paid.

THIS MONTH'S SNIP

HORSTMANN 24-HOUR TIME SWITCH

With six position programmer. When fitted to hot water systems this could programme as follows:

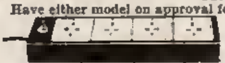
Programme	Hot Water	Central Heating
0	Off	Off
1	Twice daily	Off
2	All day	Off
3	Twice daily	Twice daily
4	All day	All day
5	Continuously	Continuously

Suitable of course, to programme other than central heating and hot water, for instance, programme upstairs and downstairs electric heating or heating and cooling or taped music and radio. In fact there is no limit to the versatility of this Programmer. Mains operated—Size: 3in × 3in × 2in deep. Price £2·85 each. As illustrated but less case.

PORTABLE ELECTRIC DRILL

Very superior quality made by a famous Dutch Toolmaker. Model No. ASM830. 300W—2 speed 2,200/3,000. With ⅜in chuck and chuck key, also separate side handle and hammer facility for dealing with concrete, etc. An equivalent British made drill would cost £15. £10·90—similar model but without the hammer attachment £8·75. Have either model on approval for 7 days.

DISTRIBUTION PANELS

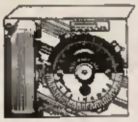


Just what you need for work bench or lab. 4 × 13 amp sockets in metal box to take standard 13 amp fused plugs and on/off switch with neon warning light. Supplied complete with 7 feet of heavy cable. Wired up ready to work, £2·50 plus 20p post and insurance.

CAPACITOR DISCHARGE CAR IGNITION

This system which has proved to be amazingly efficient and reliable was first described in the *Wireless World* about a year ago. We can supply kit of parts for an improved and even more efficient version (*Practical Wireless*, June). Price £6·55 plus 20p post. When ordering please state whether for positive or negative systems. De-luxe model including printed circuit board, etc. £7·65.

24-HOUR TIME SWITCH



Made by Smiths, these are A.C. mains operated, NOT CLOCKWORK. Ideal for mounting on rack or shelf or can be built into box with 13A socket. Two completely adjustable time periods per 24 hours, 5A changeover contacts will switch circuit on or off during these periods. £2·75 post and ins. 25p. Additional time contacts 55p pair.

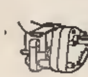
THYRISTOR LIGHT DIMMER

For any lamp up to 1kw. Mounted on switch plate to fit in place of standard switch. Virtually no radio interference. Price £2·95, plus 20p post and insurance. Industrial model 5A £3·30.

BATTERY CONDITION TESTER

Made by Mallory but suitable for all batteries made by Ever Ready and others, most of which are zinc carbon types but also mercury manganese—nicad—silver oxide and alkaline batteries may be tested. The tester puts a dummy load on the battery and the meter scale indicates the condition depending upon which section the pointer rests. The section reads "replace" "weak" or "good". The tester is complete in its case, size 3¾" × 6¼" × 2" with leads and prods. Price £2·48 plus 20p postage.

SPIT MOTOR



200-250V Induction Motor, driving a Carter gear box with 1½" of output drive shaft running at 5 revs per minute. Intended for roasting chickens also suitable for driving models—windmills, coloured disc lighting effect, etc. etc. £2·04 plus 20p post and insurance.

DRILL CONTROLLER

NEW 1KW MODEL

Electronically changes speed from approximately 10 revs. to maximum. Full power at all speeds by finger-tip control. Kit includes all parts, case, everything and full instructions. £1·65. Made up model also available. £2·75.

MAINS TRANSISTOR POWER PACK

Designed to operate transistor sets and amplifiers. Adjustable output 6v., 9v., 12 volts for up to 500mA (class B working). Takes the place of any of the following batteries: PP1, PP3, PP4, PP6, PP7, PP9, and others. Kit comprises: mains transformer rectifier, smoothing and load resistor condensers and instructions. Real snip only £1·10.

SWITCH TRIGGER MATS

So thin is undetectable under carpet but will switch on with slightest pressure. For burglar alarms, shop doors, etc.
24in × 18in £1·54.
18in × 10in £1·10.

PP3 BATTERY CHARGER

Almost 3 times the life can be obtained from PP3 battery if you re-charge it from the mains—this ready to use charger with instructions only 55p.

15A ELECTRICAL PROGRAMMER

Learn in your sleep: Have radio playing and kettle boiling as you awake—switch on lights to ward off intruders — have a warm house to come home to. All these and many other things you can do if you invest in an electrical programmer. Clock by famous maker with 15 amp. on/off switch. Switch-on time can be set anywhere to stay on up to 6 hours. Independent 60 minute memory jogger. A beautiful unit. Price £2·15 + 20p p. & p. or with glass front chrome bezel 33p extra.

BAKELITE INSTRUMENT CASE

Size approx. 6½" × 3¾" × 2" deep with brass inserts in four corners and bakelite panel. This is a very strong case suitable to house instruments and special rigs, etc. Price. 50p each.
Paxolin lid 11p extra.

ROCKER SWITCH

13 amp self-fixing into an oblong hole. Size approximately 1" × ½" 9p each, 10 for 81p.

THERMAL CUTOUT

A miniature device ½in dia. on one screw fixing mount—can be used for motor overload protection, fire alarm, soldering iron, switch off, etc., etc. 15 amp contacts open with flame—radiant or conducted heat. 11p each or 10 for 99p.

HONEYWELL PUSH BUTTON MICRO SWITCHES

As used in some vending machines, etc. Each switch is a changeover type rated at 15A 250V a.c. Intended for panel mounting with fixing nuts and single black push knob. Single changeover switch 28p, Double switch 42p, Triple switch 61p.

KETTLE ELEMENTS

Made by the famous A.E.I. Co. Complete with washers and combined fixing ring and plug shroud. Normal 2 round pin and flat pin earth connection and overload reset push button. 2 Models—1⅛in (approx.) suitable for Swan and other similar models—1⅜in (approx.) suitable for G.E.C. Hotpoint, etc. All quick boil 2¼kW elements at 240V. Price £1·38 each.

MAINS TRANSFORMER BARGAIN

Standard mains 240V input Secondary 2·4V 9A intermittent 5A continuous. Price 55p.

BULGIN 4 PIN PLUG AND SOCKET

Plug has shielded pin and flex entry and socket for panel mounting. 33p per pair. *Ditto*—but 3 pin, 22p per pair.

MACLAREN THERMOSTAT

Make and break 20A a.c. with the sensor probe coupled by 2 feet capillary covering range of 10–100°C—complete with large engraved control knob. Price 85p.

Where postage is not stated then orders over £5 are post free. Below £5 add 20p. Semi-conductors add 5p post. Over £1 post free. S.A.E. with enquiries please.

J. BULL (ELECTRICAL) LTD.

(Dept. P.E.), 7 Park Street, Croydon CRO 1YD

Callers to 102/3 Tamworth Road, Croydon

Sinclair Project 60

Now–the Z.50 Mk.2

with built-in automatic transient overload protection

When originally introduced, the Sinclair Z.50 proved how it was possible to design and produce a popularly priced modular power amplifier having characteristics to challenge the world's costliest amplifiers. Many thousands of Z.50's are now giving excellent service day in, day out. But we have also learned that constructors do not always use their Z.50's ideally. That is why we have introduced modifications whereby risk of damage through mis-use is greatly reduced and performance further enhanced. The Z.50 Mk.2 has improved thermal stability, more accurately regulated D.C. limiting to ensure more symetrical output voltage swing and clipping and still less distortion at lower power. Z.50 Mk.2 is compatible with all other Project 60 modules, and may be incorporated to advantage in existing systems. Eleven silicon epitaxial planar transistors are now used, two more than in the original Z.50; circuitry has been re-designed, making this versatile high performance amplifier better than ever.

with free manual

£5.48

Z.30 the power amplifier for quality and economy

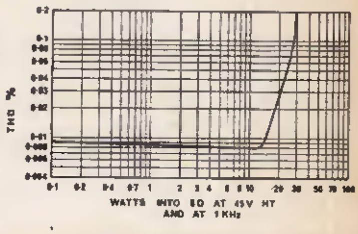
with free manual

£4.48

The Z.30 provides excellent facilities for the constructor requiring a high fidelity audio system of less power than that available from Z.50's. Using a power supply of 35 volts, Z.30 will deliver 15 watts RMS into 8 ohms, or 20 watts RMS into 3 ohms using 30 volts. Total harmonic distortion is a fantastically low 0.02% at 15 watts into 8 ohms with signal to noise ratio better than 70 dB unweighted. Input sensitivity 250mV into 100K ohms. Size 80 x 57 x 13 mm ($3\frac{1}{8}$ x $2\frac{1}{4}$ x $\frac{1}{2}$) Z.30, Z.50 and Z.50 MK.2 modules are compatible and interchangeable.

Brilliant new technical specifications

Input impedance 100 KΩ
Input (for 30w into 8Ω) 400mV
Signal to noise ratio, referred to full o/p at 30v HT 80dB or better
Distortion 0.02% up to 20W at 8Ω. See curve
Frequency response 10Hz to more than 200 KHz ±1dB
Max. supply voltage 45v (4Ω to 8Ω speakers) (50v 15Ω speakers only)
Min. supply voltage 9v
Load impedance – minimum: 4Ω at 45v HT
Load impedance – maximum: safe on open circuit



Typical Project 60 applications

System	The Units to use	together with	Units cost
Simple battery record player	Z.30	Crystal P.U., 12V battery volume control, etc.	£4.48
Mains powered record player	Z.30, PZ.5	Crystal or ceramic P.U. volume control, etc.	£9.45
12W. RMS continuous sine wave stereo amp. for average needs	2 x Z.30s, Stereo 60; PZ.5	Crystal, ceramic or mag. P.U., F.M. Tuner, etc.	£23.90
25W. RMS continuous sine wave stereo amp. using low efficiency (high performance) speakers	2 x Z.30s, Stereo 60; PZ.6	High quality ceramic or magnetic P.U., F.M. Tuner, Tape Deck, etc.	£26.90
80W. (3 ohms) RMS continuous sine wave de luxe stereo amplifier. (60W. RMS into 8 ohms)	2 x Z.50s, Stereo 60; PZ.8, mains transformer	As above	£34.88
Indoor P.A.	Z.50, PZ.8, mains transformer	Mic., guitar, speakers, etc., controls	£19.43

F.M. Stereo Tuner **(£25)** & A.F.U. **(£5.98)** may be added as required.

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Each Project 60 module is tested before leaving our factory and is guaranteed to work perfectly. Should any defect arise in normal use, we will service it at once and without any charge to you, if it is returned within two years from the date of purchase. Outside this period of guarantee a small charge (typically £1.00) will be made. No charge is made for postage by surface mail. Air Mail is charged at cost.

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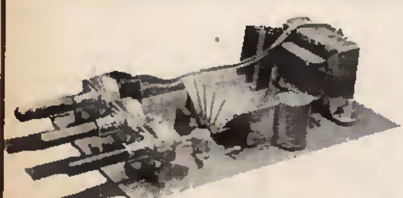

SPECIFICATIONS
OUTPUT 5W RMS (10W peak)
FREQUENCY RESPONSE 10Hz to 50kHz ± 3dB
TOTAL HARMONIC DISTORTION less than 1%

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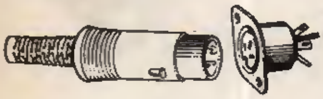
by Hirshmann, 4A rating



2 way LS —socket **10p**, plug **12p**
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TRANSISTOR ACCESSORIES
TO3 cover, **7p**; Heat sinks 1°C/W, type 6W1, undrilled, **60p**.

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1011 SPST toggle, **20p**; 409 DPDT toggle, **29p** (these are chrome plated, 2·5A rating); 7201 sub-miniature DPDT 250V a.c./2A, **48p**.

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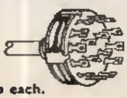
Radiospares Miniature Maka-switch (in assembly kit form). Shaft, **48p**. Wafers, MBB-2P5W, 1P11W: BBM1P12W, 2P6W, 3P4W, 4P3W, 6P2W, **32p** each.

WAVECHANGE SWITCHES



1P12W, 2P6W, 3P4W, 4I3W, **24p** each.

ELECTROLYTIC CAPACITORS AXIAL LEAD

Rated voltage: / Capacity μF	3V	6·3V	10V	16V	25V	40V	63V	100V
0·47	—	—	—	—	—	—	7p	7p
1·0	—	—	—	—	—	7p	—	7p
2·2	—	—	—	—	7p	—	7p	7p
4·7	—	—	—	7p	—	7p	7p	7p
10	—	—	7p	—	7p	7p	7p	7p
22	—	—	7p	7p	—	7p	7p	8p
47	7p	—	7p	7p	7p	7p	8p	12p
100	7p	7p	7p	7p	7p	8p	12p	18p
220	7p	7p	7p	8p	9p	10p	17p	26p
470	7p	8p	9p	9p	12p	17p	24p	41p
1,000	9p	12p	12p	17p	20p	23p	40p	—
2,200	14p	16p	22p	25p	36p	40p	—	—
4,700	23p	26p	37p	40p	—	—	—	—
10,000	37p	40p	—	—	—	—	—	—

Prices subject to amendment by the manufacturer.

POLYCARBONATE—5% TOLERANCE
250V up to 0·1μF: 100V, 0·1μF and above.
0·01; 0·012; 0·015; 0·018; 0·022; 0·027; 0·033; 0·047; 0·056; **4p** each. 0·068; 0·082; 0·1; 0·12; 0·15; **4p** each. 0·18; 0·22; **5p** each. 0·27; 0·33; **6p**, 0·39 **7p**, 0·47 **8p**, 0·56 **10p**, 0·68 **11p**. 1μF **13p**. *Prices subject to amendment by the manufacturer.*

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Type 3015F. Seven Filament segment indicators to make 0–9 + decimal point. Compatible with standard logic modules, nett **£2**. Decoder driver type FLL 121T nett £1·36. DIL socket, nett **£2**.

RESISTORS – 10%, 5%, 2%

Code	Power	Tolerance	Range	Values available	1 to 9	10 to 99 (see note below)	100 up
C	1/20W	5%	82 Ω–220K Ω	E12	9	8	7·5
C	1/8W	5%	4·7 Ω–470K Ω	E24	1	0·9	0.75
C	1/4W	10%	4·7 Ω–10M Ω	E12	1	0·9	0·75
C	1/2W	5%	4·7 Ω–10M Ω	E24	1·2	1	0·8
C	1W	10%	4·7 Ω–10M Ω	E12	2·5	2	1·6
MO	1/2W	2%	10 Ω–1M Ω	E24	4	3	2
WW	1W	10% ± 1/20 Ω	0·22 Ω–3·9 Ω	E12	7	7	6
WW	3W	5%	1 Ω–10K Ω	E12	7	7	6
WW	7W	5%	1 Ω–10K Ω	E12	9	9	8

Codes: C = carbon film, high stability, low noise.
MO = metal oxide, Electrosil TR5, ultra low noise.
WW = wire wound, Plessey.
Values:
E12 denotes series: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82 and their decades.
E24 denotes series: as E12 plus 11, 13, 16, 20, 24, 30, 36, 43, 51 62, 75, 91 and their decades.

Prices are in pence each for quantities of the same ohmic value and power rating. NOT mixed values. (Ignore fractions on total value of resistor order.)

We regret that where substantial price increases have occurred in some items, they are due to increased costs of imported goods. S.A.E.

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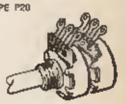

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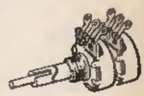

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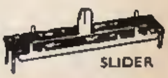

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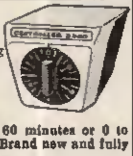

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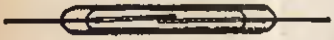

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